Capgemini

# Shaping Tomorrow's Energy Landscape:

## *Balancing Sovereignty, Affordability and Climate Responsibility*

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WORLD ENERGY MARKETS OBSERVATORY

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# GLOBAL OUTLOOK

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The major event of the year 2022 was Russia's unjustified invasion of Ukraine, which led to a historic increase in gas and electricity prices in Europe. Following these events, measures to strengthen security of supply and energy sovereignty were taken in addition to those to accelerate the energy transition. Carbon-free electricity production technologies have progressed, but despite this, greenhouse gas (GHG) emissions have continued to increase. The summer of 2023 was one of the hottest in history.

In this Outlook, we examine the questions of energy sovereignty and the West's dependence on China, whose weight in the energy transition is continuously increasing. While regulations must be strengthened to reduce dependence on fossil fuels, the speed of implementation of these regulations depends on their costs and their acceptability.

Despite this, it is likely that the objectives of limiting temperature to 1.5°C in 2030 will not be achieved. Adaptation measures must therefore be taken quickly, which requires the mobilization of numerous stakeholders (governments, infrastructure managers, businesses, citizens).

Consumer behavior and financing of the energy transition are key points for success.

These and other topics are analyzed in this Outlook.

**I hope you enjoy reading it.**

# The 2021-2022 crisis and 2023 perspective:

## How Europe freed itself from its dependence on Russian gas:

Before the unjustified invasion of Ukraine by Russia (February 2022), Russian gas, mainly imported by pipeline, represented 40% of European gas supplies, around 140 billion cubic meters (bcm) per year.

As I had written in previous WEMO[1] Outlooks, this heavy dependence on Russian gas posed a threat to European security of supply. This threat materialized in 2022.

**Russian gas:**

In response to the invasion of Ukraine, the European Union (EU) took sanctions against Russia, particularly on Russian oil and coal. It avoided taking sanctions on gas because of Europe's heavy dependence on Russian gas. It is President Putin who decided to progressively reduce the gas flowing by pipeline to Europe. The sabotage of the two North Stream giant pipelines on September 22, 2022, further reduced these flows. Thus, Russian flows transiting by gas pipelines represented in June 2023 only around 7% of the Union's supplies.

Since the last quarter of 2022, in addition to "TurkStream", only two gas pipelines crossing Ukraine are still supplying Europe with Russian gas. However, gas transit contracts between Russia and Ukraine end in 2024 and may not be renewed.

Unveiled in May 2022, the REPowerEU[2] plan aimed to "reduce the EU's dependence on Russian gas by two-thirds by the end of 2022"; additionally, it aims to "make Europe independent of Russian fossil fuels well before 2030". The first part of the plan addresses gas supply sources diversification. The second part deals with acceleration of the energy transition, deployment of energy efficiency measures, and the accelerated commissioning of renewable electricity production means.

**Diversified supplies:**

1. ***Oil:*** Due to the EU sanctions, Russian oil imports dropped sharply. While they accounted for 31% of EU oil imports in January 2022, by March 2023 it was only 3%. Nevertheless, some of the EU's new imports may trace back to Russia.[3]
2. ***Gas:*** Europe has successfully diversified its gas supply sources:
   a. First, by increasing imports by pipeline from its traditional suppliers (Norway, Algeria, and the United Kingdom). However, these countries have limited potential to increase their exports.
   b. Secondly, by increasing imports of liquefied natural gas (LNG) on international markets (United States and Qatar, in particular), including 45 to 50% on the spot market.

In 2022, the EU imported just over 130 bcm of LNG, a 60% increase from the 80 bcm imported in 2021. In the future, Europe will be able to receive additional LNG as it expands its regasification capacity and as global LNG supplies increase. The global LNG flows are expected to increase by 23 bcm in 2023, largely due to the ramp-up of liquefaction projects in Africa and the United States.

In 2022, the U.S. represented roughly 40% of LNG European imports. Despite cuts in Russian piped gas, the EU increased its Russian imports from sea through LNG imports. Russia overtook Qatar as Europe's second-largest LNG supplier. ***In the first seven months of 2023, EU countries imported 40% more Russian LNG than the same period in 20214 ,*** making up around 16% of the EU's total LNG imports from January-July.[5] ***This is against the EU's aim to end its reliance on Russian fossil fuels (coal, oil, piped gas or LNG) by 2027!***

1 https://www.capgemini.com/insights/research-library/world-energy-markets-observatory/
2 https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en

3 https://www.energymonitor.ai/industry/a-missed-opportunity-eus-new-oil-imports-are-a-backdoor-to-russia/#:~:text=In%20January%202022%2C%20Russia%20accounted,back%20to%20Russia%20after%20all.

4 https://www.globalwitness.org/en/press-releases/eu-imports-russian-lng-have-jumped-40-invasion-ukraine/
5 https://www.reuters.com/business/energy/lng-imports-russia-rise-despite-cuts-pipeline-gas-2023-08-30/

**2023 gas supply still presents threats:**

The diversification of Europe's gas supply sources strengthens its security of supply. However, the EU is exposed to a double risk of rising prices and price volatility on one hand and availability of volumes on the other.

1. ***Higher prices and volatility:*** LNG prices are usually higher than those of gas imported by pipeline (due to factors such as the cost of liquefaction, transportation by vessel, and regasification). Also, their GHG emissions are worse than for piped gas. Being exposed to the spot market, the prices of LNG imports are, by nature, more volatile than the long-term contracts prices of piped gas.

   a. Volume availability: In 2022, confined China saw a drop of more than 20% in its LNG imports.

   However, a rebound in Chinese demand for LNG could limit LNG availability. In June 2023, China imported 32% more LNG than the previous year, and approached its June 2021 record.[6] However, this increase was mainly due to exceptional weather events and low LNG spot prices. For the whole year, China's demand for gas and LNG is expected to grow but not at the same pace as during the first half. Indeed, the current national policy prioritizes energy security of supply with coal and renewables. In addition, continued growth in domestic gas production and ramped-up delivery from Russian pipeline imports will limit the growth of LNG imports.

   At the end of August 2023, the LNG market was not under pressure, as reflected by the U.S. LNG export price, which dropped to around half its August 2022 level.

   b. Some leaders in the energy world are expressing concerns for the year 2024, given the link to the elections in the United States. If the Republican Party returns to power, the United States could ban or limit LNG exports because they are pushing American domestic prices up. It would be a shock for Europe, since the region relies significantly on the U.S. However, shale gas is produced in the U.S. by private companies; these organizations could launch litigation procedures against those penalizing decisions.

**Deployment of new regasification infrastructures:**

Europe Member States and, in particular, Germany have reacted to the 2022 crisis by increasing the number of Floating Storage and Regasification Unit (FSRU) projects. By mid-2023, eight new terminals were commissioned, and the EU's LNG import capacity is expected to increase by a further 20% by 2024.

However, at the European level, LNG import capacities were already oversized before the crisis. The deployment of new gas infrastructure responds to the poor distribution of LNG terminals on the continent and the difficulty of transporting gas in Europe. For many years I stressed in the WEMO outlooks, the need to invest in pipelines to increase reverse gas flows. During the crisis, it was clear that those investments were not done as it was impossible to transport gas from Spain (which has many re-gas facilities) to Germany, which had none. Also, it is very difficult to transport gas from Western Europe to the very landlocked Eastern European countries.

***Several new LNG import terminals are planned for 2026. However, they go against the objective of climate neutrality and could become stranded assets.***

6 https://www.spglobal.com/commodityinsights/en/ci/research-analysis/chinas-lng-imports-surged-early-summer-2023-under-the-impact.html#:~:text=According%20to%20S%26P%20Global%20Commodity,record%20for%20June%20in%202021.


**Prices:**

During the 2022 crisis, electricity and gas prices reached historical heights. They have sharply fallen because of moderate demand linked to the flattish economies and the fear of a new financial crisis.

The European gas price has fallen sharply (€34/MWh in August 2023) since its historic peak of €346/MWh (in August 2022).

Even if the American gas prices (which are around five times lower than European ones thanks to shale gas) did not reach historical heights as in Europe, U.S. Henry Hub[7] spot gas price fell from $8.8/million British thermal unit (MBTU) in August 2022 to $2.6/MBTU one year later.

The European electricity spot prices, which are linked to the gas prices, also fell from €576/MWh (for France) in August 2022 to €96/MWh one year later.

This dependance of electricity prices on the gas prices was questioned in Brussels by certain countries (such as France) that use very little gas for their electricity generation. These considerations, together with the sharp increase of spot prices and its consequences on citizen budgets, pushed European leaders to launch a reform of the European electricity prices mechanism (see below).

The drop in European electricity prices was, however, less spectacular than for gas prices. They remained relatively high during the 2023 summer due to very hot weather pushing demand up (through the increased use of air conditioning), the limitation of nuclear plants electricity output (in order not to heat rivers beyond a certain level) and fears around nuclear power availability during the winter.

**Reduction in gas consumption:**

If the Union has reduced its gas consumption by 13% for the year 2022 compared to 2021, this drop remains largely linked to a mild winter. For example, changes in behavior would have contributed only to one-quarter of the energy savings made in buildings. Energy efficiency levers (beyond building insulation) should be further increased to reduce heating and cooling energy consumption. Since the Russian invasion of Ukraine, heat pump installation, which displaces natural gas to the benefit of electricity, grew at an unprecedented rate (+100% in H1 23 in Germany and +140% in Belgium).

On the industrial side, almost half of the drop in gas demand came from stopping production activities due to the increase in energy prices (gas and electricity). Finally, because of the poor functioning of French nuclear power plants in 2022, there has been no reduction in gas used at power plants as the latter had to make up for missing nuclear electricity.

***It is difficult to predict the sustainability of these reductions in consumption,*** a large part of which was linked to the fear of shortages (notably power cuts) and high prices.

7 https://www.cmegroup.com/education/courses/introduction-to-energy/introduction-to-natural-gas/understanding-henry-hub.html

## The year 2023 is full of uncertainties:

The evolution of the conflict in Ukraine is uncertain as all options are open, ranging from a territorial compromise, to the attack by Russia of other neighboring countries and even to a nuclear war. It is important to note that Russia has targeted major energy facilities such as the Zaporizhia nuclear power plant and the Kakhovka dam.

The destruction of the latter by bombardment on June 6, 2023, caused the flooding of more than 600 square kilometers, causing a human and ecological disaster.

This raises questions about the safety of major energy equipment in war zones.

In addition,the October 2023 savage attack by Hamas terrorists in Israel, could destabilize the Middle East.

**Inflation:**

A series of compounding issues such as rising energy and food prices and high governmental subsidies in the wake of the pandemic, have created high inflation rates. Global inflation in 2022 is estimated to have reached 8.75%.

In 2023, lower energy prices, slower economic growth, stricter monetary policies of the central banks, and supply chain improvements are contributing to decreasing global inflation with divergent inflation trends in western economies.

To curb this inflation, central banks have increased interest rates, triggering increases in everyday products, and creating difficulties for part of the population. This growth in precariousness could be a source of *social conflicts.*

The increase in interest rates leads to an increase in the cost of electricity produced by renewable energies and nuclear[8] (see below).

While the economic slowdown has potential negative consequences on employment, it has the positive consequence of slowing energy consumption and therefore keeping energy prices at reasonable levels.

**The winter of 2023-2024 is showing more promising conditions compared to the previous one:**

1. At the end of August, European gas storage facilities were 96% full on average, which is a high historical level for this time of year and beyond the rate imposed by European regulations.
2. In 2022, the discovery of stress corrosion in the emergency cooling circuits of a number of nuclear reactors led to a significant drop in French nuclear production. Since then, EDF, with the agreement of the French Nuclear Safety Authority, has undertaken to repair these defects. Thanks to the optimization and control of repairs, the annual cumulative nuclear production was 8% higher in August 2023 than that of the same period in 2022.

The economic slowdown will probably trigger lower energy consumption. ***However, mild temperatures and sustained energy savings remain key to having a non-eventful winter.***

**Following the 2021-2022 energy crisis, besides climate change issues and energy transition acceleration, new concerns have emerged, most notably around energy sovereignty.**

8 The levelized cost of the electricity produced by these plants is mainly linked to the investments (the cost of fuel being either zero for renewables or relatively low for nuclear).

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# Energy sovereignty has become an objective.

## Fossil fuels security of supply:

As analyzed above, the unjustified invasion of Ukraine invasion by Russia in 2022, has pushed Europe to diversify its gas procurement sources and hence to increase its security of supply. Threats to European security gas supply have also been looked at: the most important one seems to be a limitation of the U.S. LNG exports linked to a potential Republican victory at the 2024 U.S. elections.

Over 2022 and 2023, the Organization of the Petroleum Exporting Countries and its partners (OPEC+) have continued to restrict their supply to push oil prices up. It also agreed to set a new, lower target for 2024. Meantime, Saudi Arabia decided to unilaterally cut oil production by 1 million barrels per day (b/d) until the end of the year. In July, Saudi crude production dropped to below 9 million b/d, its lowest level since June 2021. Oil prices rose following the news, with Brent rising above $90/barrel.

As happened in the past, oil procurement can be subject to embargos. However, OPEC countries need the oil revenue to balance their budget. This is even more true for Russia, which badly needs those dollars to finance its war efforts. As seen also in the past, high oil prices boost the U.S. shale oil production output, which in turn, limits market prices increase.

## Electricity sovereignty issues:

According to the Energy Transition Commission (ETC)[9], a successful energy transition will lead to:

- A dramatic increase in global electricity use, rising from ~28,000 TWh in 2022, to as much as ~110,000 TWh by 2050, with over 75% of this supplied by wind and solar. The rest will be provided by a mix of nuclear, hydropower, and other zero-carbon sources, along with battery and other storage equipment.
- A major expansion of electricity grids, expanding from the current 75 million kilometers of transmission and distribution to over 200 million kilometers by 2050. Knowing the local public oppositions on new overhead line projects and the resulting delays, the grid could become the Achilles' heel of the energy transition.
- A major role for low-carbon hydrogen, requiring electrolyzer capacity of up to 7,000 GW in 2050.
- The near-total decarbonization of the global passenger vehicle fleet by 2050, requiring over 1.5 billion electric cars and ~200 million electric trucks and buses. This requires a total battery capacity of up to 150 TWh.
- Carbon Capture, Utilization and Storage (CCUS) capacity increase of around 7–10 $GtCO_2$ per year, is needed to offset remaining fossil fuel.

9 https://www.energy-transitions.org/publications/material-and-resource-energy-transition/file/

## Rare metals security of supply:

ETC studied the supply and demand balance equation of six key energy transition materials (cobalt, copper, graphite, lithium, neodymium, and nickel). It appears that over the long term, there are sufficient resources[10] of all the raw materials (and of land area and water) to support the energy transition. If assessed "reserves" fall short of potential demand – for copper and nickel, for example – prices will go up. Geological research will be triggered, and new mines will open. However, there could be a time lag between growing needs and minerals availability, creating tensions on supply. Presently, for some energy transition metals, projected supply does not seem sufficient to meet rapidly growing demand. For example, from now to 2050, lithium requirements should grow by 15 times, graphite by 12 and copper and cobalt by 5.

Lithium procurement is a strategic issue. Most of the world's lithium reserves are in Bolivia (21 million tons), Argentina (19 million tons), Chile (9.8 million tons), Australia (7.3 million tons), and China (5.1 million tons). None in Western Countries.

China has a dominant position in refined lithium supply and aims to increase its position in mines. For example, in June 2023, Chinese and Russian companies announced a common investment of more than $1.4 billion in the extraction of lithium in Bolivia, to unleash the country's large reserves of the mineral.

10 A resource is that amount of a geologic commodity that exists in both discovered and undiscovered deposits. Reserves are that subgroup of a resource that have been discovered, have a known size, and can be extracted at a profit

There is major potential to reduce future lithium demand via technology, materials efficiency, and recycling.

1. *Technology:* For example, battery manufacturers are developing batteries without cobalt. Sodium-ion batteries development would reduce the need for lithium.
2. *Efficiency:* An increase in renewables generation equipment efficiency (as wind turbine capacity factors increase, or solar panels yield improvement) would reduce the mineral needs per kWh.
3. *Recycling and reuse* of recycled metals decreases the need for fresh metals. Finally, higher prices triggered by tight supply chains will increase reserve volumes and decrease consumption.

However, this global long-term positive view on supply and demand balance of critical metals does not exclude short-term problems for various reasons, notably public oppositions delaying new mines opening.

Finally, geopolitical considerations can create shortages. As a retaliatory act for the limitations placed on the Chinese semiconductor industry by the U.S., Japan, and the Netherlands, in July 2023, China, the world's top supplier of gallium and germanium, two minor metals used to make semiconductors, announced restrictions on their exports.

Could China be tempted to do the same for lithium and graphite (used notably in batteries) or polysilicon (used in solar panels) products where it has a dominant position?

***Strong action to open new mines and accelerate both materials efficiency and recycling should be taken by governments.*** The U.S. and Europe have launched strategic plans.

Nearly immediately after his election, President Biden issued an Executive Order on America's Supply Chains. Having identified critical minerals and materials as central pieces of the U.S. economy and national security, this strategic plan relies on three key pillars: diversifying supply, developing substitutes, and improving reuse and recycling.

Similarly, in March 2023, the European Commission put forward a European Critical Raw Materials Act, which aims to have at least 15% of the critical, strategic, and rare earth metal needs domestically sourced through similar actions as the U.S. Act.

In May 2023, France presented a plan to launch a €2 billion investment fund for critical metals. More funding is expected in the future. The good news is that high concentrations of lithium have recently been discovered in certain brines from European (Italy, Germany, France, and the United Kingdom) and U.S. geothermal operations. If the projects, now underway, prove that battery-grade lithium can be extracted from these brines at a competitive cost, they would become a very significant lithium resource located in the western world.[11]

11 https://theconversation.com/how-a-few-geothermal-plants-could-solve-americas-lithium-supply-crunch-and-boost-the-ev-battery-industry-179465

**Nuclear energy:**

In 2022, the European Union finally recognized that nuclear power plants are climate-friendly.[12] Is it a sovereign electricity source?

The operation of nuclear power plants depends on the supply of uranium; questions have arisen about uranium security of supply. However, ***uranium security of supply is not a tangible threat*** since:

1. Uranium resources are well distributed throughout the world. In 2022, Kazakhstan produced the largest share of uranium from mines (43% of world supply), followed by Canada (15%), Namibia (11%), and Australia (10%).[13] However, there are uranium resources in the U.S. and in Europe.
2. It's very high energy concentration makes it possible to store years of production.
3. Typically, nuclear operators have 2- to 5 years of strategic stocks. Nuclear operators have a policy of diversifying their supplies.
4. As in other industry there is recycling. Recycled uranium and plutonium (produced in nuclear plants), currently saves about 5% of fresh ore. It is also theoretically possible to re-enrich and recycle depleted uranium. Because of the relatively low price of uranium, it is not done presently.

The coup in Niger at the end of July 2023 was an interesting test. Niger is the second largest supplier of natural uranium to the EU (with a share of 25%) behind Kazakhstan. But its share in global supply is only around 5%.

The situation presented low supply risk because other sources were available. Moreover, Niger, whose economy is highly dependent on its uranium exports, should resume exportations in the mid-term.

The price of uranium increased by only 10% after the coup. However, by September, uranium prices increased by 20% compared to the previous years caused by an increase in demand for nuclear energy worldwide. This increase has a very little impact on nuclear electricity competitiveness since uranium cost is less than 5% of nuclear electricity total cost.

**The circular economy is essential to ensure sustainable growth:**

It is what the EU is implementing with the *battery passport EU regulation.*[14]

By 2030, the EU will need 5 times more cobalt and 18 times more lithium compared to the demand in 2018, numbers which exponentially increase when estimating demand in 2050.

An update to the 2006 Battery Directive aims to ensure the growth of the battery industry is done sustainably. In July 2023, the EU Battery Regulation Amendment was adopted by the EU Council, laying out the structure to achieve sustainable battery lifecycles. This includes a digital record system to enable the transfer of key information between parties – the battery passport.

According to this regulation, by the beginning of 2030, batteries must contain a minimum of 12% cobalt, 85% lead, 4% lithium, and 4% nickel which is from non-virgin sources. To meet these targets, all waste batteries collected must enter a recycling process. This process should improve its efficiency over time.

Battery producers will be obligated to report the carbon footprint associated with the overall lifecycle (excluding the use phase) of the specific manufacturing batch of batteries. As more data requirements are added to battery passports, it will also lead to greater traceability in battery supply chains.

12 https://www.reuters.com/business/sustainable-business eu-parliament-vote-green-gas-nuclear-rules-2022-07-06/
13 https://world-nuclear.org/information-library/nuclear-fuel-cycle/uranium-resources/supply-of-uranium.aspx
14 https://www.circularise.com/blogs/eu-battery-passport-regulation-requirements#:~:text=According%20to%20the%20Battery%20Regulation,listed%20in%20the%20European%20market.

**Lifecycle assessment:**

It is the only sustainable approach to compare the emissions of different electricity generation technologies.[15] These assessments over the lifecycle show a wide range of emissions per kWh. Most of renewable technologies' GHG emissions are embodied in infrastructure (up to 99% for photovoltaics), which suggests high variations in lifecycle impacts due to raw material origin, energy mix used for production, transportation modes, and installation.

Nuclear power is the lowest emitting technology with a range of 5.1-6.4 g $CO_2$ eq./kWh while coal power shows the highest scores, with a range of 751-1095 g $CO_2$ eq./kWh. Equipped with Carbon Capture and Storage, and accounting for the $CO_2$ storage, the coal plants score can fall to 147-469g $CO_2$ eq./kWh

A natural gas combined cycle plant without CCS emits around half the emissions as compared to coal plants, but 80 times more than nuclear electricity. ***This demonstrates that gas is not a long-term viable option regarding climate change and that it should be considered as a transition generation source.***

Wind power emits between 50-200% more GHG than nuclear.

For solar photovoltaic power, 40% of GHG emissions is due to the electricity consumption for silicon refining. Thus, this technology has a large range of lifecycle GHG emissions per kWh depending on the electricity carbon content. Under European conditions, photovoltaic technologies show lifecycle emissions of about 37 g $CO_2$ eq./kWh, around 800% more than nuclear. In other regions, emissions can be much higher.

***In addition to the sovereignty benefit, one advantage of manufacturing PV cells in Europe is to lower emissions by using low-carbon electricity and avoiding transportation.***

**Industrial sovereignty:**

In 2022, President Biden signed the U.S. Inflation Reduction Act (IRA)[16], a program that proposes almost $370 billion in federal incentives to shift the U.S. grid to 80% clean electricity and cut climate pollution by 40% by 2030. It also contains significant incentives to located clean energy plants in the U.S. One year later, the results are impressive: $278 billion have been announced in new private clean energy investments. Projects announced account for 170,000 new jobs.[17]

Given the rapid uptake, the estimate of public IRA investment over the next decade could reach more than $1 trillion.

In March 2023, Canada's federal government adopted a 30% Investment Tax Credit plan for solar, wind, and energy storage projects. This plan mirrors the U.S. Inflation Reduction Act.[18]

In Europe, the Net-Zero Industry Act[19], presented in March 2023, has the ambition of redeveloping a decarbonized and more autonomous industry in Europe.

***This act is a positive step but much less powerful than the IRA. Hence, the latter could attract projects formerly designed to be in Europe.***

French President Macron has successfully launched the "Choose France"[20] program with a dedicated agency "Business France" to bring low-carbon investments to France. Thanks to these actions, four battery plants will be built in the north of France (ACC, Verkor, AESC- Envision, and ProLogium). Gravithy, the green steel company, will build its first plant in the south of France and Holosis (a solar panel plant) will be built in Sarreguemines (Eastern France). More details on these projects are presented later.

15 unece.org/sites/default/files/2021-11/LCA_final.pdf
16 On August 16, 2022, President Biden signed the Inflation Reduction Act into law, marking the most significant action Congress has taken on clean energy and climate change in the nation's history. https://www.whitehouse.gov/cleanenergy/inflation-reduction-act-guidebook/
17 https://rmi.org/its-the-iras-first-birthday-here-are-five-areas-where-progress-is-piling-up/
18 https://pv-magazine-usa.com/2023/03/30/canada-formalizes-six-year-30-federal-itc-credit-among-other-incentives/
19 https://single-market-economy.ec.europa.eu/industry/sustainability/net-zero-industry-act_en
20 https://www.diplomatie.gouv.fr/en/french-foreign-policy/economic-diplomacy-foreign-trade/news/article/the-choose-france-summit-france-s-flagship-forum-for-economic-attractiveness

**European electricity market reform:**

In previous WEMO Outlooks, I stressed the urgent need for this reform.

Because of the 2021-2022 energy crisis and the need to decouple electricity prices from gas prices, the EU heads of States pushed the Commission to launch this reform.

On March 14, 2023, the European Commission (EC) published a proposal to reform the EU electricity market. The objectives are[21]:

1. Protecting consumers from volatile energy prices.
2. Enhancing stability and predictability of the cost of energy, thereby contributing to the competitiveness of the EU economy; and
3. Boosting investments in renewable energy.

To address the *first* objective, the proposal foresees notably:

» To allow Member States to implement a specific type of regulated retail prices (i.e., block tariffs), which have been used during the 2021-2022 crisis to protect consumers.

» To allow consumers to share renewable energy more easily.

» To encourage suppliers to shield against high prices through the increased use of long-term contracts with generators to stabilize energy supply for their customers.

To address the *second* objective:

» The proposal aims to optimize the functioning of short-term markets, for example, reducing the minimum bid size for intraday and day-ahead markets to 100 kW to improve liquidity.

» The *proposal encourages customers to enter stable long-term contract*s, such as Power Purchase Agreements (PPAs[22]) and Contracts for Difference (CfDs[23]). It also seeks to increase forward markets liquidity.

Access to PPAs is currently available only to major actors in a few Member States. The States are thus asked to implement measures to make PPAs more widely accessible, notably by decreasing risks associated with buyers' payment default (through state guarantees).

21 https://fsr.eui.eu/a-summary-of-the-proposal-for-a-reform-of-the-eu-electricity-market/

22 PPAs are long-term private contracts between a renewable energy or low-carbon generator and a consumer.
23 CfDs are Contract for Difference based on a difference between the market price and an agreed "strike price".

The European Commission EC recommends two-way CfDs[24], which imply setting a minimum that can be earned by the energy producer, but also a maximum price, so that any revenues above it are paid back to the public actor. CfDs have already been used for wind and solar. Their use would be extended to geothermal, hydro without reservoir, and nuclear power (existing plants and new ones).

As for the *third* objective, CfDs and PPAs could give reliable revenues to renewable energy suppliers (lowering the financial risk and reducing the cost of capital). This would contribute to the objective of tripling renewables deployment in line with European Green Deal goals.

The ***European electricity market reform is a particularly sensitive topic in France*** because the regulated system for the sale of nuclear electricity, Accès Régulé à l'Electricité Nucléaire Historique (ARENH), ends in December 2025. This regulation obliges EDF to sell 100 TWh (between one-third and one-quarter of its nuclear electricity production) to its competitors at the very low price of €42/MWh. This regulation is very penalizing for EDF and partly explains its financial difficulties.

There is a certain urgency for EDF and its customers to define the conditions of sale from 2026 onwards. EDF, heavily indebted and which must finance (at least in part) the construction of the new EPRs[25] needs visibility on its finance trajectory. Its major customers also wish to know the conditions for purchasing electricity two years in advance.

EDF defends the conclusion of long-term electricity sales contracts in the form of PPAs to set its prices more freely to finance its investments in existing power plants and new means of production (renewable and nuclear). These investment needs should reach around €25 billion.

In this context, on September 7, 2023, EDF announced the launch of an experimental auction system with the placing on the wholesale electricity market of volumes to be delivered in 2027 and 2028 (over five years). Presently, the French wholesale market only allows electricity to be purchased until 2026 (three-year contracts). EDF wants to increase its visibility and that of consumers in the context of high prices.

The agreement that took place in October 2023 between France and Germany has cleared the way to the finalization of this import reform. However numerous details have still to be agreed upon before the 2024 European elections.

24 In two ways CfDs if the "strike price" is higher than a market price, the CfD Counterparty must pay low carbon generator the difference between the "strike price" and the market price. If the market price is higher than the agreed "strike price», low carbon generator must pay back the CfD Counterparty the difference between the market price and the "strike price."

25 European Power Reactor or Evolutionary Power Reactor

## Climate change consequences are happening quicker than expected.[26]

June, July, and August 2023 were the hottest months ever recorded since 1940. According to the Copernicus Climate Change Service[27], "The world will continue to see more climate records and more intense and frequent extreme weather events, until we stop emitting greenhouse gases."

Global energy related GHG emissions grew by 0.9% or 321 Mt in 2022, reaching a new high of over 36.8 Gt. This growth was slower than 2021's 6% increase, which followed a 4.6% drop in 2020 as lockdowns in the first half of the year restricted global mobility and hampered economic activity.[28]

Increased deployment of clean energy technologies such as renewables, electric vehicles, and heat pumps helped prevent an additional 550 Mt in $CO_2$ emissions. Industrial production curtailment, particularly in China and Europe, also averted additional emissions.

$CO_2$ growth in 2022 was well below global GDP growth of 3.2%, reverting to a decade-long trend of decoupling emissions and economic growth which was broken by 2021's sharp rebound in emissions.

26 https://www.iea.org/reports/co2-emissions-in-2022
27 https://climate.copernicus.eu/summer-2023-hottest-record
28 https://www.iea.org/reports/co2-emissions-in-2022
29 https://www.lemonde.fr/en/international/article/2023/09/08/un-world-not-on-track-to-meet-paris-climate-goals_

According to a new climate report issued by the United Nations in early September 2023, "the world is not on track to meet the long-term goals of the Paris Agreement," including capping global warming at 1.5° Celsius since pre-industrial times[29] and achieving net zero carbon by 2050.

**What measures should be taken?**

### Accelerate clean technologies deployment.

A successful energy transition to reach net zero carbon in 2050, implies a huge growth in electricity generation. According to the Energy Transition Commission[30], it should rise from ~28,000 TWh in 2022, to as much as ~110,000 TWh by 2050, with over 75% of this supplied by wind and solar. The rest will be provided by a mix of nuclear, hydropower, and other zero-carbon sources, along with battery and other storage.

*China has a dominant role in clean technologies, both by its domestic investments and by its position in the international market.* The country spent $546 billion in 2022 on investments that included solar and wind energy, electric vehicles, and batteries. That is nearly four times the amount of U.S. investments, which totaled $141 billion. The European Union was second to China with $180 billion in clean energy investments.[31]

30 https://www.energy-transitions.org/publications/material-and-resource-energy-transition/
31 https://www.scientificamerican.com/article/china-invests-546-billion-in-clean-energy-far-surpassing-the-u-s/#:~:text=The%20country%20spent%20%24546%20billion,billion%20in%20clean%20energy%20investments.

We will concentrate our analysis on clean electricity generation by acknowledging that "green heat", as provided by biomass and geothermal, is an important complement notably because it is storable.

We will not analyze in detail the progress in CCUS, as this was done extensively in the 24th edition of WEMO.[32] We can note that with solid market carbon prices[33], CCUS competitiveness could increase thanks to industrialization, and that it is certainly a technology that is needed. In the United States, Oil & Gas companies are strongly committed to developing this technology and the IRA provides subsidies. Europe is late (compared to the U.S.) in CCUS development; however, the EC has launched a consultation to state its vision.

Finally, China is making significant progress on CCUS development.[34] This is of the utmost importance as China is commissioning two large coal plants per week.[35]

Finally, as stated in 2022, Direct Air Capture is not a mature technology, since it consumes a lot of energy and because it is expensive.

**Nuclear:**

***Climate changes and energy sovereignty issues are triggering nuclear revival.*** In early 2023, at the initiative of France, the European Nuclear Alliance was created. It aims to bring together all the countries of Europe wishing to rely on nuclear energy, alongside renewables, to carry out their energy transition. In May, the 16 European countries participating in this alliance (Belgium, Bulgaria, Croatia, the Czech Republic, France, Finland, Hungary, the Netherlands, Poland, Romania, Slovenia, Slovakia, Estonia, Sweden, Italy, and the United Kingdom) announced that they will prepare a roadmap to develop an integrated European nuclear industry reaching 150 GW[36] of nuclear power capacity in the EU's electricity mix by 2050. They call on the European Union and international partners to consider the contribution of all affordable, reliable, fossil-free, and safe energy sources to achieve climate neutrality by 2050.

Nevertheless, actions must follow the announcements. ***Further, financing terms for new nuclear power plants have not yet been decided, including notably in France*** where there are ambitious plans to build six new EPR reactors and consider building a further eight.

At the end of August 2023[37], in addition to EDF funding, the U.K. government announced that it has made available a further £341 million (€400 million) on the Sizewell C nuclear power plant. Sizewell C is expected to host two EPRs of 1.6 GW capacity each, like the Hinkley Point C plant, which is under construction. The construction of Sizewell C remains subject to a final investment decision and depends notably on the project financing as the U.K. government must raise £20 billion (€20.3 billion) of private finance through debt and equity before construction can start. To make the investment attractive to institutions (such as pension funds), the U.K. government has adopted the Regulated Asset Base (RAB) regulation[38] for the electricity to be produced by Sizewell C. In comparison with the CfD model used for Hinkley Point C, under RAB, construction risks would fall on the public (most likely as electricity consumers, but also as taxpayers). However, it will probably take until the end of 2024 to close Sizewell's construction funding.

32 https://www.capgemini.com/insights/research-library/world-energy-markets-observatory/
33 In Europe, Emission Trading System (ETS) carbon price is around €90/t
34 www.globalccsinstitute.com
35 https://energyandcleanair.org/publication/china-permits-two-new-coal-power-plants-per-week-in-2022/#:~:text=A%20total%20of%20106%20GW,from%2023%20GW%20in%202021.

36 100GW in 2023. As there will be nuclear plants decommissioning from 2023 to 2050 the new plants capacity to be built will exceed 50GW.

37 https://world-nuclear-news.org/Articles/More-funding-for-Sizewell-C-preparations
38 https://www.lowcarboncontracts.uk/

1. ***Existing reactors have been operating safely*** as no important incident or accident happened since the 2011 Fukushima accident.

   In 2023, there are about 440 nuclear power reactors operating worldwide with a combined capacity of about 390 GW.[39] They provide around 10% of the worldwide electricity needs. The 2022 IEA Net Zero Emissions by 2050 Scenario (NZE)[40] sees nuclear capacity increase to 871 GW by 2050. Out of the 60 power reactors currently being constructed, the vast majority is in Asia (China, India, and North Korea) and Russia has four reactors under construction.

» *Lifetime:*

The nuclear power plants lifetime should be linked only to its safety condition and price competitiveness. However, these technical and economic considerations are not considered by politicians that decide to close safe and competitive reactors. This was unfortunately the case in France with the closure of Fessenheim's two reactors in 2020.

After the Fukushima accident in 2011, the German Chancellor decided to phase out the country's 17 nuclear reactors. Accordingly, all have been stopped by mid-2023, including the three last ones that were provisionally kept open during the 2022-2023 difficult winter. This happens while Germany is increasing its renewable output and may be confronted with grid stability problems.

During the summer of 2023, two important lifetime extension decisions were announced. On the one hand, Belgium reached an agreement with operator Engie to extend the use of the country's nuclear reactors by 10 years after Russia's invasion of Ukraine prompted Belgium's governing coalition to rethink plans to rely more on natural gas.

Initially, Belgium was to have exited nuclear power entirely by 2025, but will now extend the lives of its two newest reactors, Doel 4 and Tihange 3, according to the agreement.

On the other hand, the French Nuclear Safety Authority issued a decision allowing for the continued operation of EDF's Tricastin 1 nuclear reactor in southern France. It is the first lifetime extension granted to a French reactor after 40 years of operation. These decisions will allow to keep the existing nuclear fleet while waiting for the new nuclear plant to be built.

» In addition, *reactor uprates*[41] provide immediate solutions to maintaining and increasing power capacity in existing reactors. Since 2001, globa net nuclear capacity has increased from 352.72 GW to 392.61 GW[42], an 11% increase, while the number of operational nuclear power plants has not increased significantly (438 vs. 442). Some of this is attributable to smaller reactors being replaced by larger ones, but most of the increase is due to improvements in existing reactors. These investments usually have a compelling payback for utilities as capital investment represents around 80% of the nuclear electricity cost. Uprates are relatively small investments leading to capacity increases ranging from 0.4% to 20%.

The French nuclear operator was prevented from increasing its fleet capacity by the 2015 law capping the total nuclear output at 63 GW. Thanks to the new 2023 law on "nuclear acceleration", this non-understandable constraint has been lifted and EDF is engaging in an uprating program.

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39 https://world-nuclear.org/information-library/current-and-future-generation/plans-for-new-reactors-worldwide.aspx
40 'Net Zero Emissions by 2050 Scenario' (NZE), "maps out a way to achieve a 1.5°C stabilization in the rise in global average temperatures, alongside universal access to modern energy by 2030."

41 An uprate is any change that increases the power output of

42 https://sprott.com/insights/special-uranium-report-why-nuclear-power-plant-life-extensions-uprates-matter/

1. *New large reactors:*

**Out of the 60 power reactors currently being constructed, the vast majority is in Asia** (China, India, and North Korea) and Russia has four reactors under construction. Most of these constructions are progressing along the initial plant. This is not the case in western world.

» On July 31, 2023, the U.S. utility Georgia Power announced that the AP1000 Vogtle 3 was in commercial service. It becomes the 93rd reactor in the country. Unit 4 is expected to generate electricity in the first quarter of 2024 at the latest. They are seven years late and $17 billion over budget. Some of the key promises of Vogtle — like building modules offsite and shipping them for cheaper on-site assembly — did not materialize.

» In Europe, Finland's Olkiluoto 3 EPR (1600 MW) finally entered in service more than ten years later than planned and with a several billion Euro cost overrun. Olkiluoto 3 is the first EPR to enter service in Europe and the third in the world after the Taishan 1 and 2 plants in China. The French Flamanville 3 EPR should start operations in the first quarter of 2024. Similarly to Olkiluoto EPR, the delay will be 12 years and the cost overrun around €10 billion. (The project's cost at completion is estimated at €12.7 billion, more than four times the initial estimate of €3.3 billion). These examples ***illustrate the difficulty of building new large third-generation reactors in western countries.***

2. *SMRs:*

Development on small modular nuclear reactors (SMRs) is underway globally and is generating a lot of interest. SMRs promise technological advances that address key challenges in the nuclear power generation cycle, including project size, cost and financing, time to market, and location flexibility.

In 2021, after a nine-year construction, research and technological development, the China Huaneng Group Co.'s 200 MW Unit 1 reactor at Shidao Bay has started operations in Shandong province, using helium as the cooling fluid instead of water.

In 2019, the floating nuclear power plant Akademik Lomonosov was connected to the grid, generating electricity for the first time in Russia's far east.

There are currently four SMRs in advanced stages of construction in Argentina, China, and Russia. In addition, several existing and newcomer nuclear energy countries are conducting SMR research and development.

- *Design:* There is a large range of SMR designs in development (more than 70 different designs as of 2023). The most mature SMR concepts being proposed by vendors are evolutionary variants of Light Water Reactors (LWR) operating worldwide; these benefit from many decades of operating and regulatory experience. They represent approximatively 50% of the SMR designs under development.

  The other 50% of SMR designs corresponds to Generation IV reactors (Gen IV SMR) that incorporate alternative coolants (i.e., liquid metal, gas, or molten salts), advanced fuel, and innovative system configurations. While Generation IV-based designs do not have the same levels of operating and regulatory experience as that of LWRs, and additional research is still needed in some areas, they nevertheless benefit from an extensive history of past research and development.

  These reactors have advanced engineered features and are deployable either as a single- or multi-module plant. Some are classified as micro SMRs, producing as little as 10 MW, while many are designed for a capacity of about 300 MW.

- *Benefits:* Small modular reactors offer a lower initial capital investment and thus a reduced risk, greater scalability, and siting flexibility for locations unable to accommodate larger reactors. They also have the potential for enhanced safety and security compared to earlier designs. Their small size and modularity facilitate their adoption in regions and sectors where the use of large nuclear power plants is more limited.

- *Challenges:* The smaller size of SMRs implies that they don't benefit from economies of scale.

  To overcome this economic challenge, "series construction" will become an imperative. Factory fabrication also provides an environment of enhanced quality control that can reduce construction risks and enable the introduction of new manufacturing techniques. ***Some of these benefits*** have already been demonstrated in other industries but ***still need to be proven for SMRs.***

  At the same time, higher levels of regulatory harmonization are needed to support a global market, as well as a reduction in the number of designs proposed by vendors. Obtaining licensing agreements is potentially a challenge for SMRs, as design certification, construction, and operation license costs are equivalent to those of large reactors that generate much more electricity. In addition, the dispersion of SMRs could raise concerns on nonproliferation management.

Finally, due to their smaller size and deployment over larger areas; harnessing the same amount of electricity from SMRs than large reactors will require an increased number of grid connections (similar to wind or solar farms). This places additional demands on grid operators. They will encounter the same challenges in grid connection as dispersed wind or solar farms.

An illustration of these challenges is the NuScale SMR project development. It has long been named the most advanced company in the field of SMRs. Its design, composed of 50 MWe modules, is also the first to have received certification from the U.S. safety authority (NRC) in January 2023. However, at the end of 2022, the company announced a 53% increase in the SMR's target electricity price, driven by a dramatic 75% jump in the project's estimated construction cost, which has risen from $5.3 billion to $9.3 billion. The new estimate makes the NuScale SMR about as expensive (on a dollars-per-kWh basis) as the two-reactor Vogtle nuclear plants (see above), undercutting the claim that SMRs will be cheap to build.[43]

***While SMRs will certainly contribute in the future to clean energy generation, it is likely that they will not contribute meaningful amounts in western countries, for another decade.***

43 https://ieefa.org/resources/eye-popping-new-cost-estimates-released-nuscale-small-modular-reactor

» *Start-ups:* SMR development is proceeding in western countries with a lot of private investment, including small start-up companies. Out of the 83 SMR projects from many different players surveyed by IDTechEx[44], around 30% of the organizations involved are start-ups. The involvement of these new investors is positive, as it brings fresh financing to the nuclear industry, new ideas, and entrepreneurial management skills.

3. ***Nuclear fusion breakthrough:***

Present reactors are based on fission nuclear reaction that split atoms to generate energy. A fusion reaction would force lighter atoms (for example deuterium) together to create heavier atoms. Both reactions generate carbon-free energy, but fusion avoids much of the radioactive waste that fission creates. Fusing atoms together requires extreme heat and pressure. Up until recently, the development was based on magnetic confinement (Tokamak), notably with the very large ITER[45] international project. Recently, fusion confinement triggered by laser has made a scientific breakthrough.

In December 2022, scientists at Lawrence Livermore National Laboratory in California achieved fusion ignition.[46] However, the efficiency of a potential fusion energy power plant remains to be seen as the reported fusion net gain required about 300 megajoules of energy input, which was not included in the energy gain calculation. This energy input, needed to power 192 lasers, came from the electric power grid. In other words, the experiment used as much energy as a typical household does in two days while the fusion reaction output was enough energy to light just 14 incandescent bulbs for one hour! ***So, a real break-even was not reached.***

Presently there is an appetite for funding nuclear fusion from governments and the private sector. For example, Germany, which has phased out its nuclear plants, announced in September 2023, that it will invest more than €1 billion in fusion research over the next five years. On the private sector side, entrepreneurs and start-ups are investing and getting public funding (from the Department of Energy, for example). Presently there are 39 companies in nuclear fusion[47] and this number is growing.

However, billions of dollars are needed before fusion can meaningfully contribute to our energy system.

**Solar and wind power development must accelerate:**

1. ***In 2022, investment in clean energy technologies48 has significantly outpaced spending on fossil fuels,*** triggered by affordability and security concerns. 2022 was a record year for renewable electricity capacity additions, with annual capacity additions amounting to about 340 GW.[49] Public policies in the United States (IRA), Europe, and China (14th Five-Year Plan) have pushed renewable energies and should continue in the future. The capacity of offshore wind farms is continuously increasing thanks to the wind turbine capacity increase. The development of the cable industry and floating offshore platforms enables the construction of very large offshore farms at a longer distance from the coast (which reduces local opposition).

   For example, the Seagreen[50] offshore wind farm in Scotland is expected to be fully operational during the summer of 2023 with 114 turbines and a total capacity of 1,075 MW. Its electricity will be exported via 19 kilometers of underground cables. The largest solar farms are in China, India, and the Middle East. The Golmud Solar Park in China is the world's largest

44 https://www.idtechex.com/en/research-article/the-future-of-nuclear-smrs-will-start-ups-disrupt-established-players/29374
45 https://www.iter.org/fr/mach/tokamak

46 https://theconversation.com/nuclear-fusion-breakthrough-decades-of-research-are-still-needed-before-fusion-can-be-used-as-clean-energy-196758
47 https://tracxn.com/d/trending-themes/startups-in-nuclear-fusion/__9FrsspZn9m17N8HDaicS29LcdRJCyceX3ICOmPdAn98

48 The report shows that investment in clean energy technologies is significantly outpacing spending on fossil fuels, as affordability and security concerns triggered by the global energy crisis strengthen the momentum behind more sustainable options.
49 https://www.iea.org/energy-system/renewables#tracking
50 https://www.power-technology.com/projects/seagreen-offshore-wind-farm/

solar farm with an installed solar capacity of 2.8 GW, generated by nearly seven million solar panels. Plans are to expand the site to reach 16 GW within the next five to six years. Despite those impressive achievements, renewable deployment must accelerate. Several factors can contribute to this needed acceleration.

2. ***Accelerating the permitting process,*** since it can be an obstacle to renewable energy projects by increasing delays and cost. To address the issue, the revised Renewable Energy Directive includes provisions that simplify permitting processes. In the U.K., the Simplifications Decree-Law for renewable energy, green hydrogen, and electricity grid entered into force on April 19, 2022[51]. In March 2023, France adopted the law on the acceleration of the production of renewable energies, the aim of which is to halve the deadlines for carrying out renewable energy projects. In 2020, wind, solar, as well as wood and hydro energies, represented 19.1% of country gross final consumption, which was below its EU target of 23%.

   The law is thus structured around four pillars:

   » Accelerate the procedures: In France, it takes, on average, five years of procedures to build a solar park requiring only a few months of work, seven years for a wind farm, and 10 years for an offshore wind power park – twice as long as its European neighbors.

   » Free up the necessary land, by mobilizing car parks, degraded land, and the edges of motorways to deploy photovoltaic panels.

   » Accelerate the deployment of offshore wind projects through less complex consultation procedures with local stakeholders and through field planning that would be carried out on the scale of a seafront.

   » Improve the financing and attractiveness of renewable energy projects.

3. ***Boosting innovation: The innovation goals for renewables are like those analyzed in the 24th edition of the WEMO.***[52]

   For PV solar technology, they aim to:

   - Increase the solar panels' yield[53], with innovative material such as perovskites.
   - Develop longer-lasting solar cells.
   - Develop solar cells printable onto flexible surfaces.
   - Implement solar panels that track the sun from east to west throughout the day.
   - Develop solar power plants that work at night.

   - Extend the surfaces covered by PV panels by installing them on rooftops and lakes (floating solar).

51 https://www.cuatrecasas.com/en/global/art/portugal-simplification-of-procedures-for-renewable-energy-projects
52 https://www.capgemini.com/insights/research-library/world-energy-markets-observatory/

53 https://www.energymatters.com.au/renewable-news/latest-advances-in-solar-pv-technology-could-make-solar-panels-more-efficient-and-affordable/

For wind technology, innovations aim to:

- Increase wind turbines size: China Three Gorges Corporation announced that a 16 MW turbine had been successfully installed at the company's offshore wind farm on July 19, 2023. The behemoth is 152 meters tall, and each single blade is 123 meters and weighs 54 tons!
- Design wind turbines with innovative aerodynamic and structures.
- Use better materials, including advanced nanomaterials like graphene for turbine blades, and consider hybrid materials for wind turbine towers, combining both steel and concrete for enhanced durability and performance.
- Adapt oil offshore floating platform technologies to offshore wind, enabling the construction of wind farms further from the coast.

For both solar and wind there is a need to

- Recycle equipment.
- Improve operations, control, and maintenance; and
- Implement a data-driven approach, by developing advanced measurement systems and improving numerical prediction tools.

4. ***Improving wind and solar competitiveness:*** After years of impressive drops in cost, wind and solar levelized cost of electricity (LCOE) started to increase in 2021. In 2022, this trend continued. Like nuclear electricity costs, the initial capital investment accounts for the majority of solar PV and wind power plant generation cost (as operations and maintenance costs are very low). In late 2020, the prices of major inputs such as steel, copper, aluminum, and polysilicon began to rise sharply, as did freight and land transport costs, due to supply chain challenges and growing demand during the post-Covid-19 global economic rebound.

   During 2022, freight and commodity prices have fallen significantly below their peaks, but they remain elevated compared with 2020. For example, polysilicon price (where China has a dominant position) in Q1 2023 was 200% higher than the January 2020 average price. U.S. steel increased by 100% during the same period.

   These cost increases were not offset by cost reductions from technological innovation and, according to IEA54, the resulting LCOE increase for 2022 is estimated at 15-20% for these technologies. Except for China, many regions experienced cost increases, especially for offshore wind.

   In Europe55, between 2020 and 2022, LCOE onshore wind cost increased from €38/MWh to €50/MWh, solar utility scale farms cost rose from €48/MWh to €67/MWh, and offshore wind cost jumped from €101/MWh to €114/MWh.

   *Although their costs continue to exceed pre-Covid-19 levels, solar PV and onshore wind remain the cheapest option for new electricity generation in most countries.*

5. ***Overcoming industry difficulties and increasing sovereignty:***

   » Three recent events illustrate the wind sector difficulties.

   - On August 30, 2023, Denmark's Orsted[56], the world's largest offshore wind farm developer, announced impairments of €2.3 billion due to supply chain problems, soaring interest rates, and a lack of new tax credits, especially on U.S. offshore projects. In one year, production costs rose significantly, while the long-term electricity purchase prices offered by States have continued to fall. This situation makes operators dependent on subsidies. Part of Orsted's disappointment comes from a reduction in the expected subsidy for the establishment of its field off the North American coast.

54 iea.org/reports/renewable-energy-market-update-june-2023/will-solar-pv-and-wind-costs-finally-begin-to-fall-again-in-2023-and-2024.

55 https://www.woodmac.com/news/opinion/renewable-energy-costs-europe/

56 https://www.reuters.com/business/energy/denmarks-orsted-anticipates-730-mln-impact-us-portfolio-2023-08-29/

- In July 2023, Swedish utility Vattenfall[57] announced that it would stop development of its British Norfolk Boreas offshore wind project (1.4 GW) due to rising costs. Vattenfall President and CEO Anna Borg said that costs rose by 40% and she warned that Britain could struggle to meet its wind targets without improved incentives.
- In August 2023, Siemens Gamesa[58] booked a €2.6 billion loss in its fiscal third quarter due to higher-than-expected charges associated with its onshore turbines. The turbine company expects to record a total loss for the year of around €4.5 billion, reflecting lower profit contributions from the execution of its current order backlog mainly related to increased product costs. These challenges highlight a broader issue facing wind turbine manufacturers. They are actively investing in research and development to enhance the size of their turbines with the goal of reducing costs. However, they find it challenging to recover these R&D investments, as clients are demanding even faster cost reductions. Indeed, the latter (utilities and Oil & Gas companies) are bidding for new projects at continuously lower electricity prices to win. To secure their wind turbine procurement, European renewable companies are opening their supplier list to Chinese firms (Goldwind and Envision Energy, for example).
- According to Renewable Digital[59], five out of the 10 largest wind turbine manufacturers[60] are Chinese. ***Governments, regions, and States in the U.S. and EU should either increase subsidiaries on wind projects or increase the allocated price to avoid bankruptcy of their domestic wind turbine companies, which would endanger their energy sovereignty.***

» While the U.S. government has limited the Chinese suppliers' access to the US by legislations such as the IRA, in Europe, the solar PV sector is totally dominated by Chinese suppliers. Now the EU is reacting by encouraging PV panels manufacturing in Europe.

In June 2023, the French President announced an investment of €700 million by Holosolis in a 5 GW production plant for photovoltaic solar cells and modules in France. This factory complements another 5 GW project with an investment of €1.5 billion over the entire solar module cycle, from the formation of ingots. In the medium term, new PV production capacity should reach 10 GW on French territory.[61]

However, China is dominant in polysilicon procurement. Its share of world's polysilicon production has grown from 30% to 80% in just one decade (2012-2021)[62] and should expand to 90% soon. Out of the top 10 polysilicon manufacturers in 2021, only two are situated outside of Asia: Wacker (Germany/United States, ranking 4th) and Hemlock (United States, ranking 9th). The remaining seven suppliers are based in China.

57 https://www.reuters.com/sustainability/vattenfall-halts-project-warns-uk-offshore-wind-targets-doubt-2023-07-20/
58 https://renews.biz/87372/siemens-gamesa-records-26bn-q3-loss/

59 https://renewables.digital/product/wind-turbine-manufacturers/
60 Vestas Wind Systems (Denmark), Siemens Gamesa (Spain),Goldwind (China), Nordex SE (Germany), General Electric Renewable Energy (France),Envision Energy (China),Zhejiang Yunda Wind Power (China),VENSYS Energy AG (Germany), Mingyang Smart Energy (China), HZ Windpower (China )

61 https://www.enerplan.asso.fr/industrie-solaire-une-ambition-enfin-a-la-hauteur-des-defis-en-france
62 https://www.solarpowerworldonline.com/2022/04/chinas-share-of-worlds-polysilicon-production-grows-from-30-to-80-in-just-one-decade/

Russia's invasion of Ukraine has opened the eyes for what it means to be dependent on a country for energy supply. Western governments should not make the same mistake with China.[63]

*"It is high time to establish non-Chinese solar supply chains. China has demonstrated what the ingredients of success are: low electricity rates for power-hungry polysilicon and ingot production, loan guarantees for private investment, cost-efficient equipment manufacturing, and strategic foresight."*

**Johannes Bernreuter**
Founder and head · Bernreuter Research

**Electricity storage development is of the utmost importance to balance electricity grids.**

According to IEA, to reach climate change mitigation objectives, the world needs to triple the global installed capacity of renewable power by 203064 (mainly intermittent wind and solar).

In March 2023, the European Union members committed65 to sourcing 42.5% of their energy from renewable sources by 2030, with a potential top-up to 45%. This increasing share of intermittent renewable generation and the closure of "peaker plants" (powered by natural gas) that insure the grid balance at critical hours, is triggering an increasing need for electricity storage.

For example, in Australia, renewable energy sources supply about 27% of Australia's electricity generation, and at times up to 52%. Such rapid penetration of renewables is already posing significant challenges to grid stability with utility-scale energy storage becoming increasingly important. The recently drafted Australian Integrated System Plan (ISP) highlights challenges for energy storage in Australia.

They include:

» The need to triple the firming capacity that can respond to a dispatch signal, including utility-scale batteries, hydro storage, gas generation, smart behind-the-meter batteries, or virtual power plants (VPPs).

» By 2050, a National Electricity Market (NEM) without coal will require 45 GW/620 GWh of storage, in all forms.

1. ***Pumped storage hydropower (PSH)[66]:*** *Presently, the largest storage capacity is provided by PSH.* With more than 100 projects in the pipeline, International Hydropower Association (IHA)[67] estimates that PSH capacity is expected to increase by almost 50% – to about 240 GW – by 2030. The IEA has set a target of 420 GW of pumped storage worldwide by 2050. China leads installed PSH capacity with 50.7 GW, holding 30% of the world's total. For prospective capacity, China is the first country with 80% of the global projected capacity followed by Europe, Australia, India, and Northern America.

   An innovative project in Germany is studied by scientists. It consists of filling opencast lignite mines (at

63 Research: https://www.bernreuter.com/
64 https://www.iea.org/commentaries/tripling-renewable-power-capacity-by-2030-is-vital-to-keep-the-150c-goal-within-reach
65 https://www.reuters.com/business/sustainable-business/eu-reaches-deal-more-ambitious-renewable-energy-targets-2030-2023-03-30/#:~:text=Negotiators%20of%20the%20European%20Parliament,a%2032%25%20renewable%20energy%20share.
66 https://www.energy.gov/eere/water/pumped-storage-hydropower
67 https://www.hydropower.org/factsheets/pumped-storage

a depth of 500 to 300 meters) located in Rhineland and installing PSH. Feasibility studies with elaborated cost estimation are the next step.

2. ***Batteries*** offer a complement to creating a lower emission[68], more resilient grid. The world will need nearly 600 GWh of battery energy storage by 2030 to achieve net-zero emissions by 2050, according to estimates from the IEA.[69] In 2021, there was less than 60 GWh of battery storage capacity, hence *the need for a big acceleration of stationary batteries installations.*[70]

   In 2021, about 25 GWh of battery energy storage system (ESS) capacity was added globally, which amounts to 10-15% of EV battery demand. Although the demand for ESS batteries is growing substantially—more than 100 GWh of new capacity has been announced for 2022-2024, the market is concentrated in just a few regions: the U.S. (mainly California), China, and Europe.

   In China, for grid stability reasons, wind or solar farms will be connected to the grid only if they have stationary storage equivalent to about 5-20% of the total power generated. Some U.S. states have similar legislation.

   ***With the higher renewable generation and its intermittency, curtailments of solar or wind generation will be more frequent.***

   Either these solar or wind farms are collocated with hydrogen electrolyzers[71] to produce hydrogen at near zero electricity cost, or this electricity is lost, thus destroying the value of investing in these farms. This is why the value of stationary storage is growing.

   In August 2023, French utility company Engie has reached a deal, with an equity value of over $1 billion, to purchase Texas-based battery energy storage firm Broad Reach Power.[72] As part of the transaction, Engie will now own 350 MW of grid-scale battery assets in operation, along with 880 MW under construction and 1.7 GW of storage projects in the pipeline. U.S.-listed private equity firm KKR is set to acquire joint control of U.K. battery storage developer Zenobē in partnership with existing investor Infracapital, according to reports.[73] The deal totals $1.089 billion of investment.

   This growth in ESS battery demand is ramping up at the same time as the need for EV batteries, meaning that both types of battery makers are seeking the same resources, such as lithium or cobalt (see above).

   However, the specs for stationary batteries are not the same as for EV batteries. The latter can accommodate a lower energy density since weight and space constraints are not a concern.

   ESS battery manufacturers are opting for lithium-iron-phosphate (LFP) batteries, which have a lower energy density compared to nickel-manganese-cobalt (NMC) batteries. However, this lower energy density is not a significant concern for ESS applications, especially considering that LFP batteries do not rely on nickel and cobalt, unlike NMC batteries.

   It's worth noting that NMC batteries are still the primary choice for electric batteries.

   » ***Technologies:*** Lithium-ion batteries are the best option for stationary storage today.

   - Sodium-ion batteries are non-flammable (thus safer), have a longer life cycle, perform well in low temperatures and can be more sustainable due to their reduced use of critical materials. They also share a similar design to lithium-ion batteries, making manufacturing less of a challenge.
   - The main drawback today is their relatively lower energy density compared to lithium-ion

68 They can be considered as "green" only if they are recycled.
69 https://www.iea.org/energy-system/electricity/grid-scale-storage#tracking
70 https://www.emergingtechbrew.com/stories/2022/04/19/batteries-beyond-evs-everything-you-need-to-know-about-stationary-storage

71 However, hydrogen transportation to the industrial consuming plants is usually not yet available expensive and probably ammonia plants will have to be built also as liquid ammonia is easier to transport.
72 https://www.engie.com/news/broad-reach-power
73 https://www.energy-storage.news/private-equity-firm-kkr-agrees-us1-billion-deal-for-uk-developer-zenobe-reports/

batteries (which is not a problem for stationary batteries). Ongoing R&D[74] aims at improving their performance to reach energy density similar to LFP batteries. Lower cost can be expected once production is scaled up. CATL[75], the world's largest battery-maker of Chinese origin, announced it plans to have a supply chain for sodium-ion batteries in place by 2023. Other early-stage battery technologies are being developed for stationary storage applications, such as: flow batteries, metal-air (notably aluminum-air) batteries, or liquid metal batteries using molten salt.

- Flow batteries[76]: A flow battery is a rechargeable battery in which electrolytes flow through one or more electrochemical cells from one or more tanks. Expanding the energy storage capacity of a flow battery is a straightforward process accomplished by increasing the volume of electrolyte stored in the tanks. The electrochemical cells can be electrically connected in series or in parallel, thus determining the power of the flow battery system. This decoupling of energy rating and power rating is an important feature of flow battery systems.

- However, the system is complex as it requires a pump and flow management system. Moreover, flow batteries have high costs at present.
- As a final consideration, many players in the flow battery industry have recently stumbled, including Imergy, Aquion, and ViZn. It is likely that only a few will be able to capitalize on the potential advantages of flow batteries.

» ***Recycling plays a vital role in ensuring the sustainability of batteries and electric vehicles (EVs).***

To achieve true sustainability, it is essential to recycle batteries, and simultaneously, ensure that the electricity used for recharging them comes from low-carbon sources.

- EV batteries no longer suitable for vehicles: When an EV ultimately retires (or crashes), its battery pack can be reused for stationary storage. For example, the Mobility House (Zürich) already earns ~€1000 per EV battery pack per year by selling ~13 services from stationary or parked EV battery packs to the electricity grid in several European countries.
- Recycling: Interest and investment in lithium battery recycling have grown in recent years as critical materials needs are exploding (see above) and carbon emissions from metals need to decrease. New legislations, such as the European battery passport, are making recycling compulsory.

74 They can be considered as "green" only if they are recycled.
75 https://www.iea.org/energy-system/electricity/grid-scale-storage#tracking
76 https://www.emergingtechbrew.com/stories/2022/04/19/batteries-beyond-evs-everything-you-need-to-know-about-stationary-storage

Prior to recycling, batteries are collected, sorted, and dismantled. Then plastics and metals will be separated. Metals are crushed, producing "black mass" which is a powder containing a mixture of cathode and anode materials. It is made up of many metals such as copper, manganese, cadmium, lithium, cobalt, etc., and contains recoverable metal oxides. The objective is to separate each metal from this mass and remove toxins from the material to avoid contaminating the metals. The purer the metal, the better it can be recycled. For this purpose, two techniques are used: pyrometallurgy and hydrometallurgy.

*"Black mass" is on the verge of becoming a raw material in its own right.* The S&P Global[77] launched regular pricing of this material in 2023.

Car manufacturers are becoming more and more interested in black mass[78], with BMW, Ford, and Mercedes announcing partnerships for the development of battery recycling projects.

Specialists in metals and chemistry are doing the same. In May 2023, Glencore joined forces with the Canadian Life Cycle to process black mass and create the largest European battery recycling center.

*The sector has a few challenges – first and foremost that of profitability.*

The economic viability of recycling plants will be negatively impacted by the increased usage of LFP batteries, which makes metal recovery less profitable. At the current market price, a NMC battery contains approximately $10,000 of metals per ton of battery cells. Conversely, the value of the metals in an LFP battery is only $4,000 per ton.

- The carbon footprint of an electric battery must consider the footprint of mining. Recycled material has a much lower carbon footprint. The carbon footprint of a ton of aluminum is between 4 and 15 tons of $CO_2$ while the carbon footprint of recycled aluminum is 5 to 25 times lower.
- According to S&P Global forecasts, recovery will represent approximately 15% of the global supply of lithium, 11% of nickel, and 44% for cobalt in 2030. Thus, recycling would significantly reduce the risk of shortage linked to these metals' rapid increase needs. According to Energy Transition Commission models[79], lithium consumption will be 30% higher than global supply in 2030, but with an emphasis on recycling and efficiency, the gap can be reduced to 10%.
- Recycling facilities: In 2022, Redwood Materials[80], the battery recycling company founded by a former Tesla executive, announced that it will build a massive $3.5 billion facility in South Carolina that would produce 100 GWh of cathode and anode components annually. The DOE acknowledges that the U.S. needs to expand its battery recycling capabilities to meet growing demand for EVs, and to lower the cost of EVs. In February 2023, it committed $2 billion in a new, conditional loan to help Redwood Materials build out its battery recycling campus.

**Batteries costs:**

Thanks to the scaling up of electric vehicle production and to the construction of mega factories, battery costs have fallen dramatically in recent years. However, after more than 10 years of decreases, the volume-weighted average price for lithium-ion battery packs has risen to $151/kWh in 2022, a 7% increase from the previous year in real terms. Battery costs increase is notably linked to high lithium prices. Higher adoption of less expensive chemistries like LFP was overtaken by the rising cost pressure on batteries. BloombergNEF[81] anticipates that average battery pack prices will not decrease in 2023.

77 https://press.spglobal.com/2023-08-29-S-P-Global-Commodity-Insights-Launches-First-of-Kind-Daily-US-Black-Mass-Price-Assessments
78 https://www.lesechos.fr/finance-marches/marches-financiers/la-black-mass-nouvel-or-noir-de-la-transition-energetique-1973527
79 https://www.energy-transitions.org/publications/material-and-resource-energy-transition/
80 https://www.theverge.com/2022/12/14/23509031/redwood-materials-ev-battery-recycling-factory
81 https://about.bnef.com/blog/lithium-ion-battery-pack-prices-rise-for-first-time-to-an-average-of-151-kwh/

**Battery production:**

In 2022, the world added 102 gigafactory projects to the ten-year pipeline, with a total capacity of 3.1 TWh. In 2022[82], $131 billion in battery production investment was pledged, a 24% increase over the previous year; 74% of these investments are in China.

***By 2030, thanks to these investments, worldwide lithium-ion batteries manufacturing will grow by more than five times.***

China has a leading position in batteries manufacturing, followed by Europe, the U.S., South Korea, and Japan.[83]

China produces three-quarters of all lithium-ion batteries and is home to 70% of production capacity for cathodes and 85% for anodes. Over half of lithium, cobalt, and graphite processing and refining capacity is in China. South Korea and Japan have considerable shares of the supply chain downstream of raw material processing, particularly in the highly technical production of cathode and anode material.

Due to the extent of its investment in new capacity, China is expected to remain the leading producer by the end of the decade. According to estimates, *China should produce 69% of the world's lithium-ion batteries by 2030.*

There are already 125 battery gigafactories[84] operating in China, more than ten times the combined number in Europe and North America. China also has twice as many plants in planning or under construction.

Outside China, the race is on to build bigger and better battery facilities, especially in South Korea, another major manufacturer of EVs.

The U.S. is the region with the second largest number of gigafactories currently in operation, with many of these clustered around a newly emerging "battery belt" in the Midwest and South, close to the Tesla plants in Texas and California. Driven by its decision to ban the sale of combustion engines after 2035, Europe is catching up. 60% of all new cars sold in 2030 are expected to be battery electric vehicles, rising to a 100% share by 2035. This regulatory push, combined with climate-conscious policies, has led to significant investments in Europe's battery industry.

82 https://evmarketsreports.com/300-billion-in-new-lithium-ion-battery-gigafactories/
83 https://www.iea.org/reports/global-supply-chains-of-ev-batteries

82 The term 'gigafactory' was coined by Tesla to mean a battery factory capable of producing batteries on the gigawatt-hour scale of capacity

Currently around 50 Li-Ion batteries factories have been planned in Europe[85], although only a handful of these are currently operational. One of the best known of these is Swedish battery manufacturer Northvolt, which started operations in May 2022. The factory is expected to ramp up to a total capacity of 60 GWh per year.

Poland, Hungary, Germany, France, and Sweden are emerging as key players.

Except for lithium supply, Europe could achieve self-sufficiency in battery cells, meeting 100% of its Li-ion battery cell demand by 2027.[86]

While Europe's progress is promising, there are potential challenges. Notably, IRA U.S. subsidies and ITC Canadian subsidies[87], to attract investments in clean power and green infrastructures, are luring European battery manufacturers away from Europe. For example, Northvolt is concluding a $5.3 billion deal to build a new battery plant near Montreal.[88]

85 https://www.transportenvironment.org/wp-content/uploads/2023/03/2023_03_Battery_risk_How_not_to_lose_it_all_report.pdf
86 https://evmarketsreports.com/300-billion-in-new-lithium-ion-battery-gigafactories/
87 IRA for the US and Canada Infrastructure Bank Act
88 https://www.bloomberg.com/news/articles/2023-06-29/northvolt-is-near-deal-with-canada-on-5-3-billion-battery-plant?in_source=embedded-checkout-banner

**Hydrogen:**

1. ***Hydrogen production technologies:*** At present, nearly all hydrogen production worldwide is grey hydrogen that is produced from methane or coal through natural gas reformation or coal gasification. It emits high volumes of GHG. Blue hydrogen refers to hydrogen derived from fossil fuels but where reforming/gasification plants are coupled with carbon capture facilities. It is classified as low-emitting hydrogen. However, it is not an emission-free hydrogen production route. In fact, the lowest possible emission intensity of blue hydrogen, will be ~30% that of grey hydrogen produced with natural gas.

   Green hydrogen refers to hydrogen produced by water electrolysis with green electricity. This process does not emit GHG. By mid-2023, the EU finally recognized[89] that nuclear electricity produces green hydrogen. With this decision, Europe is aligned with all other regions in the world.

   ***Green hydrogen is considered a crucial solution to decarbonize 'hard-to-abate' sectors (which represent around 25% of the global economy).***

2. ***Green hydrogen goals:*** As part of their net zero roadmaps, many countries and regions have set up *ambitious goals* for clean hydrogen production in the coming decades. For example, in September 2022, the U.S. DOE identified opportunities for 10 Mt/y of clean hydrogen production by 2030 and 50 Mt/y by 2050.

   In May 2022, the EU announced[90] its target of reaching 20 Mt/y of renewable hydrogen use by 2030; in March 2019, the Ministry of Economy, Trade, and Industry of Japan (METI) targeted a "one-fourth cost" for water electrolysis equipment – from $1,500/kW installed capacity to $380/kW by 2030.

   In 2022, more than 1,000 projects have been announced globally, of which 795 aim to be commissioned by 2030. Total announced investments through 2030 have increased by 35% in the first eight months of 2023 – from $240 billion to $320 billion.

   The global green hydrogen market is poised to grow at a CAGR of 55% from 2023 to 2032 (from $4 billion in 2022 to $332 billion by 2032).

3. ***2022 achievements:*** In 2022, global green hydrogen production capacity grew by 44% compared to 2021[91] to reach around 100 kT/year. It is still very small compared to the 120Mt of total hydrogen production.[92]

   » The largest green hydrogen projects in the world[93] are in Saudi Arabia, China, Australia, and Europe. In 2023, two large renewables-based hydrogen projects started operations in two Chinese provinces: Xinjiang (developed by Sinopec) and Inner Mongolia (developed by Three Gorges Corporation). Their combined annual hydrogen production capacity is 30 kT/year.[94]

   Both projects will utilize solar photovoltaic power to electrolyze water and produce green hydrogen. According to the nation's broad decarbonization plan, Inner Mongolia and Xinjiang will be developed into giant solar PV and wind power hubs. Sinopec's project, located in Xinjiang, is a pilot to construct an entire value chain for green hydrogen: renewable power generation, hydrogen production from water electrolysis, hydrogen storage, hydrogen transportation, and hydrogen utilization by refining

89 By mid-2023, the EU finally recognized that nuclear electricity produces low carbon hydrogen. By this decision Europe is aligned with most countries in the world.
90 REPowerEU plan

91 https://www.greencarcongress.com/2023/02/20230222-globaldatah2.html#:~:text=In%202022%2C%20green%20hydrogen%20production,data%20and%20analytics%20company%20GlobalData.
92 https://www.irena.org/EnergyTransition/Technology/Hydrogen#:~:text=Hydrogen%20is%20produced%20on%20a,of%20a%20mix%20of%20gases

93 Largest green hydrogen projects: NEOM Green Hydrogen Project in Saudi Arabia, Sinopec's Ordos Green Hydrogen Project in China, FFI ad TES green hydrogen project in Germany, Plug Power Green Hydrogen Plants in Finland, Western Green Energy Hub (WGEH) in Australia.
94 https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/energy-transition/063023-two-green-hydrogen-projects-totaling-30000-mtyear-of-capacity-start-up-in-china#

facilities. Sinopec's aim to produce more than 2 Mt/year from 2025 and is developing a giga-scale electrolysis plant in Inner Mongolia.

***These announced large-scale renewable hydrogen projects deepen China's role as a renewable energy giant.***

» *Infrastructure deployment* is progressing and is critical to ensuring that (low-cost) clean hydrogen supply matches demand. Committed investments in hydrogen infrastructure have grown from about $5 billion to about $7 billion, of which more than three-quarters are in Asia.

» *Electrolyzers manufacturing capacity:* Electrolyzers are a critical technology to produce low-emission hydrogen from water electrolysis.[95] According to OEM statements, electrolyzer[96] manufacturing capacity has reached nearly 9 GW/year in 2022. Future electrolyzer capacity is forecasted at 230 GW in 2030, which is very ambitious. However, a bigger significant acceleration is needed to get on track with the NZE 2050 IEA Scenario[97], which requires installed electrolysis capacity to reach more than 550 GW by 2030.[98]

*As in all green electricity equipment, China is reaching a dominant position in electrolyzers.* Among the 307 MW capacity added in 2022, 224 MW were contributed by China and 83 MW were added by the rest of the world.[99]

» *For fuel cell manufacturing,* the total global capacity stated by OEMs stands at 12 GW in 2022, with Japan and South Korea as the largest supply markets.

» *Total investments* increased by 35% from May 2022 to January 2023 ($320 billion in direct investment between now and 2030, up from $240 billion). However only 9% of total investments have reached final investment decision (FID). These investment announcements are spread globally, with Europe leading on announcements, while North America leads with committed investments ($10 billion). Europe ($7 billion) and China ($10 billion) However, China is catching up with giant projects.

4. ***Green hydrogen cost:*** At present, grey hydrogen cost is in the range of $1-2/kg (the lower range being in the U.S. where gas is cheap). The cost of green hydrogen is in the range of $4-6/kg. To make green hydrogen competitive, its cost should decrease very significantly (to $2/kg).

CRU projections[100] find that, even for green hydrogen production facilities in very favorable renewable energy locations, ~$2/kg is already a stretch goal for 2050. This cost level projection assumes halved renewable power costs[101] and a 75% reduction in electrolyzer system CapEx. In addition to this, costs associated with an electrical grid or renewables connection (~$0.7/kg additional cost) as well as hydrogen storage, compression, and distribution (~$0.8/kg additional cost) must be added. Taking these costs into account, the total green hydrogen cost to a typical end-user is expected to exceed $3/kg in 2050. Most countries exhibit green hydrogen costs above blue and grey hydrogen costs by 2050.

If carbon prices (that penalize grey and blue hydrogen costs) are very high, green hydrogen could become competitive with grey and blue hydrogen by 2035.

At present, China developers claim that with, very cheap solar and wind electricity in certain provinces (such as Xianjian and Inner Mongolia), combined with

95 https://www.iea.org/news/promising-signs-in-electrolyser-manufacturing-add-to-growing-momentum-for-low-emissions-hydrogen
96 https://hydrogencouncil.com/en/hydrogen-insights-global-project-funnel-gains-momentum-across-value-chain-and-geographies/
97 https://www.iea.org/reports/global-energy-and-climate-model/net-zero-emissions-by-2050-scenario-nze
98 https://www.iea.org/energy-system/low-emission-fuels/electrolysers#tracking
99 https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/energy-transition/063023-two-green-hydrogen-projects-totaling-30000-mtyear-of-capacity-start-up-in-china#
100 https://sustainability.crugroup.com/article/energy-from-green-hydrogen-will-be-expensive-even-in-2050
101 In 2022 and 2023 these costs have increased (see above)

collocation of renewables and hydrogen electrolyzers, hydrogen production cost is as low as \$2/kg.

5. ***Innovations:***

   a. *Electrolyzers:* Australian researchers have developed a "capillary-fed electrolysis cell" producing green hydrogen from water at 98% cell energy efficiency compared to 75% (or less) for existing electrolyzer technologies. This technology could increase green hydrogen cost-competitiveness.[102]

   b. *Methane pyrolysis* is a process that uses heat to split methane into hydrogen and solid carbon. Unlike conventional methods of hydrogen production, methane pyrolysis produces hydrogen without any carbon emissions.

   Methane pyrolysis is a two-step process. In the first step, methane is heated to a high temperature (around 900°C) in the absence of oxygen. This causes the methane molecules to break down into hydrogen gas and solid carbon. In the second step, the solid carbon is collected and can be used for various applications.

   One of the main challenges of this new technology is the high temperature required for the process, which can lead to significant energy consumption. Additionally, the technology is still in the early stages of development and needs further research and development to scale up to commercial levels. However, it has the potential to become a mainstream solution for zero emissions hydrogen production.

   c. *White hydrogen,* also known as natural hydrogen, is hydrogen gas that is naturally generated within the earth's crust through water-rock reactions.[103]

   There is growing interest in white hydrogen given its abundance, renewability, and low carbon footprint.

   However, the scientific community is still working to understand the mechanisms behind its generation, accumulation, and migration. Achieving cost-effective methods for extraction and distribution on a large scale is also a critical challenge. Finally, just like any resource, the extraction of white hydrogen could have potential environmental impacts.

   There is a long way to go before white hydrogen can be used on a commercial scale.

102 https://www.uow.edu.au/media/2022/breakthrough-opens-door-to-low-cost-green-hydrogen.php

103 https://energyadvicehub.org/what-is-white-hydrogen/

HOME

d. *Innovative projects* overcoming the negative economic impact of green hydrogen's higher cost are underway in Europe:

» *GravitHy*[104] : The steel sector is responsible for 8% of global energy demand and 7% of $CO_2$ emissions from the energy sector and must become more sustainable. To support the transition to lower GHG emissions, an industrial group[105] gave birth to GravitHy. This company aims to reduce the GHG impact of metallurgy by producing and using green, low-carbon hydrogen to produce direct reduced iron (DRI). The DRI can either be used directly at the plant or exported.

The extra cost of green hydrogen is only around €1/ton which is negligeable compared to the cost of an EV Mercedes, for example. If the latter is powered by green electricity, it can be marketed as a "real green car"!

» *FertigHy*[106] : In June 2023 an industrial group[107] announced the creation of FertigHy, which plans to build and operate several large-scale, low-carbon fertilizer projects. The first plant will be built in Spain and produce more than one million metric tons per year of low-carbon nitrogen-based fertilizers from 100% renewable electricity and green hydrogen. Its construction is planned to start in 2025. The agriculture sector alone is responsible for 13% of the EU's total greenhouse gas emissions. By localizing fertilizer production in Europe, the FertigHy project is also answering to the recent challenges of the EU and global food security due to supply chain disruption[108] and global uncertainties in the natural gas supply.[109]

**E-fuels:**

Another way to use green hydrogen is its conversion into synthetic fuels, or e-fuels, by reaction with "green" $CO_2$.

E-fuels are not yet commercially available. So far there are only very few demonstration plants worldwide. Around 60 new e-fuel projects have been announced through 2035, of which only 1% have been secured with a FID.

The ramp-up of the e-fuel market is being hampered by high costs and a lack of visibility on the market demand. The pilot plant in Chile (Haru Oni which was inaugurated in December 2022) would deliver costs of around €50/liter of e-fuel, which is one hundred times more than the typical wholesale price of fossil gasoline (around €0.50/liter).

The industrial ramp up of e-fuel should lead to production cost decreases. However, this production increase depends heavily on the speed of the global demand increase.

With e-fuel quotas in air and shipping traffic, politicians have a lever to accelerate the e-fuel market ramp-up. One of the initial large-scale applications of e-fuels could be in the aviation sector, which, apart from biofuels, has limited options for mitigating its GHG emissions.[110]

104 https://gravithy.eu/
105 EIT InnoEnergy, Engie New Ventures, Plug, Forvia, Primetals Technologies and the Idec group
106 https://fertighy.com/
107 EIT InnoEnergy, RIC Energy, MAIRE, Siemens Financial Services, InVivo and Heineken
108 Around 40% of EU potash is imported from Russia and Belarus
109 Gas is used as both a raw material and an energy source to power the fertilizer's production process
110 The electrical plane is not yet a commercial option

For example, the EU reached a political agreement in April 2023 on the aviation sector emissions regulation, ReFuelEU.[111] The new rules will require fuel suppliers at EU airports to blend sustainable aviation fuels (SAF) with kerosene in increasing amounts from 2025. It mandates a minimum SAF supply at EU airports of 2% by 2025, 6% by 2030, 20% by 2035, and up to a maximum of 70% by 2050. Of these amounts, 1.2% in 2030, and 5% in 2035 must be e-fuels, increasing to 35% by 2050.

Triggered by this regulation, some projects were announced in France during the summer of 2023. EDF announced that it would mobilize €700 million together with Holcim and IFPEN to build a plant to produce e-kerosene for Air France KLM.[112] At the same time, Engie announced its participation in the France KerEAUzen project, a synthetic fuel production unit for air transport and green chemistry.[113]

According to a study published by the ICCT[114,115], that assumes low $CO_2$ costs, a combination of technologies that gives lowest green hydrogen cost and mid-level future cost reductions assumptions, e-kerosene is not projected to be cost-competitive with fossil kerosene before 2050.

111 https://ec.europa.eu/commission/presscorner/detail/en/ip_23_2389
112 https://www.lesechos.fr/pme-regions/pays-de-la-loire/edf-veut-produire-du-e-kerosene-pour-air-france-klm-1957692
113 lesechos.fr/industrie-services/energie-environnement/biomethane-e-kerosene-engie-officialise-ses-projets-au-havre-en-presence-delisabeth-borne-1964888
114 ICCT International Council on Clean Transportation
115 https://theicct.org/publication/fuels-us-eu-cost-ekerosene-mar22/

**The digital revolution:**

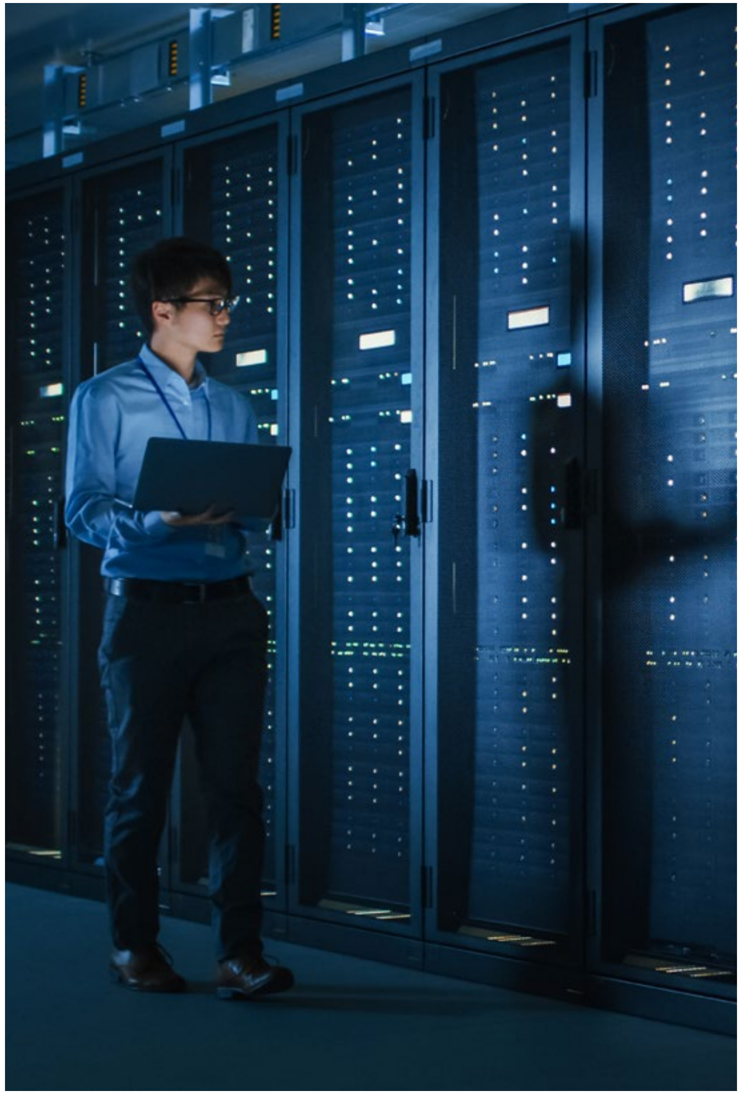
It is closely linked to the energy and climate transitions. On one hand, the use of digital technology is an energy transition enabler.

On the other hand, the increased use of digital technology, big data, and artificial intelligence (AI) are major consumers of electricity.

1. ***The use of digital technology impacts all steps of the electricity value chain:***

- Digital twins make it possible to better design, operate, maintain, and dismantle power plants. This is why EDF implemented the Switch[116] program that tracks data over the entire nuclear power plant lifecycle.
- Blockchain guarantees transactions between operators (for example, in electricity trading).
- Smart meters improve interaction between customers and the electricity network. Thanks to dedicated applications, these meters, which give real-time consumption information, should promote energy control. They make it possible to set up dynamic tariffs needed for demand side management that contribute to network balancing.
- Smart grids: The smart meter and other sensors on smart networks capture a lot of data. Organizing and analyzing this data makes it possible to better anticipate network congestion and other grid balancing issues. This is increasingly important with the development of intermittent renewable electricity generation.
- The use of supercomputers increases the reliability of weather forecasts. This, in turn, improves the production forecast of renewable energies (such as wind and solar).
- In the building industry, the generalization of building information model (BIM) will allow new construction to be better designed and therefore more efficient in terms of energy consumption and GHG emissions. Better organized, better coordinated, and therefore more quickly completed projects will also consume less energy.
- In the transportation sector, the impact of digital tools, such as teleconferences, on energy consumption was demonstrated during the confinements linked to the Covid-19 pandemic. Communication and remote working tools have made it possible, in certain professions, to maintain activity while avoiding transport. Post Covid-19, these tools continue to reduce travel.

116 https://www.capgemini.com/fr-fr/actualites/communiques-de-presse/edf-dassault-systemes-et-capgemini-signent-un-partenariat-pour-la-transformation-numerique-de-lingenierie-nucleaire-dedf/



» *Electricity consumption linked to digital technology* can be broken into:

- Transit and storage of data: Progress made in these technologies led to a reduction by a factor of 7 in energy consumption per gigabyte transported.[117] But traffic has increased[118] faster than the drop in unit consumption, resulting in an increase in the share of digital consumption within the overall electricity consumption.
- Data centers, housing IT equipment such as data storage servers and redundant power supplies, generate significant heat as a byproduct of their operations, nearly equivalent to the energy they consume They require energy-consuming cooling. At the global level, this energy represented between 200 and 900 TWh[119] in 2019.
- Supercomputers, boasting computing power measured in exaflops, are essential for tasks like developing artificial intelligence models and demand substantial power resources. For instance, the Fugaku supercomputer has a power supply requirement of approximately 38 MW.
- Crypto assets[120] also require substantial energy consumption. This is due to blockchain technology and data mining for cryptocurrencies. In 2022, the global electricity consumption related to crypto assets was between 120 and 240 TWh, volumes which exceed the total annual consumption of countries such as Argentina or Australia.
- Everyday equipment: Nearly 30 billion pieces are connected to the network, including computers, televisions, tablets, smartphones, and other everyday equipment. Their combined consumption represented a total of more than 150 TWh in 2022. In addition to this daily life equipment, there is the Internet of Things (IoT) equipment. Its consumption in 2020 was estimated at more than 60 TWh. Forecasts show an increase in efficiency, which will make it possible to partially compensate for the increase in the number of devices. Indeed, the number of these control objects should increase from 7 billion in 2020 to more than 20 billion in 2030.

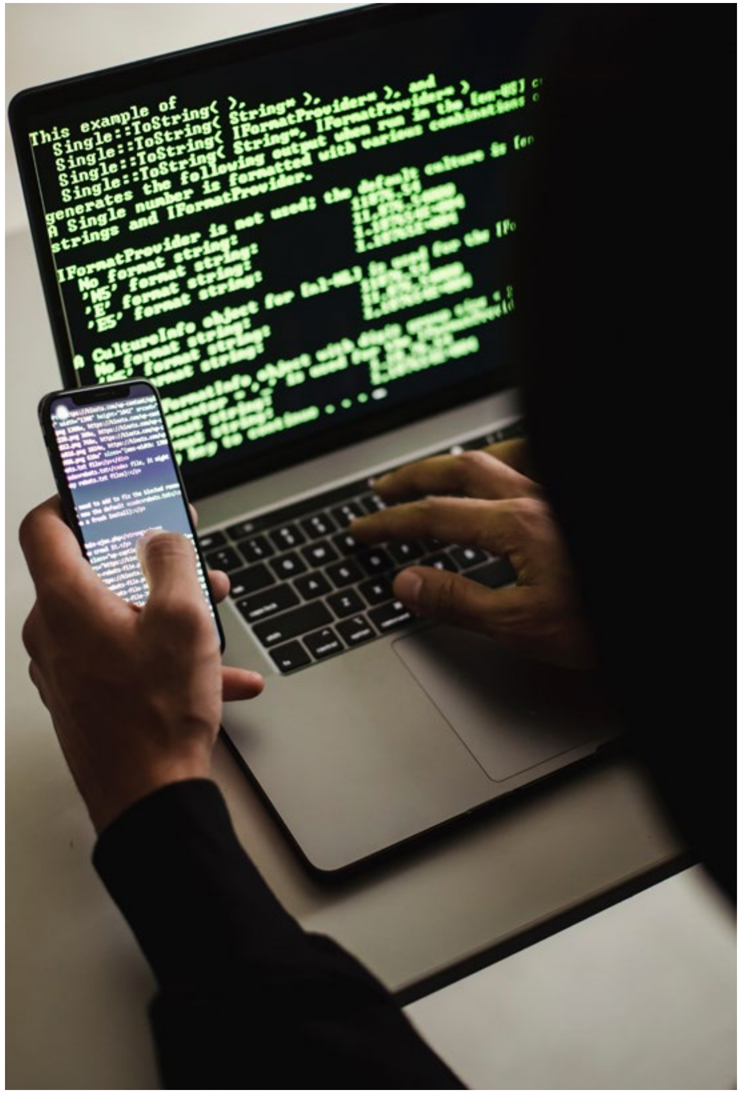
117 Between 2015 and 2020
118 The annual growth rate of network users was estimated by CISCO at +6%, representing a forecast of 5.3 billion users in 2023.
119 The methodologies for metering the energy consumption of these centers are not standardized, resulting in very different results.
120 Crypto assets are a digital representation of value that you can transfer, store, or trade electronically.

*2. The solutions:*

- The first incentives to demonstrate *"sobriety"* have been introduced. This includes encouraging individuals to disconnect their equipment when not in use, as well as urging professionals to avoid generating unnecessary traffic.
- These include the management of all auxiliary consumption required for data processing, such as reducing energy consumption associated with server and switch cooling. A commonly used indicator in data centers is power usage effectiveness (PUE), which is the ratio between the total energy consumed and the energy consumed solely by the information processing equipment. It appears that Google's equipment average PUE of 1.10 is the current low asymptote. Significant energy savings can be obtained by optimizing data transfer protocols, as well as system architectures.
- Another important avenue of optimization is that of the physical architectures of microprocessors. The considerable increase in etching fineness, which has gone from 10 µm to 3 nm[121] in fifty years, and the subsequent miniaturization have had a drastic effect on reducing consumption.

All these actions make it possible to significantly reduce unit consumption. This is imperative to compensate for the expected strong growth in traffic.

**To conclude, it is necessary to emphasize that the increased use of digital technology entails significant risks, such as those associated with cyberattacks and the misappropriation of data, for commercial or even criminal purposes.**



121 A µm is equal to 0.001 mm, a nanometer(nm) is equal to 0.001 µm.

**R&D funding:**

In 2022, investment in energy innovation rose . Public spending on energy R&D grew by 10% in 2022 (estimated at $44 billion), with 80% devoted to clean energy. For listed companies in energy-related sectors, data shows a similar rise in R&D budgets in 2022, while early-stage venture capital investment into clean energy start-ups reached a new high of $6.7 billion.

However, due to higher cost of capital, the situation has reversed in Q1 2023 with very weak growth-stage funding.[123]

In addition, private equity funds started, by mid-2022, to withdraw from start-up funding and many innovative small companies have financial difficulties. This is worrying when considering the needed clean technologies progress that often originate from start-ups.

**Electric grids:**

As mentioned above, a successful energy transition requires a major expansion of electricity grids. According to the REPowerEU strategy, the goal is to double the proportion of energy demand covered by electricity, increasing it from the current 25% to over 50% by 2050. Hence, an additional supply of about 4,000 TWh would be necessary, the equivalent of Europe's current total electricity consumption in 2019.

123 Growth-stage funding requires more capital than early stage but funds less risky innovation.

Part of the electrification increase is driven by heat waves; a further uptake from 110 million cooling units in 2019 to 275 million units in 2050 is expected. These devices, as well as additional distributed renewable energy sources put the distribution grids at the center of the current transition.

Distribution system operators are continuously enhancing the resilience of their grids through various approaches. These include expanding the deployment of sensors to gather more data, implementing smart meters, improving forecasting techniques, adopting demand-side management strategies like increased energy efficiency, implementing intelligent EV charging solutions, and enhancing storage capacity.

On the transportation grid, it is necessary to develop new flexibility levers, such as rapid frequency adjustment, improved forecasting systems, intraday markets, and virtual power plants. Moreover, TSO/DSO coordination on data exchanges must be improved.

As described above, implementation of digital technologies is key to making grids smarter and increasing their resilience. Overall, it is estimated that European distribution system operators require about €400 billion[124] of additional investments by 2030 to maintain and modernize electricity grids and to connect distributed clean generation.

124 Growth-stage funding requires more capital than early stage but funds less risky innovation.

**Critical industrial equipment** for energy transition must be available. This includes electrical cable with proper copper procurement, inverters for solar farms, edge loggers at the factory floor, which provide operations and maintenance related data, and silicon carbide power transistors to control both the charging of electric batteries on the grid and their injection of electricity when the vehicle is not used.

One can mention new catalysts to improve the energy efficiency of industrial installations. Also, membranes have the potential to become a key element of the energy transition.
They can be used as electrolytes in membrane-based fuel cells and electrolyzers to produce hydrogen, as separators in lithium batteries, in thermoelectric and electrokinetic energy conversion etc. Some membrane technologies are already being applied in industries at a large scale, while others remain in the early stages of development.

## Increased financing, proper regulations, and good citizen behaviors are critical for achieving climate goals:

In previous WEMO Outlooks we performed a thorough analysis of climate regulations and citizen behaviors. This year, we shall concentrate on financing issues.

As stated above, progress in clean technologies is promising. However, a huge acceleration of their deployment is needed. This was acknowledged by the G20 Heads of State (responsible for around 80% of GHG emissions) at their September 2023 meeting. They pledged to triple global renewable energy capacity by 2030.[125]

According to Irena[126], investment in renewable energy in 2022 was at a historic high, amounting to $500 billion. However, these investments represented less than one-third of the investments needed each year to stay on the 1.5°C pathway.

### How to focus public investments[127]

In the 2000's, **the marginal abatement cost emerged** as a measurement and decision-making tool. It is simply the cost of an intervention that will reduce greenhouse gas emissions by one ton.[128]

It was adapted to climate policies concentrated on marginal changes.

However, since the Paris Agreement, the aim is to reduce emissions to almost zero in 2050. Thus, one cannot ignore hard-to-abate emissions. The challenges are no longer to identify low-cost opportunities, but to avoid all emissions at the lowest cost possible.

The problem is complex given:

» That each measure cannot be considered individually since they interact with one another. For example, emissions reductions from an electrical vehicle depend on the carbon content of the electricity used.

125 https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/energy-transition/090923-g20-leaders-pledge-to-support-tripling-of-global-renewables
126 https://www.irena.org/Publications/2023/Feb/Global-landscape-of-renewable-energy-finance-2023

127 https://www.i4ce.org/en/proper-use-abatment-cost-streer-transition-climate/
128 As seen before, the carbon emissions on the life cycle that have to be considered.

- That there is the question of the velocity of the energy transition. It is not possible, for example, to wait until all electricity is decarbonized to start deploying electrical vehicles. The industry and users need time to adapt to these changes. So, there is a need to start earlier even if the marginal cost of abatement is high.
- The variability in technologies' availability and associated costs. However, technologies costs depend also on demand. High demand pushes for innovative efforts and deep tech research. Also, larger production volumes push prices down. This was the case of solar, wind, and battery technologies whose costs decreased year-over-year during the last ten years. If there were no political decisions to subsidize and deploy them, they would have kept a high abatement cost.

These public investment policies aimed at accelerating technology maturity could be reproduced in critical industries where scale effect leads to cost decrease. For example, electrolyzers are well suited to this approach.

A more comprehensive, albeit intricate, approach involves shifting the focus towards long-term strategies. These strategies consider sector interactions and technological advancements with the aim of minimizing the overall cost of the transition, rather than solely concentrating on marginal costs. These examples demonstrate that public financing modeling of zero carbon is very complex, hence the lack of economic coherence between climate change-related policies.

Also, side effects can be damaging : for example, French regulation on building isolations (that forbid renting apartments that don't comply with isolation rules), could result in scarcity of housing to rent. Owners of apartments that would need to invest significant amounts to continue to rent them could opt not to do so. Housing is already a critical issue for residents of France.

## Private financing

Companies across all sectors of the global financial system have pledged their support to climate goals. It is the case for the Glasgow Financial Alliance for Net Zero[129], a global coalition of leading financial institutions committed to accelerating the decarbonization of the economy. It has more than 550 members, including many of the world's largest banks, insurers, asset managers, and asset owners. They have all committed to support the transition to a net zero global economy.

129 https://www.gfanzero.com/

Also, to respond to growing demand for investments that are focused on climate solutions, asset managers are launching more funds. The number of climate-oriented funds has grown at a 7% annual rate since 2016, with 113 such funds starting in 2022. The amount of capital raised for such funds reached $75 billion in 2022, a 29% increase from the previous year.

***However, private capital flows to green projects are still far too small.*** A recent study by the Rockefeller Foundation and BCG found that the needs are exceeding current flows by 66%.[130]

130 https://www.bcg.com/publications/2023/asset-owners-can-supply-push-in-climate-finance

## Enterprises

They are committing to limit their carbon footprint. For example, the Science-Based Targets initiative (SBTi) that was created in 2015, at the same time as the Paris Agreement's signature, has become an international reference. It provides tools to help set decarbonization objectives for companies. These objectives are "aligned with science" and compatible with limiting global warming in 2030 to +1.5°C.[131]

By the end of 2022, the cumulative number of companies with science-based targets validated by the SBTi represented 34% of the global economy by market capitalization. SBTi has taken note of the difficulties of decarbonizing the company value chain, and therefore tolerates that part of the emissions (related to scope 3) is not subject to reduction objectives.[132]

More and more companies include climate change related KPIs in the variable and long-term remunerations of their managers. Beside public policies, enterprise commitments are an efficient way to increase climate change achievements.


131 Compared to the pre-industrial era
132 https://www.climatepartner.com/en/scope-1-2-3-complete-guide

## Adaptation measures:

As analyzed previously, present climate mitigation actions and policies are not sufficient to be on the right trajectory to meet the Paris Agreement objectives. ***Climate adaptation[133] action need to be implemented urgently.***

A comprehensive risk assessment must be conducted, and equipment and infrastructure need to be adapted to address the consequences of climate change This must be done at all stages of the lifecycle (design, construction, operations, and maintenance) as well as across the electricity value chain (electricity generation, transmission, and distribution).[134,135]

As will be detailed below, these risks are related to exceptional events triggered by climate change.

### Thermal power plants must be adapted to exceptional hot weather.

For thermal power generation (including nuclear power), the temperature increase of cooling water decreases their efficiency. In addition, in the case of an exceptionally hot climate, the plants that collect their cooling water from rivers, must lower their generation output to preserve natural live-in rivers.

This question has been tackled at the design level with closed water circuits and air coolers reducing the amounts of water used. Now that sea corrosion consequences are mastered, nuclear plants, for example, can be built along the seashore.

The experience of the exceptionally hot summer in France in 2003 led to a vast program of modifications to better cope with extreme heat waves. The cooling units of power plants were resized, and operating practices were reviewed.

Moreover, temperature rise is expected to increase electricity demand for cooling in many countries, which will become a driving factor for generation capacity additions.

Finally, lessons learned from incidents or accidents must lead to modifications. In France, all nuclear plants have been retrofitted to take into account the lesson learned from the 2011 Fukushima accident (emergency diesels, onsite water reserves). The EPR design has also been revised.

### Renewables' main resource is directly linked to climate variables such as precipitation, temperature, irradiation, or wind.

1. ***Hydropower,*** **like other infrastructures, is starting to experience negative impacts due to climate risks:**

» Water availability and hydropower generation are affected by changes in hydrological patterns and extreme weather events.

» Change in rainfall patterns[136] can impact river flows and water levels, thus affecting production. The main risks are related to flooding and intense rain, which can pose a significant risk to dam safety.

» Higher air temperature would increase evaporation, reducing water storage and power dam output.

» Changes in the ice melting patterns can alter the seasonal inflow of water to dams that rely on snowfall or glaciers. A study published in the journal Water[137] about flood and drought risk to hydropower dams found that by 2050, 61% of all hydropower dams would be in river basins at "very high or extreme risk for droughts, floods or both". According to studies, the global impact of climate change on hydropower generation is not significant (0.9-2.4%) but can be important locally.

To manage the changing climate, asset owners are using more advanced weather and water forecasting technologies to help increase project resilience.

» *Design:* To mitigate the consequences of flooding, installations are fitted with flood discharge systems to cope with extreme flow rates. If needed, these flood discharge systems are increased. For example, EDF has invested in new discharge systems on 60 dams in

133 Climate adaptation means anticipating the adverse effects of climate change and taking appropriate action to prevent or minimize the damage caused.
134 https://www.iea.org/reports/power-systems-in-transition/climate-resilience
135 https://www.eurelectric.org/in-detail/climate-adaptation/

136 https://www.sciencedirect.com/science/article/pii/S1364032119306239
137 https://www.iea.org/reports/power-systems-in-transition/climate-resilience

recent years. In the U.S., the Biden administration's infrastructure bill earmarked $500 million over five years to fund dam safety projects.

» *Operations:* Asset operators, such as EDF, carry out daily weather monitoring in 1,100 measurement stations to anticipate any out-of-the-ordinary weather events. In addition, exceptional rains can have an impact on the dam's safety. If a dam breaks, the impact on populations is huge (see above example regarding the Kakhovka dam break following the Russian bombing).

2. ***Wind power is also impacted by exceptional weather events.***

» Changes in wind speed can reduce generation (as turbines cannot operate in very high or very low winds). Also wind turbine output is greatly affected by wind speed, as the energy provided by the wind is the cube of wind speed.

» Ice on turbine blades can affect performance and durability.

» Rising sea level could damage offshore turbine foundations in low-lying coastal areas, as well as onshore turbines in coastal locations.

» Some turbines, especially the bigger and taller ones, will have to be redesigned and safety margins should be increased.

***Globally, changes in wind energy output can range from ±12% depending on the region.***

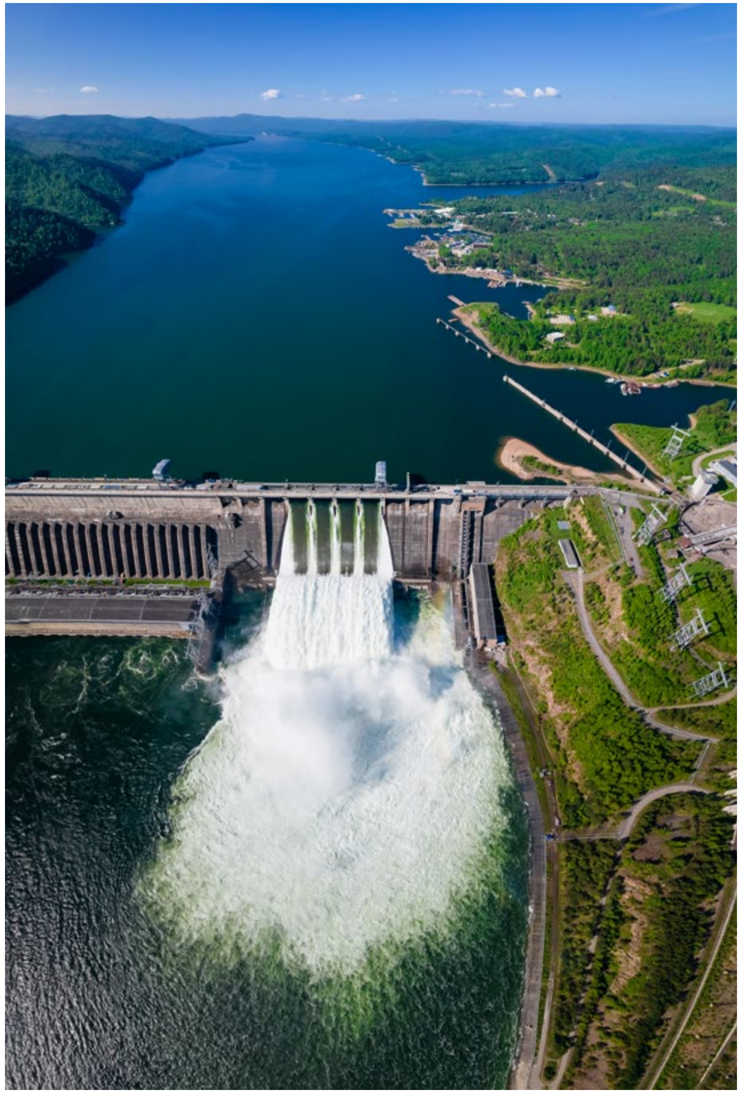
3. ***Solar energy:***

Climate change impacts on solar generation has received less attention than that of wind or hydropower. Solar PV installations are usually smaller with lower capital costs and a shorter lifetime (around 20 years) than hydro or wind. This reduces the importance of climate impacts.

The available projections are uncertain: depending on the model and assumptions, differences in results can be substantial. One study[138] suggests a global reduction in direct normal irradiation of 5%. The biggest output increases are expected in Europe (up to 10%), while the greatest reductions are expected in Africa (up to 10%).

Other climate change-related events, such as fires or sandstorms, have an impact on solar generation. The smoke produced by the huge fires in Canada in May 2023 reduced solar generation by 30% in impacted regions.

138 Huber I, Bugliaro L, Ponater M, Garny H, Emde C, Mayer B. Do climate models project changes in solar resources? Sol Energy 2016;129:65–84. https://doi.org/ 10.1016/j.solener.2015.12.016.



## Transmission and distribution networks:

Electricity network damages have a large impact on electricity supply, and hence customer satisfaction.

- Climate change impacts on transmission and distribution networks are important and result in higher electricity losses, a decrease in transfer capacity, and physical damages.
- Intense and concentrated rainfall leads to high water levels and even floods. If coupled with storms and winds, restoration is even harder.
- Heatwaves cause loss of load due to reduced grid capacity and overheating of transformers.
- Wet snow can cause icing and snow sleeves.

The key dimensions of an electricity network's climate resilience are robustness and speed of recovery.

1. ***Enhancing robustness involves both physical investments and the utilization of digital tools***

   - Investments: TSOs are investing each year to adapt and reinforce the network. For example, pylons are built with specific materials in wind-exposed regions and their foundations are reinforced in stressed climate areas.[139]

     Vegetation management is important to avoid the risk of contact between trees and overhead conductors. In California, where wildfires are a major threat, good forest maintenance is crucial.

     Underground transmission and distribution cables, which require a higher upfront investment and higher maintenance costs than overhead lines, can significantly reduce damage from climate impact and save recovery costs.

   - Digital tools: TSOs and DSOs are improving their forecasting tools and meteorological alerts to predict extreme climatic events. They have digitized their inspection regime using aerial Light Detection and Ranging (LiDAR)[140] and drone footage image processing technology.

2. ***Recovery: The speed of reconnection is very important for customers.***

   Physical damage to energy networks can result in interruptions in service to customers.

   TSOs and DSOs have human forces and specific tools (such as temporary generation) to deal with the potential damage that threatens the network. As soon as a storm is forecasted, network operators deploy special teams ready-to-go on-the-ground.

   The deployment of smart meters allows for the localization of customers experiencing power outages and enables a quicker response.

   Technological innovations that allow for remote reconfiguration of networks can help reduce the number of customers affected by faults.

Studies suggest that the benefits of resilient electricity systems outweigh the costs in most scenarios, especially when considering the increasing impacts of climate change. According to the World Bank, if the actions needed for resilience are delayed by ten years, the cost will almost double.[141]

139 https://www.sia-partners.com/en/insights/publications/grid-resilience-climate-change

140 Lidar : which stands for Light Detection and Ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges. It is well suited for topographic surveys of vegetation or hard access zones

141 https://www.iea.org/reports/power-systems-in-transition/climate-resilience

## Conclusion and recommendations

To achieve the decarbonization objectives of our economy, **world electricity consumption will have to quadruple** from ~28,000 TWh in 2022, to as much as ~110,000 TWh by 2050, with over 75% of this supplied by wind and solar.

Security of supply concerns, prompted by Russia's unwarranted invasion of Ukraine in February 2022, have boosted renewable electricity production. This renewable energy not only offers a clean source of power but, under specific circumstances, also contributes to domestic electricity generation. **2022 was a record year for renewable electricity capacity additions**, with annual capacity additions amounting to about 340 GW. In 2022, investment in clean energy technologies has significantly outpaced spending on fossil fuels.

However, **this growth is far below what is needed to achieve net zero carbon in 2050** as global renewable capacity should grow by 2400 GW over the 2022-2027 period (i.e., an annual average growth of 480 GW). This amount is equal to the entire power capacity of China today.

**Nuclear electricity** output, which has finally been recognized under certain conditions by the EU as green energy, **will have to increase.** To achieve net zero by 2050, projections show that total nuclear energy capacity will need to triple by 2050.[142]

142 https://www.oecd-nea.org/jcms/pl_83775/government-industry-conference-to-chart-the-nuclear-energy-path-to-net-zero#:~:text=To%20achieve%20net%20zero%20by,priority%20in%20several%20NEA%20countries.

It will be necessary to extend the life of existing reactors and build new reactors. In the western world, construction times for large reactors are very long (around 15 years) and budgets are often more than tripled compared to initial forecasts. SMRs raise hope, but their promises have yet to be confirmed.

**The expansion of electrical grids** is linked to growing electrification and the need to connect more decentralized means of production (solar and wind farms, SMRs, etc.). They should grow from the current 75 million kilometers of transmission and distribution to over 200 million kilometers by 2050. Their construction (especially overhead lines) arouses local opposition, which extends delays and costs. The instantaneous balance between an increasingly intermittent supply and a demand which may experience peaks linked to extreme climatic events must be ensured. Networks are becoming smarter with more stationary storage, sensors, and intelligent exploitation of large masses of data. **Without these adaptations, networks will become the Achilles heel of the energy transition.**

**The digital revolution** is a facilitator of the energy transition but also a source of electricity demand growth. In 2022, the total electricity consumption related to crypto assets[143] is estimated between 120 and 240 TWh/year, volumes which exceeds the annual consumption of countries such as Argentina or Australia.

**All this equipment must be sustainable,** which requires the analysis of their carbon footprint over their lifecycle. Batteries must be recycled. Recycling facilities are already being built in China and Europe. The recycling industry will be boosted by legislation. For example, in Europe by 2030, all batteries will have to use a minimum of 12% cobalt, 85% lead, 4% lithium, and 4% nickel coming from recycled sources.

The 2021-2022 crisis was a wake-up call in Europe regarding the security of energy supply. Legislation, such as the IRA in the U.S. and RepowerEU in Europe, aims to help these regions reclaim their **sovereignty** over equipment, metals, rare earths, and industrial installations related to the security of electricity supply. These legislations also aim at reshoring, in their territories, critical equipment production.

After years of impressive cost decreases, **wind and solar LCOE[144] started to increase** in 2021. In 2022, this trend has continued. These cost increases were not offset by cost reductions from technological innovation and, according to IEA, the resulting LCOE increase for 2022 is estimated at 15-20% for these technologies.

Wind equipment manufacturers need to recuperate the higher cost of manufacturing products and amortize their R&D costs. However, they cannot as they are pushed by their clients (that are bidding for new projects at continuously lower electricity prices) to decrease costs even more. Some manufacturers are in a difficult financial position and utilities are opening their suppliers list to Chinese manufacturers.

Europe's solar power industry is in a precarious situation as solar PV prices reached record lows due to China manufacturing excess capacity and fierce competition. As for offshore wind, European companies' bankruptcies, would hurt the EU's goal of reshoring policy.

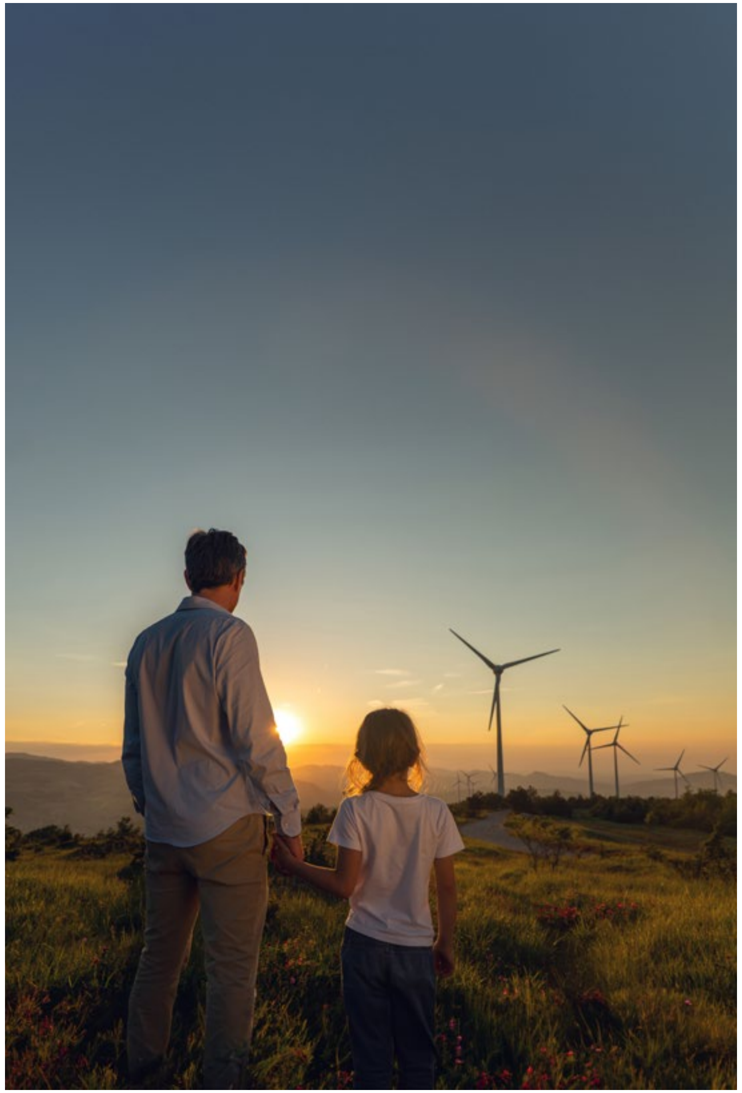
The emergence of a **hydrogen economy** is happening even if there are still challenges over low-carbon electricity availability and green hydrogen cost decrease. What usage should be prioritized (hard-to-abate sectors versus mobility) is still unclear. More than 1,000 projects have been announced globally, of which 795 aim to be commissioned by 2030. Total announced investments through 2030 have increased by 35% in the past 8 months – from $240 billion to $320 billion.[145]

**China has a dominant position in clean technologies** (including nuclear) both by its domestic investments and by its position in the international market. The country spent $546 billion in 2022 on investments that included solar and wind energy, electric vehicles, and batteries. That is nearly four times the amount of U.S. investments, which totaled $141 billion. The European Union was second to China with $180 billion in clean energy investments.

143 Crypto assets can be defined as a digital representation of value or rights which may be transferred and stored electronically, using distributed ledger technology or similar technology.

144 LCOE: Levelized Cost of Electricity

145 https://hydrogencouncil.com/wp-content/uploads/2023/05/Hydrogen-Insights-2023.pdf



It is also becoming a leader in the production of green hydrogen, thanks to the installation of significant electrolyzer capacities in provinces such as Inner Mongolia, which have a very low cost of producing renewable electricity.

It plans to develop CCUS, which is crucial because China is commissioning two large coal-fired power plants per week.

Despite this progress, the world is not on the right climate trajectory. The main obstacle is linked to the **difficulty of adapting our economy quickly.** Citizens are slow to change their lifestyles, local oppositions are slowing down the installation of carbon-free electricity production capacities, and new industries lack skills while there is unemployment of workers in industries that are disappearing. Finally, the cost of these actions for citizens is significant as they must spend more money to comply with legislations. In Europe, people will have to buy an EV after the internal combustion cars ban (in 2035) or to insulate their houses to be able to rent or sell it.

**Financing is also lacking.** Even if investments in renewable energy in 2022 reached an unprecedented high – at$ 500 billion– it represented less than one-third of the average investment needed each year to stay on the 1.5°C pathway. Climate tech funding dropped in 2023, but is resilient compared to other sectors, especially in EVs and batteries technologies.[146] It is critical for Europe to unlock funding to scale up the deployment of innovation to avoid losing this new industrial revolution battle and being squeezed between the U.S. and China.

**Each investment decision should be taken regarding its impact on sustainability and energy sovereignty as well as affordability for citizens.**

**Adaptation measures** are necessary for all electricity production, transport, and distribution equipment. The return time on these investments is indeterminate. Beyond compliance with regulations (for example the ban on building in seismic or flood zones) the control authorities should require the implementation of these adaptation measures. This is what the French Nuclear Safety Control Authority did by requiring new investments in nuclear reactors to take into account the feedback from the Fukushima accident. The multitude of actors (governments, local authorities, energy producers, infrastructure operators, network concessionaires, etc.) makes the implementation of these adaptation measures complex.

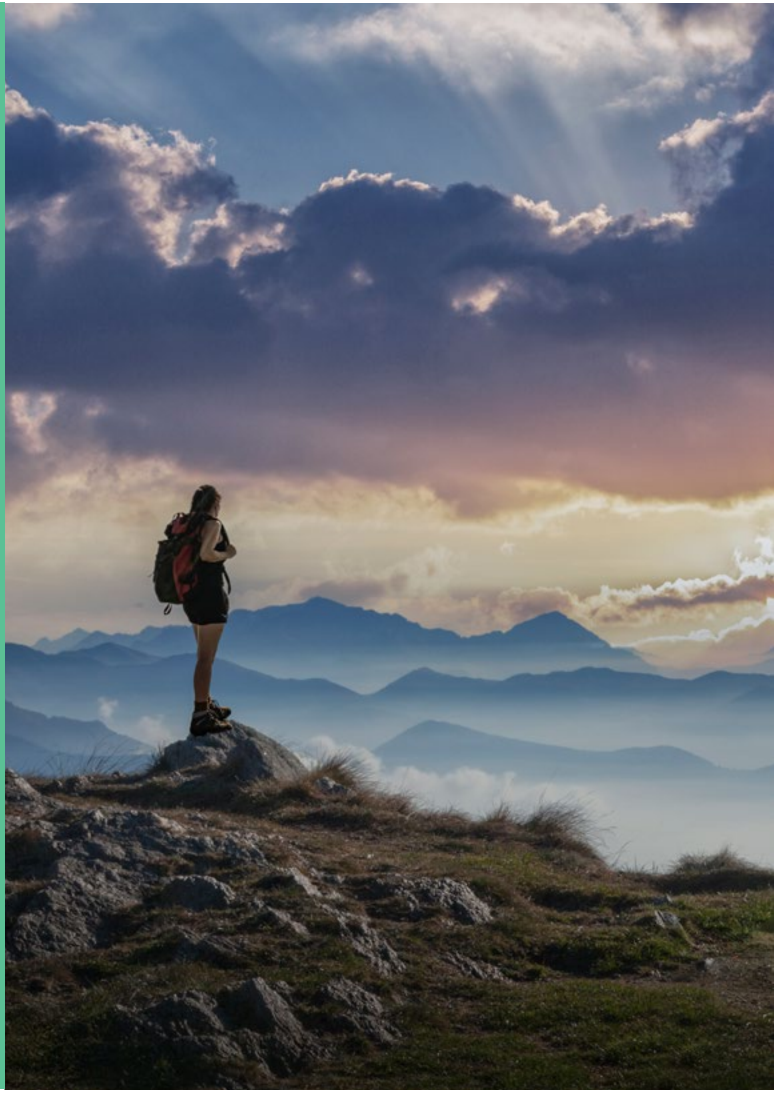
146 https://www.cleantechforeurope.com/publications/cleantech-q2-briefing-2023 and CTVC https://www.ctvc.co/climate-tech-h1-2023-venture-funding/).

## The year 2023 was full of uncertainties:

Firstly, the evolution of the conflict in Ukraine, where all options are open, creates a high level of uncertainty. Moreover the savage agreesion of Hamas terrorists in Israel could generate instabilty in the Middle-East which is a large oil and gas  producing region

Secondly, inflation remained high, despite lower energy prices and supply chain improvements. To curb this inflation, central banks have increased interest rates, triggering increased food prices and precariousness that could be a source of social conflicts. While the economic slowdown could have negative consequences on employment, it has the positive consequence of slowing energy consumption and therefore keeping prices at reasonable levels.

The winter 2023-2024 presents itself in Europe under better circumstances than the previous winter. However, mild temperatures and sustained energy savings remain key to having a non-eventful winter.



*“Finally, I wish to recall that in the combat against climate change, each of us has a role to play as a consumer, citizen, political authority, or business employee.*

*However, despite all the human efforts, nature is still present, and events such as big volcanic eruptions or huge fires contribute to increasing GHG emissions.”*

**Colette Lewiner**
Paris, October 24, 2023

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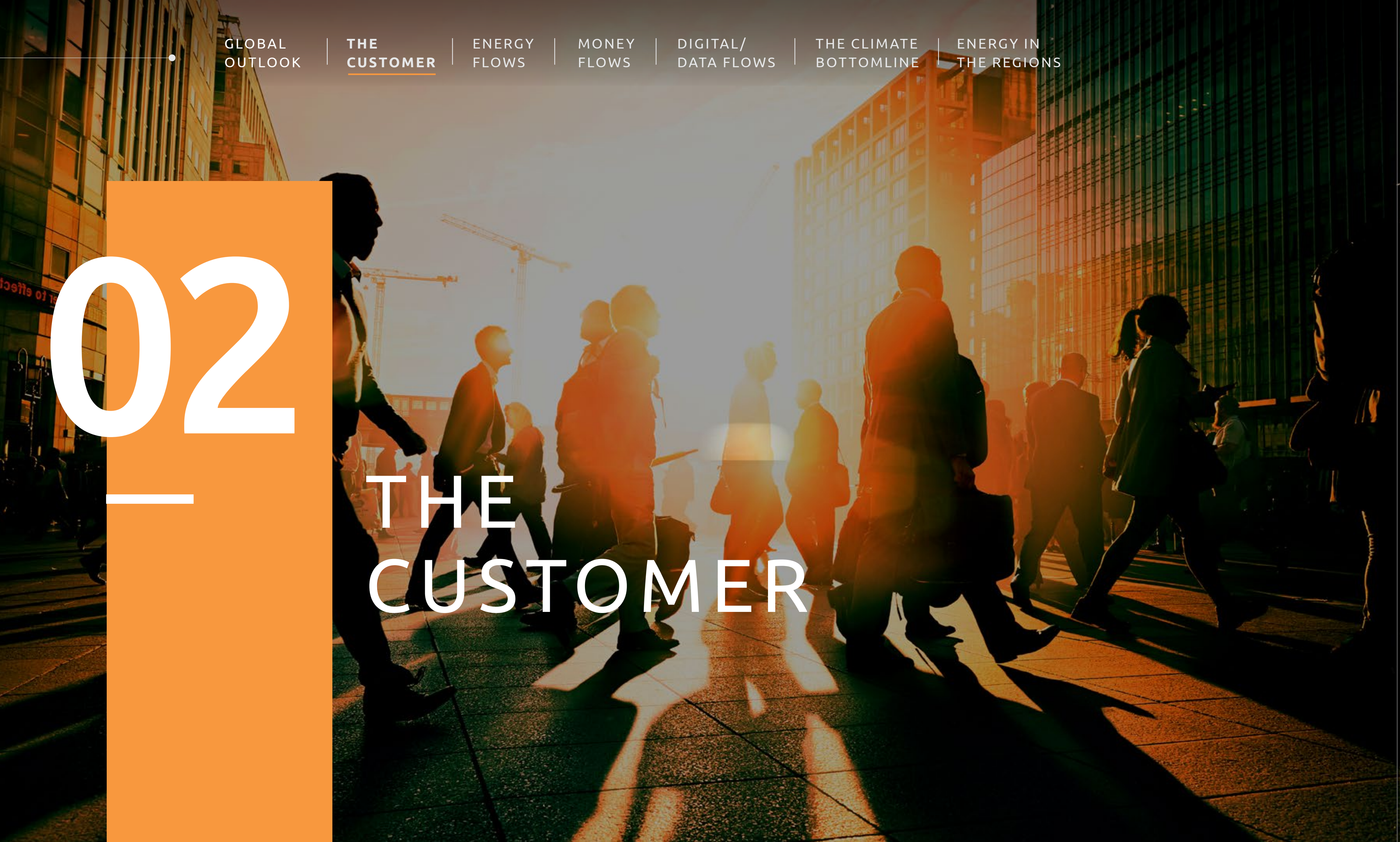


# 02

# THE CUSTOMER

# DOES THE CUSTOMER CARE?

**CARL HAIGNEY**
Global Vice President Energy Retail

I am old enough to have seen the transformation of the telecommunications and finance markets, with their strong parallels to the energy transformation we are about to witness. History has shown us that the old, ex-monopoly-style relationships, often with low NPS scores and a focus on cost take-out are replaced by digital, value-add customer relationships where loyalty is hard-earned, and easy-lost. History was not kind to incumbent players, though, and I believe that the energy retail sector is going to see such fundamental change that it will be unrecognisable in 10 years time.

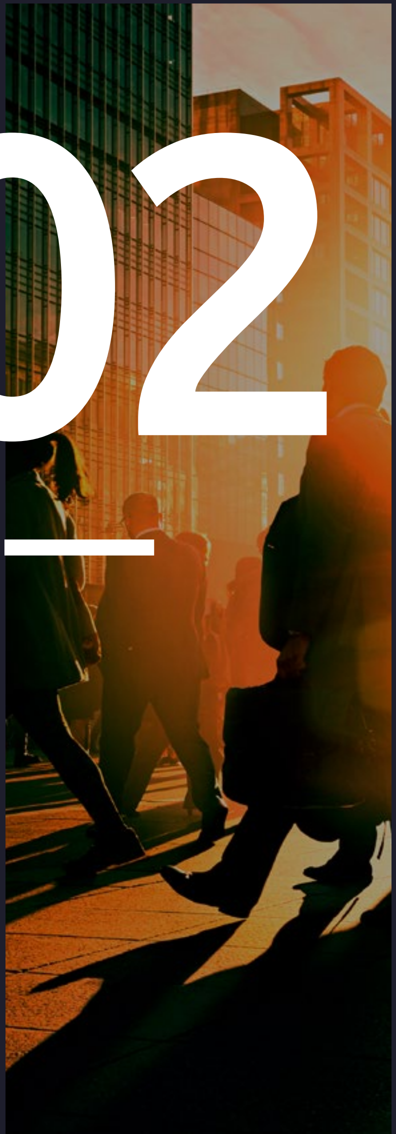
In the articles in this chapter we explore how the customers want to see change, indeed are beginning to drive change faster than the legacy industry can cope. The uptake of EVs, smart devices, home energy solutions etc. should all be the natural playground for the incumbents, but the lack of investment in digital customer solutions has opened up the markets to new entrants from parallel fields such as mobility.

Customers care about the ease and quality of the relationship – with demonstrable value and good service. They have the ability to change – helped by the digital world and now enabled in many geographies by the opening of the markets and smart enablement.

I contend that the energy retailers who prosper in the next decade will be digitally-focussed, energy services providers (including mobility), and will have partnered to gain skills in new offering areas. The legacy finance and telco companies experience gives us a guide to success…we have to learn from it.

This chapter includes:

1. The energy retail market is dead; long live the energy services market?
2. Power to the people! How energy consumers are taking control and working around industry constraints.
3. Transformation for all? What we have learned from telecommunications and Finance transformations? Applying history to predict the future.
4. Rethinking the value of customer service
5. What big bets are utilities in Australia making ?
6. How the market changes are pointing to new leaders.



# 02

1. THE ENERGY RETAIL MARKET IS DEAD; LONG LIVE THE ENERGY SERVICES MARKET
2. POWER TO THE PEOPLE! How energy consumers are taking control and working around industry constraints.
3. TRANSFORMATION FOR ALL? What does the future hold for the atypical consumers? Does hyper-personalisation make everyone atypical?
4. LEARNING LESSONS FROM THE UK TELCO TRANSFORMATION FOR ENERGY RETAIL
5. WHAT BIG BETS ARE UTILITIES IN AUSTRALIA MAKING IN THE CUSTOMER DOMAIN AND HOW WILL THEY PAY OFF?
6. COMMODITY TO SERVICES – HOW MARKET CHANGES ARE POINTING TO A VERY DIFFERENT PLAYBOOK FOR UTILITIES

# THE ENERGY RETAIL MARKET IS DEAD; LONG LIVE THE ENERGY SERVICES MARKET

CARL HAIGNEY, UK

## Who will survive in the battle for the customer?

**Market opening, new competition, 'seismic shifts'… the transformation of the energy retail industry is underway. We've been here before in parallel industries and transposing this history doesn't paint a rosy picture for the future of today's retail utilities unless radical action is taken now.**

At Capgemini, we've been observing energy markets for more than 20 years through the medium of our annual thought-leadership exercise: The World Energy Markets Observatory. As a company, we are partnered with utility companies from retailers, to central bodies, networks and water companies. This article focusses on the retailers and the challenges ahead.

In the 1990's the telco monopolies experienced the seismic shift of moving to a competitive and increasingly-digital market, where not only did customers get choice of provider, customers also became drivers for new services and offerings. The transformation of the customer engagement was driven to a large degree by digitisation – notably the move from voice to data and them the insatiable and ongoing demand for mobile services. Customers suddenly had choice, had information and had appetites for new services that made their lives easier – it suddenly wasn't about communications per se, it was about entertainment and control. The market had transformed.

These fundamental and irreversible changes led to the disintermediation of some of the legacy providers from their customers (e.g. BT OpenReach in the UK) and the demise of others, a notable example being AT&T in the US.

New players came to market; some survived and prospered whilst others didn't quite get the go-to-market price or offers correct but may have pointed the way for others (e.g. Squirrel local networks in the UK). Whichever way you look at it the winners were the consumers. Benefitting from commodity phone line provision now being subsumed into communications and entertainment services, with lower prices, with easier-to-access control and loyalty awards. Better service, better price, more options.

## History Repeating Itself

It is this change that we see being replayed in the energy retail sector, as digitisation ofhome services underpinned by smart metering/grid combines with electrification of mobility and demand for sustainability technology in the home (such as solar, heat pumps and batteries). Pre-COVID, customers were already beginning to explore new options in energy, with competitive markets such seeing an uptick in switching and a noted swing to new entrants. Refer to Figure 1 where newcomer Octopus has used customer intimacy through digital to take market share. Ominously for the legacy players, Octopus is portraying itself as a technology firm, benefitting from the digital brand image which has pushed their NPS up to +57.

Whilst the conflict in Ukraine and the subsequent peaking of energy prices effectively curtailed the competitive energy market in many geographies, we are now seeing a return to switching. In parallel the International Energy Agency Global EV Outlook 2023 predicts a 35% rise in EV sales in 2023 (20% of market share), increasing year on year.  Couple this with growing consumer demand for solar, home energy management and batteries and it is clear that now is the time for unified, digital service offerings to customers.

And this isn't just in the open, competitive markets…consumer demand for efficient digital services will force regulated retailers to transform too.

**FIGURE 1**

Electricity supply market shares by company: Domestic (GB) 2017 - 2022

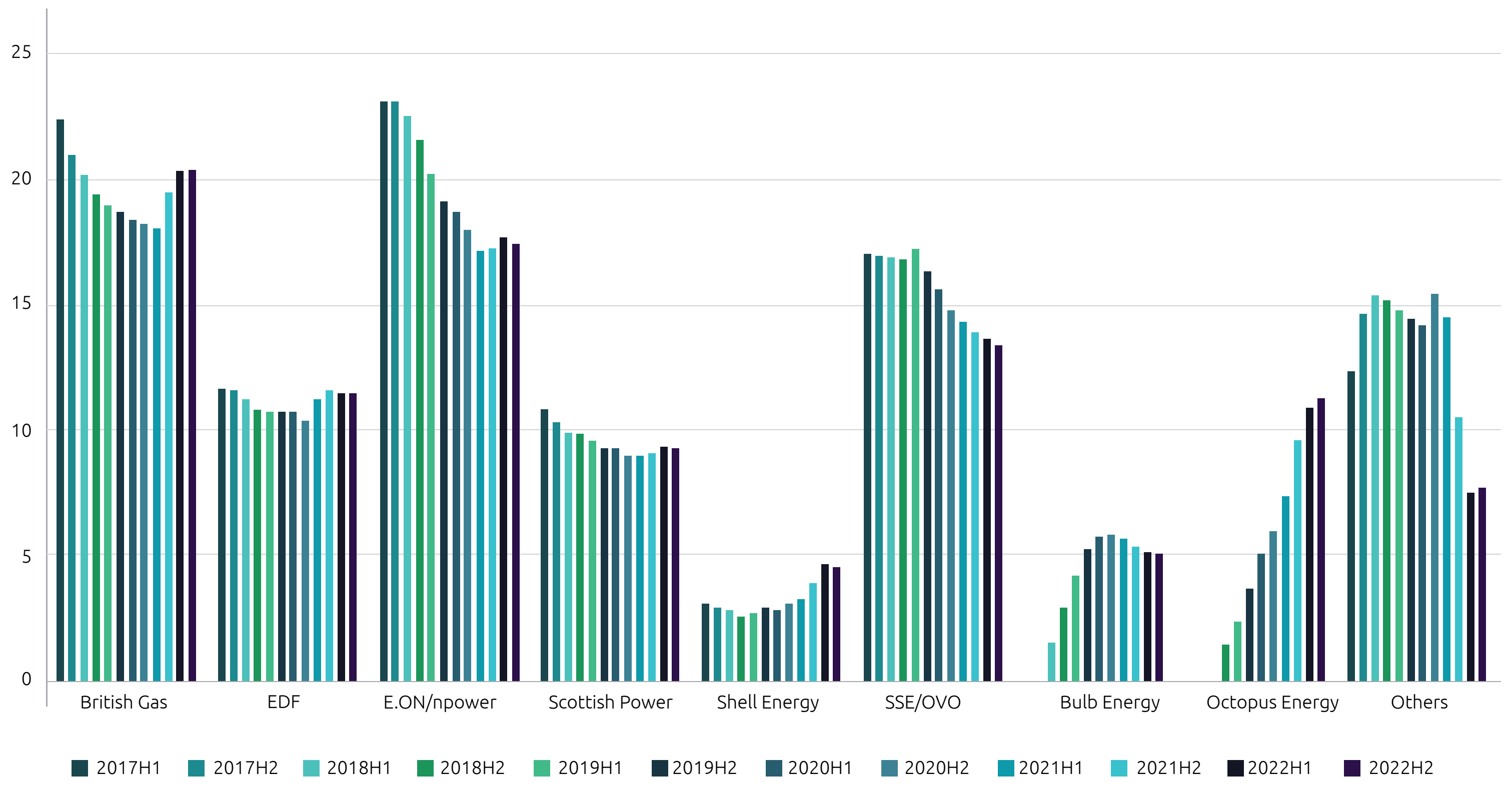



Figure 1: GB Energy Retail Market Shares –
reference: https://www.ofgem.gov.uk/energy-data-and-research/data-portal/retail-market-indicators

## Survive? Thrive?

The data underpinning WEMO (ref: xx) shows that we are at the start of a similar seismic shift to the telcos of the early years of the millennium, and there is an enormous amount of work to do if some of our oldest utility retailers are to survive. The prize for the established utilities is survival and expansion into a new customer relationship, based on broader sales opportunities to home services related to energy. This is an massive ask, though, for many of these established entities as they are encumbered with history and brand - a history of oft-siloed, data-rich, information poor, low-margin, inflexible business and a brand of 20th century dinosaurs.

The prize for newcomers is also revenue/margin expansion but they come often from a position of good market presence in mobility or retail, experts in turning data into information, slicker in leveraging their brand and marketing and with deeper pockets for investment. We contend that survival isn't good enough. Poor returns and stagnant to falling market share and NPS will see the slow demise of those who fail to thrive.

Have we hampered established utilities with too much technical- and process-debt? Or is this a consequence of decades of a focus on low cost to serve at the expense of net promoter score?

Let's think back to the days of AT&T and BT's dominance of their relevant markets. Given their scale they had invested in 20th century technology which enabled the efficient operation of their businesses. Customer contact was through the monthly paper bill and customer services was a cost centre in a cheap location without much focus on customer satisfaction overall. Sound familiar?

Many legacy utilities have invested in unwieldy ERPs, often segmenting their business units into separate systems, again focussing on corporate efficiency. Contrast this with the 'born in the cloud' approach of newcomers which takes a data-centric approach, focussing on customer engagement and exploiting the newer technologies.

AT&T post-break-up tried to invest in the newer technologies, such as home entertainment but buying in a sellers' market means a high price was to be paid. And that high price was funded by debt. And eventually that debt pile toppled the company…being eventually bought by one of the divestments it was forced to make, Southwester-Bell. This company has made further debt-leveraged investments to stay as a key player in the market.

How many of today's retail utilities can truly afford to buy their way into areas such as mobility without risking the entire venture through the debt? Worse still, in regulated markets, the ability to branch out from energy supply is often limited.

The converse picture (e.g. car manufacturers buying into the energy retail industry) is certainly possible but why buy an organisation that has a legacy brand, old processes and a waterfall mindset? Why not set up afresh, a digital energy arm as an extension of a car firm? Tesla's growing market presence spreading from automotive, to services, solar, batteries and now into energy retail is a sure sign that the change is happening now.

## Loyalty

Energy retailers can't rely on loyalty…switching is evidence of this (see Figure 2) and when you look at the potential competition and their NPS scores, it paints a worrying picture.

Many markets now have a customer group with changing attitudes – wanting a 21st century solution to home energy services management, and with the shift to electrification of transport and the further energy transition, this includes mobility and storage, heat pumps and solar. Loyalty is not there and the only constraint for new entrants such as mobility firms will likely be the speed of development of the vehicle offering.

# There is no loyalty to legacy energy retailers

## Success is possible

Whilst the picture for the established utilities seems bleak, almost to the point of 'giving up', one thing is clear, the customer relationship will be key to success for the future. This relationship will evolve from commodity to services provision, will expand into new scope including mobility and will have to be based on an integrated digital solution making it easy for customers to engage and control their approach to cost/risk.

With little in the way of loyalty or money to invest in digital services, lacking agile platforms for customer experience…it might sound like the end of the world for retailers, but they do have some strategic items of value.

Often unrecognised in the portfolio of systems and operations, legacy retailers have a most sought-after commodity – data (arguably it should be information!). Established utilities are data rich, and now need to turn this into a competitive advantage, augmenting their data with other sources to build a comprehensive picture of customers. This then has to be proactively leveraged in building the trust with customers – established utilities cannot sit back and wait for customers to call them – they won't.

Long histories in the industry give legacy retailers expertise which can be used to avoid pitfalls that others might experience. Some of the bigger challenges to be faced will be with regulation and politics – something legacy retailers are efficient at managing.

For those retailers with workforces, the set of established processes and accreditations gives an amazing opportunity to broaden the customer sale. For example, field engineers could arguably be re-trained into heat pump or EV charger installation. This addresses a challenge the mobility companies have in that they rarely have the large mobile filed forces necessary to install the home technologies.

**FIGURE 2**

| Aggregated European electricity switching rates 2021(%) | | |
|---|---|---|
| Netherlands | 27.00% | Hot Market |
| Belgium (Flanders) | 26.88% | |
| Belgium (Wallonia) | 24.11% | |
| Norway | 21.56% | |
| Spain** | 16.74% | Warm Active Markets |
| Finland | 16.30% | |
| Italy | 16.20% | |
| Czech Republic | 15.59% | |
| Great Britain | 15.58% | |
| Estonia | 15.00% | |
| Ireland (Rep. of) | 14.81% | Active Markets |
| Northern Ireland | 13.10% | |
| France | 12.30% | |
| Germany* | 11.05% | |
| Sweden | 10.51% | |
| Portugal | 10.22% | |
| Greece* | 7.72% | |
| Danmark | 7.36% | |
| Latvia | 5.94% | |
| Belgium (Brussels) | 5.62% | |
| Slovakia | 5.27% | |
| Slovenia | 4.78% | Cool Active Markets |
| Austria | 4.10% | |
| Lithuania | 3.18% | |
| Croatia* | 1.37% | |
| Hungary | 0.75% | Dormant Markets |
| Switzerland | 0.62% | |
| Bulgaria | 0.46% | |
| Luxembourg | 0.27% | |
| Poland | 0.21% | |

## Pick your battles

The future is exciting, profitable and arguably more engaged, more real-time and the time to begin this transformation is now. We will see some fall by the wayside on this journey but the winners can benefit from the experiences of the telcos, from the unstoppable force for change in the form of the energy transition and from the latest digital engagement models.

Each retailer, be they in a competitive, open market or a semi- or fully-regulated will need to make some strategic decisions…and quickly.

Firstly, the retailers will need to decide what they want to be and to whom…are they going to go head-to-head with the new digital entrants and build a full service offering? Or will a more focussed approach lead to greater shareholder value, potentially restricting on scope of market or offerings?

The global market is littered with failed retailers or those who are so heavily-indebted that without the support of governments would be failed entities. The market is also surprisingly slow to partner, possibly as a result of the historic monopolistic positions in the market. What better way, though, to gain digital traction than to partner with a new entrant. And what better way for the new entrant to gain market understanding than to partner with an established retailer?

## The future is exciting, profitable and arguably more engaged, more real-time and the time to begin this transformation is now

### This is happening now…it is not the time to prevaricate.

Finally, after 25 years of WEMO, reporting on how the retail market slowly moves forward we are at the point of acceleration. WEMO 2024 will surely include new names, and many of the old ones..but will see a rapidly-evolving proposition set.

As a call to action, we note the points below as essential activities in the short term. The consumer uptake of EVs, solar etc. and the market expectations building around the associated services pushes us to believe that there is no time for hesitation…action has to be taken now.

- **Brand and Market Offerings –** Have the courage to take a fundamental look at what your brand means and what offerings will be relevant to your consumers in the next 25 years. Pick those markets, customers, offerings which align to the outcome of this review…and benchmark against your current and expected competition.
- **Assetise Data –** The core asset of many retailers is the volume of data. Make this an asset and optimise re-sale opportunities for this recognising that data shelf-life isn't long.
- **Digitise the customer engagement –** Augmenting internal data with other sources, applying AI and leveraging customer contact will yield new sales opportunities for retailers and begin to re-build the trust in the relationship.
- **Partner –** Be bullish but don't over-estimate the fierceness of the competition. Partner as needed to benefit from the skills (and money!) coming into the market.
- **Focus on the Customer –** Customer demand is driving this revolution and the customer relationship has to be brought to the heart of your retail organisation. Contact should be a blessing…and one to be made easy.

# POWER TO THE PEOPLE!

# HOW ENERGY CONSUMERS ARE TAKING CONTROL AND WORKING AROUND INDUSTRY CONSTRAINTS.

JASON SALMON, UK

JOHN BRIGNELL, UK

ABRAR MASUD, UK

## Economically its been a very volatile year

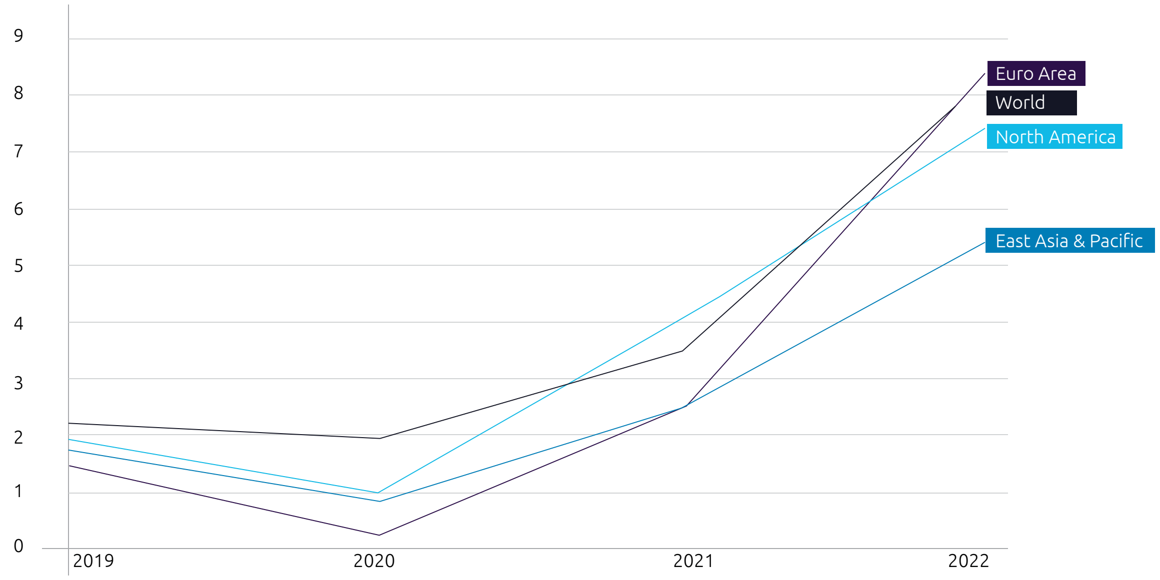
Since the start of 2022, costs to consumers have increased significantly globally in multiple sectors to levels not seen in almost a decade. The global average **Consumer Price Index has risen to over 8%, double that at the start of 2022 (figure 1), wholesale electricity prices have more than doubled (figure 2), with energy price volatility at levels not seen before (figure 3).** In Europe, the war in Ukraine has had a significant contribution, and continuing concerns around global energy security have impacted markets further afield. Whilst latest forecasts indicate costs to be falling again this winter, there is no escaping how quickly they can fluctuate.

**FIGURE 1**

Inflation, consumer prices (annual%) - Euro area, North America, East Asia & Pacific, world

International Monetary Fund, International Financial Statistics and data files.

License: CC BY-4.0




Source: World Bank

**As a result of these increases, consumers are rapidly changing their behaviours and spending habits,** seeking to make smarter choices on what and where they spend money.

In particular, consumers are becoming more price conscious with regards to energy, and with sustainability and security on everybody's minds, there are increasing pressures on retailers to deliver greater value for money.

What's more, consumers no longer fit the old mould they used to – they are more engaged, more aware of trends and external factors and see the pace of change in other sectors. They receive a tailored experience elsewhere and want the same from their energy provider.

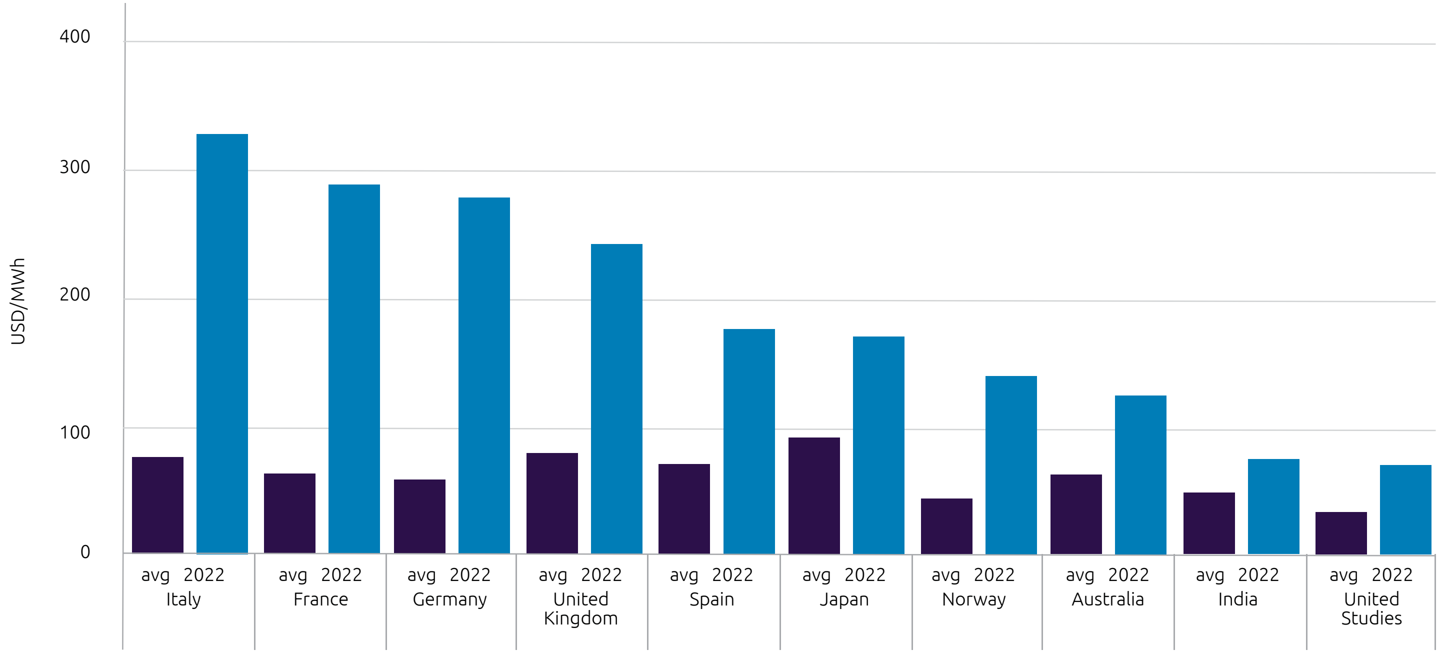
## Market challenges and constraints

Consumers may not be aware (and may not care) that traditional energy suppliers are operating in a tough environment in which margins are small - as low as 2% for the majority of suppliers. The pace of change is slow and regulation has not kept up, designed more than 20 years ago for consumer behaviours that have changed significantly since then. It does not allow for agility and limits innovation.

Consumers have benefited from the roll-out of smart meters and connected technologies, which has given them unparalleled access to data, and provided them significant opportunity to understand how and when energy is consumed. Consumers want their suppliers to utilize the data and technology to provide tailored services. However, many suppliers have not matured their service-based business models and capabilities in product management and analytics to deliver these value-add services to consumers.

**FIGURE 2**

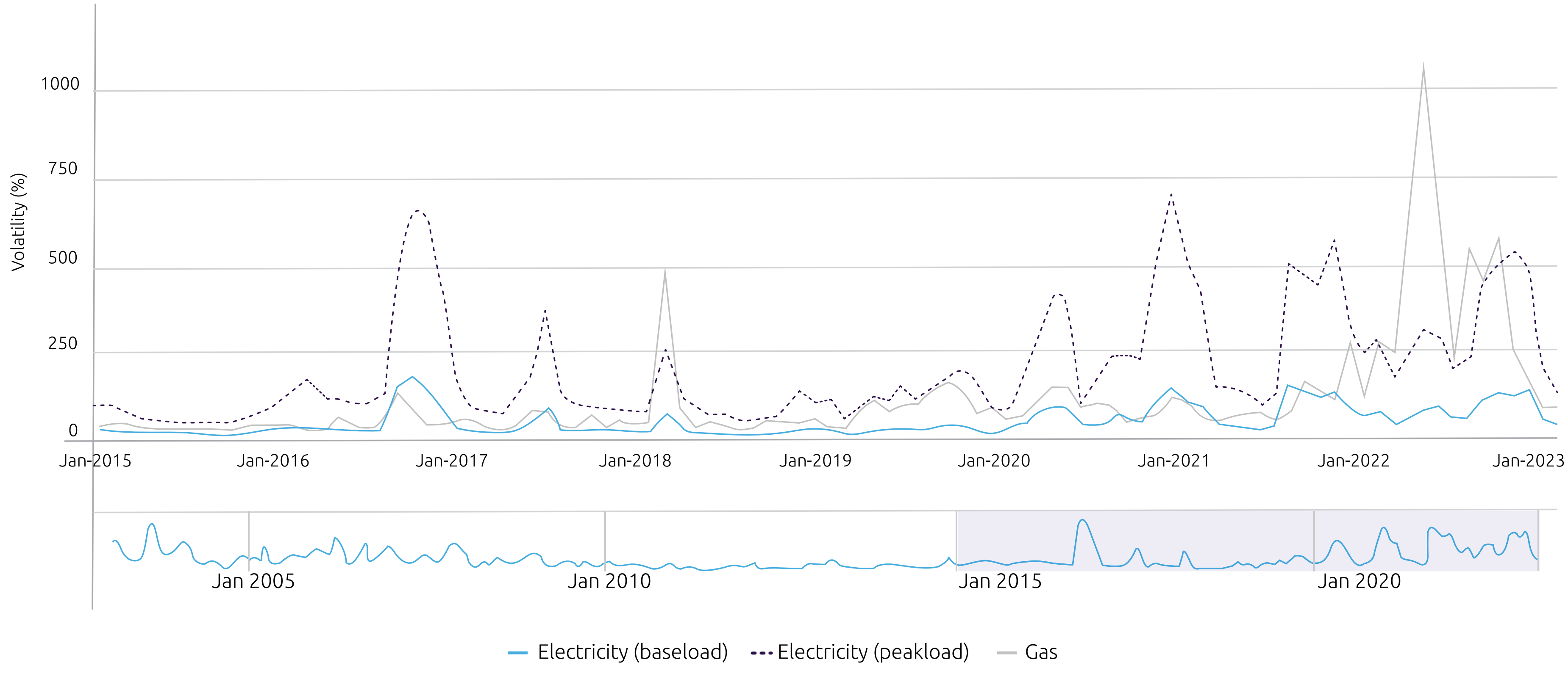
Annual wholsale prices in selected countries, 2022 and 2017-2021 average




1 Source: World Bank May 2023 2 Source: International Energy Agency 3 Source: Ofgem May 2023

**FIGURE 3**

Price volatility of gas and electricity by month: Day-ahead contracts (GB)




Source: Ofgem

## Why consumers are taking control

Similar to other industries, consumers are demanding more tailored services and propositions, with off the shelf offerings provided by many energy suppliers no longer making the cut. As such, we are now witnessing a shift to consumers seeking their own solutions.

**Consumer-driven changes, combined with digital solutions, are leading the charge in introducing innovation in the energy market.**

### Not just an energy company

Consumer-driven changes, along with the integration of digital solutions, are revolutionizing the energy market. As electrification, energy transition, distributed energy management, and digital transformation reshape the industry, energy retailers find themselves not only competing with each other but also with major technology companies. Consumers now expect the same level of innovation and convenience in their energy services as they experience in other sectors.

The 5 levers outlined here represent key factors that are driving the transformation of the energy market and empowering consumers. These levers highlight the fundamental changes occurring in the industry and shed light on the specific areas where consumers are gaining more control and influence. Let's take a closer look at each lever and why they are significant:

### Lever 1: Increases in Technology Penetration

With approximately 68% of the global population using smartphones, and even higher adoption rates in Europe reaching 77%, with Australia higher still at 88%, consumers today have unprecedented access to technology. The decreasing costs of computer software and related items over the last decade have made technology more affordable and accessible. Advancements in technology, economies of scale, and increased competition have contributed to the reduction in hardware prices. The future of personal computers is expected to be influenced by factors such as the rise of quantum computing, increased integration of AI, and the development of more energy-efficient devices.

Great Britain's electricity market has reached a smart meter penetration rate of 55%, similar to levels seen in other European countries. The next generation of smart meters will leverage private data networks, such as the Data Communications Company (DCC) in GB, enabling real-time analytics and personalized services through edge computing. This increased technological integration is shaping consumer behaviors and raising their expectations in the energy sector. One cush example is the Demand Flexibility Service (DFS), run by Octopus and National Grid ESO, which aims to reduce GB-wide electricity demand. Furthermore, Octopus has rolled out GB's first time-of-use tariffs through their Agile Octopus offering.

### Lever 2: Rise of the conscious consumer

Consumers are increasingly conscious of their purchasing decisions, driven by both sustainability and cost considerations. The economic pressures experienced during 2022/23 have introduced new nuances into consumer mindsets, with an emphasis on eco-economic behaviour. Active reduction in consumption, including energy usage, is influenced by a desire for both eco-friendly choices and cost savings.

Research by OFGEM and Citizens Advice reveals that 84% of consumers have taken proactive steps to reduce their energy bills. Affordability is a key driver, with half of consumers expressing concerns about their energy costs. Owing to this consumers are now exploring energy-efficient tariffs, adopt energy-saving hardware, and adjust their energy consumption behaviours.

### Lever 3: Accessible Services

Modern consumers are not only eco-conscious and cost-conscious but also social media-savvy and demanding convenience. Consumers want accessible services that cater to their own evolving expectations. Things they are expecting include seamless digital interfaces, personalized energy management solutions, and innovative pricing models that empower consumers to actively engage with their energy usage and costs.

## Lever 4: Decentralized Energy Generation

The increasing adoption of decentralized energy generation, such as rooftop solar panels and residential wind turbines, gives consumers more control over their energy production and reduces their reliance on traditional energy sources. Since the start of 2022 installed domestic solar PV capacity has increased by over 700MW, the same volume seen over the previous 5 years4. The shift towards self-generation aligns with consumer desires for sustainability, energy independence, and cost savings.

The trend towards decentralized energy generation is not just limited to developed countries. In many developing nations, decentralized solutions like solar panels and mini-grids are bridging the energy gap in remote areas where extending the national grid might be challenging. For instance, in parts of Africa and Asia, solar home systems are providing electricity to households for the first time. This not only empowers consumers with energy independence but also promotes sustainable development. The rapid decline in the cost of solar panels globally has further accelerated this trend.

## Lever 5: Data-Driven Solutions

The integration of data analytics and artificial intelligence (AI) allows for more accurate energy forecasting, personalized energy recommendations, and optimized energy management. By leveraging consumer data and AI algorithms, Consumers share their data in expectation of tailored solutions, so they can improve energy efficiency, and be empowered with insights to make informed decisions about their energy usage.

# The Power of Consumer Led Initiatives

Consumer knowledge and engagement with energy products and services have significantly increased. Advancements in digital capabilities and lower setup costs have empowered consumers to exercise greater control over their energy choices. Traditional relationships with energy providers are undergoing a transformation as consumers proactively seek alternative solutions.

These examples demonstrate how consumers are taking control of their energy choices across the globe, shaping the industry landscape, and driving the transition to a more sustainable and consumer-centric energy future.

## Local Energy Networks

In California, community solar projects have witnessed a remarkable 45% increase in installations over the past two years. By collectively generating clean energy, communities reduce their dependence on traditional utilities and foster a sense of energy independence.

## Energy Management Systems

The adoption of smart thermostats has grown by 23% annually, empowering homeowners to optimize their energy usage and save up to 15% on their energy bills. By taking control of their home's energy management, consumers contribute to a more efficient and sustainable energy ecosystem.

## Distributed Energy Resources

Germany has experienced a significant surge in rooftop solar installations, with over 1.9 million households producing their own renewable energy. By becoming energy producers themselves, consumers actively participate in the transition to a decentralized and cleaner energy system.

## Energy Efficiency and Sustainability

The "EcoMode" campaign in the UK demonstrated the power of consumer-led conservation efforts. Through their participation, households achieved a remarkable 12% reduction in energy consumption, highlighting the significant impact of individual actions on energy efficiency and sustainability.

## Demand Response Programmes

In Texas, a successful demand response programme has been implemented, this reduced peak energy demand by 20%. By voluntarily adjusting their energy usage during high-demand periods, consumers played a crucial role in avoiding the need for additional power plants and enhancing grid reliability.

# What do retail energy players need to do?

The 5 levers outlined here represent key factors that are driving the transformation of the energy market and empowering consumers. These levers highlight the fundamental changes occurring in the industry and shed light on the specific areas where consumers are gaining more control and influence. Let's take a closer look at each lever and why they are significant:

## Opportunities for Innovation and Expansion

Expanding service offerings beyond energy supply opens opportunities for energy suppliers to meet emerging demands of consumers. Offerings can include real-time energy management tools, smart home integration for optimized consumption, energy efficiency audits, and advisory on sustainable practices. Suppliers can also meet consumer needs by being enablers for renewable energy solutions, electric vehicle charging infrastructure, heat pumps and energy storage options, further adding to their services. These offerings empower consumers, promote energy efficiency, and contribute to a transition towards cleaner and sustainable energy solutions.

An enabler would be through multi-party partnerships across industry and cost efficiencies achieved by restructuring and transitioning to a service-based model.

## Embracing Energy as a Service (EaaS)

Energy suppliers can enhance this shift to services by adopting an Energy as a Service (EaaS) approach. Such a service could involve offering energy performance contracts, subscription-based energy plans, participation in demand response programs, and energy financing options. Advanced analytics, AI-driven technologies, and microgrid solutions optimize energy usage and enable localized energy generation and distribution. Embracing EaaS enables energy suppliers to deliver personalized, flexible, and value-added services that prioritize consumer needs, energy efficiency, and sustainability.

## Embracing Digital Transformation

Digital transformation plays a crucial role in empowering consumers. By developing user-friendly platforms, similar to popular apps like Deliveroo and Uber, energy suppliers can enhance the consumer experience matching users to wants, such as smart tariffs, or peer-to-peer trading. Providing consumer choice, flexibility, and intuitive interfaces simplifies energy management tasks and enhances user engagement through self-sufficiency. Coupled with agile development practices, it ensures continuous innovation and responsiveness to evolving consumer expectations.

## Engagement

To effectively engage with consumers, energy companies can draw inspiration from other regulated industries such as Financial Services, as well as learn from tech firms like Apple and Netflix that prioritize consumer-centric approaches. By studying their strategies, energy companies can gain insights on how to adapt and keep up with the ever-changing expectations of consumers.

## Data

Including research data on consumer engagement and its effectiveness can provide valuable insights. Highlighting successful case studies and data-driven findings can demonstrate the impact of consumer engagement and the importance of aligning business practices with consumer needs.

## Call to action

In today's dynamic energy landscape, consumers are taking control like never before. Through digital transformation and platform strategies, energy suppliers can empower consumers, drive innovation, and meet evolving demands. We must:

- Provide user-friendly platforms, personalized options, and real-time data
- Engage consumers, expand services and leverage technology
- Promote self-sufficiency in energy management

In doing so we will need adaptable governance structures to adapt to consumers and to drive sustainable growth.

The risks of inaction are clear—irrelevance, loss of market share, and ultimately, business failure. It's time for energy retailers to seize the moment and embrace digital transformation to secure their position in the market.

Companies need to empower Consumers taking control and embrace a new approach to retail energy.

# TRANSFORMATION FOR ALL? WHAT DOES THE FUTURE HOLD FOR THE ATYPICAL CONSUMERS?

MICHAEL VEIT, GERMANY

**In an era of dynamic change, the energy sector is undergoing an unprecedented transformation that is reshaping the very definition of energy consumers. The catalysts for this revolution are numerous: geopolitical shifts, fluctuating energy prices, an amplified social consciousness concerning climate change, and evolving consumer preferences.**

**The convergence of these factors is propelling us toward a future characterized by a class of consumers that is dramatically distinct from the conventional norm. The rise of this new energy consumer class is irrefutable and inevitable, fueled by technological innovation, changing market dynamics, and a compelling drive toward sustainability.**

### The Paradigm Shift: The Rise of the New Energy Consumer Class

Traditionally, energy consumers were relegated to passive roles, reliant on standardized offerings from utility companies. This archaic model is on the cusp of extinction. The metamorphosis is tangible, as more energy consumers embrace novel solutions to fulfill their energy needs. Enter the "New Energy Consumer Class." This class embodies diverse personas: the prosumer who generates electricity through solar panels, the pioneer of renewable technologies, the electric vehicle aficionado, the energy storage advocate, and those with unique energy preferences. These atypical individuals, armed with the tools to generate, store, and manage their energy, are rewriting the rules of the game.

### An Unavoidable Transition: The Erosion of the Old Consumer Paradigm

The inevitability of this transition lies in the convergence of various compelling factors. Solar energy's accessibility and plummeting costs have made renewable generation an enticing prospect for many. As battery storage technology matures, individuals can store surplus energy, gaining autonomy from the traditional grid. The electric vehicle revolution is accelerating, making clean transportation a practical reality for a broader audience. Heat pumps and geothermal systems, driven by renewable energy, are revolutionizing heating. These developments signify a profound shift toward decentralized energy systems.

### The Advent of New Winners: A Glimpse into the Future

The market landscape is witnessing the ascendancy of new players who are adeptly navigating these transformative waters by constantly developing and testing new services with beta versions and MVPs. These entities are not mere energy providers; they are orchestrators of comprehensive energy ecosystems. They understand that the allure of the new energy consumer class is not solely about data but about taking stewardship of the energy asset on behalf of the consumer. Effective cost management is paramount, as these players leverage data to optimize energy consumption patterns. Bundling energy services with innovative solutions is their hallmark, making energy management a seamless and rewarding experience.

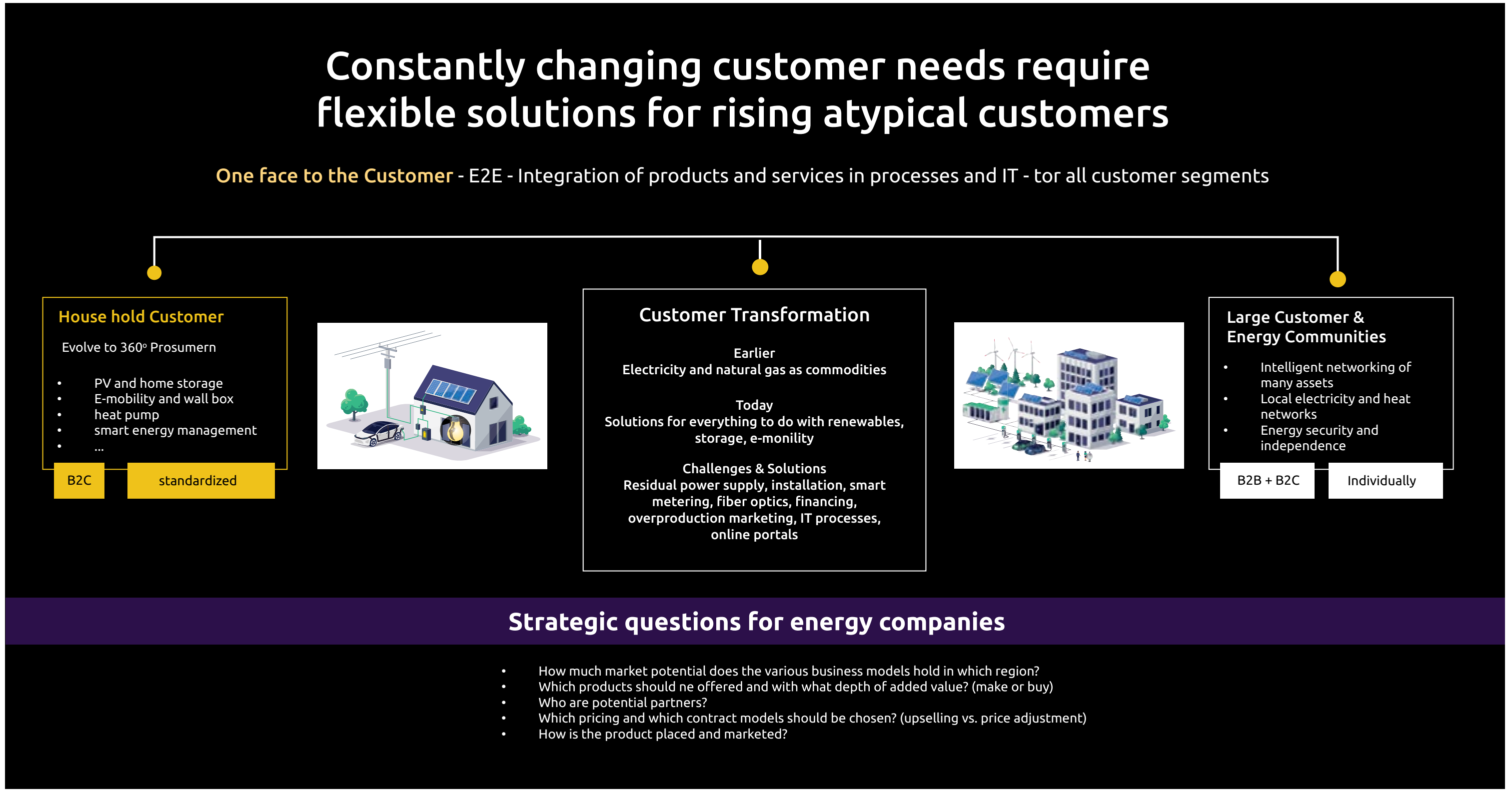
**Hyper-Personalization: The Bedrock of Transformation**

The bedrock of this evolution is hyper-personalization, which transcends mere data analytics. Hyper-personalization, fueled by advancements in data analytics and artificial intelligence, has revolutionized customer experiences across various industries. It involves utilizing advanced technologies, data analysis, and real-time personalization to tailor offerings, services, and communication based on specific customer needs, preferences, and behaviors. It engenders a unique service experience that resonates with individual consumers. By leveraging AI and real-time insights, hyper-personalization crafts bespoke energy journeys. It empowers typical consumers with energy-saving insights, tailored pricing plans, and user-friendly tools. For the atypical, it opens doors to renewable energy options, electric vehicle integration, and energy storage management. By leveraging customer data and predictive analytics, energy providers can optimize the customer experience and enhance engagement.

Comparing hyper-personalization across telco, insurance, and energy industries, there are both similarities and differences. All three industries rely on customer data to develop personalized offerings. However, telco and insurance have been at the forefront of leveraging data analytics to create targeted -products, -prices and services, while the energy industry is still exploring the full potential of hyper-personalization.

Additionally, the telco industry heavily relies on real-time customer interactions, while insurance and energy focus more on long-term relationships and data-driven insights. Hyper-personalization is not a fleeting trend; it is the new paradigm that fuses technology with personalized service.

**FIGURE 1**




However, it does not imply that every energy customer in the future will become atypical. Rather, hyper-personalization helps utility companies understand and address individual needs while still delivering a reliable and efficient service to a diverse customer base. By embracing hyper-personalization, energy providers can adapt to the changing landscape, deliver value to customers, and drive the sustainable energy transition.

### The Ineluctable Horizon: A Glimpse into the Future

Five to ten years from now, the energy landscape might be virtually unrecognizable. The tipping point toward the new energy consumer class will be heralded by widespread adoption of solar, storage, electric vehicles, and heat pumps. The traditional model will crumble further as the majority transitions to atypical consumers. Decentralized energy systems, driven by diverse energy assets, will be the norm. Utility companies will have metamorphosed into dynamic energy orchestrators, offering holistic solutions that span generation, storage, and consumption. The consumer's role will evolve from passive recipient to active energy manager.

### Cost: The Ever-Present Consideration

In this brave new world, cost remains a constant concern for all consumers. The new energy consumer class is not just about embracing sustainability; it is about effectively managing costs through empowered energy choices. The ability to generate, store, and consume energy efficiently translates into economic advantages, underpinning the attractiveness of this transformation.

### Embrace, Adapt, Thrive: The Imperative for Incumbents

The incumbents must not merely adapt; they must redefine their role. Embracing renewable energy, championing energy efficiency, and forging transparent relationships with consumers will be crucial. The winning strategy hinges on understanding the new energy consumer class and catering to their multifaceted needs. The interplay of solar, storage, electric vehicles, and heat pumps will create an integrated energy ecosystem that empowers all.

In this realm of relentless transformation, the emergence of the new energy consumer class is not just a trend; it is the future. The march toward sustainability, energy autonomy, and hyper-personalized service is unstoppable. Embrace it and be at the forefront of an energy revolution that promises a more inclusive and sustainable world."

**FIGURE 2**

Heat Pump Sales in Europe in 2021, by technology

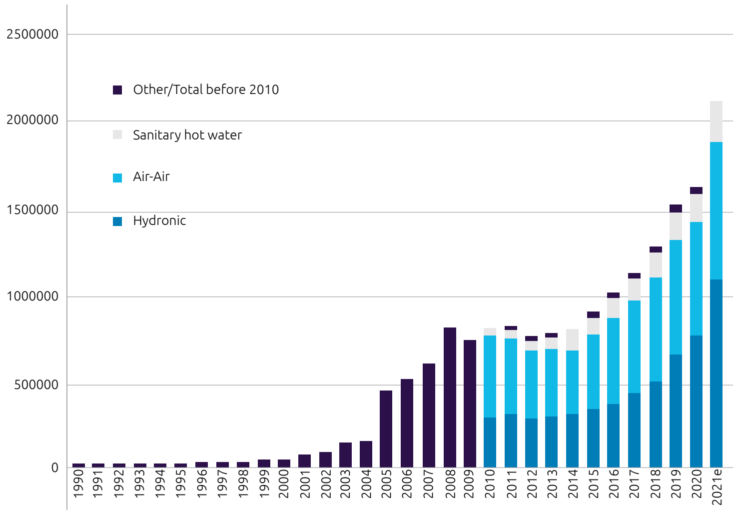
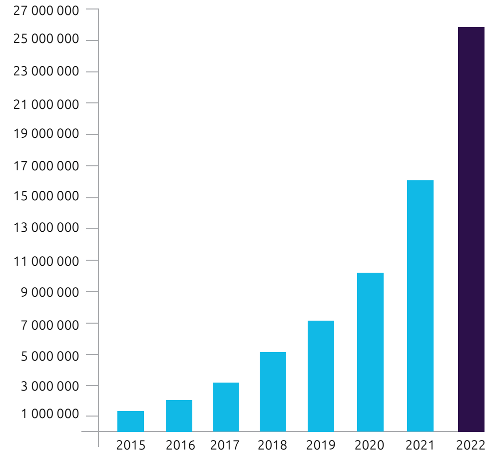
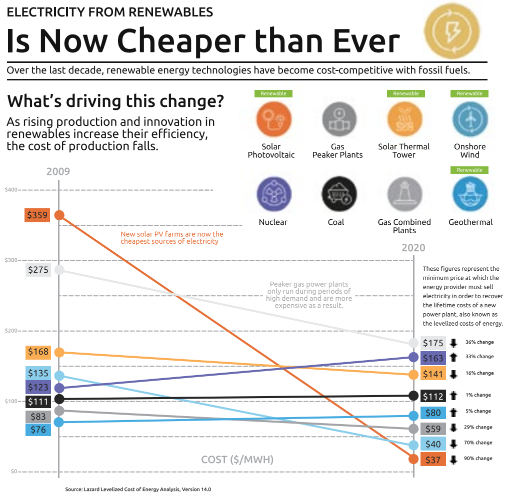



**FIGURE 3**

Global electric car fleet



# RETAIL ENERGY: LEARNING LESSONS FROM THE U.K. TELCO TRANSFORMATION

IAN MIDDLETON, UK

YARA JAMALEDDINE, UK

## Current status of the energy retail market

Historically, much of the world's energy retail market was a monopoly. In the U.K., the market was dominated by six players: British Gas, E.ON, Npower, SSE, ScottishPower, and EDF. The evolution of competitive markets in the U.K. and elsewhere greatly impacted the energy retail landscape. It provided the opportunity for many smaller players to come into the market. At its peak in 2017, there were 68 energy retailers in the U.K., compared to fewer than 20 players in the early 2000s. This number has now decreased, partly as the result of the recent wholesale price volatility combined with the lack of solid finances underpinning some utilities.

In addition, traditional retail energy providers around the world are facing increased competition from a range of new, non-traditional market entrants such as Tesla, telecoms, and oil giants. All of these players are positioning energy provision as simply another part of a more comprehensive services bundle and encouraging customers to switch away from traditional suppliers.

Together, these issues mean that electricity and gas retailers increasingly have to rethink their business model and how they engage with customers. The rise of Octopus from its U.K. roots has set the bar high in customer engagement and end-user proposition. Still, others such as E.ON, Enel, EDF, and Centrica, are all moving to more sustainability-focused offers that encompass a wider in-home footprint. This is encouraged by research that shows a willingness of customers to pass control of devices to their energy retailer. Indeed, Centrica's 2015 change in strategy to become a customer-facing business powered by technology and innovation has been followed by actions such as refocusing on sustainability programs and divesting some legacy assets.

As price volatility subsides, the battle for customers will step up. It will include attracting customers who feel they were poorly treated during the recent crises, leading to increased churn. Incumbents have to face up to the fact that the market is fundamentally changing. They need to reposition if they wish to stay relevant in the transforming energy market, working out how to improve historically low margins to free up funds for investment.

To survive and thrive in the future, energy retailers must either become super-efficient utilities with a narrow focus to maintain and potentially grow their business, or transform, maximizing the value of their customer base by extending their value proposition from a single product, electricity and gas supply, into a broad portfolio of products and services that can create increased value for customers.

Any change of strategy should consider the learnings from other industries that have undergone a similar transformation.

## The telecommunication sector

The telecommunications sector has undergone significant technological transformation over the past decade to 15 years. This transformation has largely been driven by the emergence of global technology companies, which, while relying on the foundational infrastructure provided by communication service providers, have been able to capture the majority of the market's value.

In addition, this period has also coincided with a huge increase in competition and increasingly cost-conscious customers, who see connectivity as a commodity and fundamental right, similar to the provision of energy. The result is that consumer prices have remained largely flat – customers don't want or expect to pay more for 4G vs 5G or copper vs fiber. This negatively impacts average revenue per user (ARPU) (Figures 4 and 5).

New players also arrived and disrupted the telecom sector, changing the way business was done. They offered new services with simple consumption-based payment models with limited commitment. For example, in France, the operator Free (part of Iliad) disrupted the peaceful competition between incumbents with low-cost triple-play offers that were simple to understand and consume due to their low-cost base and social marketing.

Top internet companies also succeeded in grabbing market share from telecom services and connectivity, offering a more customer-centric, omni-channel and gamified experience (Figure 6).

So far, the introduction of 5G has failed to reverse the consumer mobile ARPU decline, despite the fact that the amount of data transferred across the network has significantly multiplied. In other words, customers are now receiving a lot more service for their money. They appear hesitant to pay higher prices because there haven't been any truly revolutionary applications that leverage 5G's capabilities. The primary advantage has been an increase in bandwidth, which is largely anticipated as technology advances over time.

What is proven is that customers will pay more, but only to access additional services such as content (video streaming, gaming), which is usually provided by the big technology companies rather than the telecommunication companies.

**FIGURE 1**

Number of active domestic suppliers by fuel type (GB) (Ofgem, 2023)

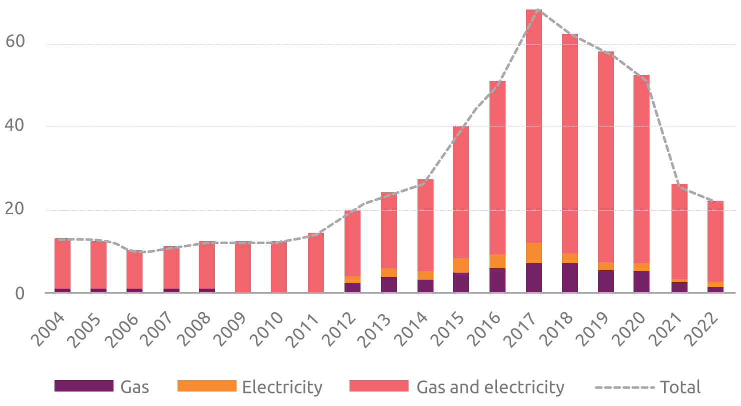



**FIGURE 2**

Gas supply market shares by company (%, data for Q4 of each year, Ofgem 2023)

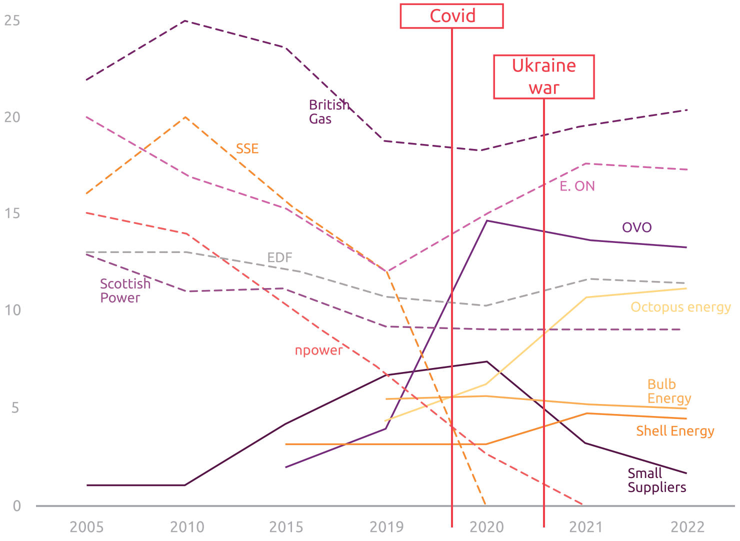


**FIGURE 3**

Gas supply market shares by company (%, data for Q4 of each year, Ofgem 2023)


**FIGURE 4**

ROIC to WACC spread for top 25 global telecom operators McKinsey, A blueprint for telecom's critical reinvention, 2021

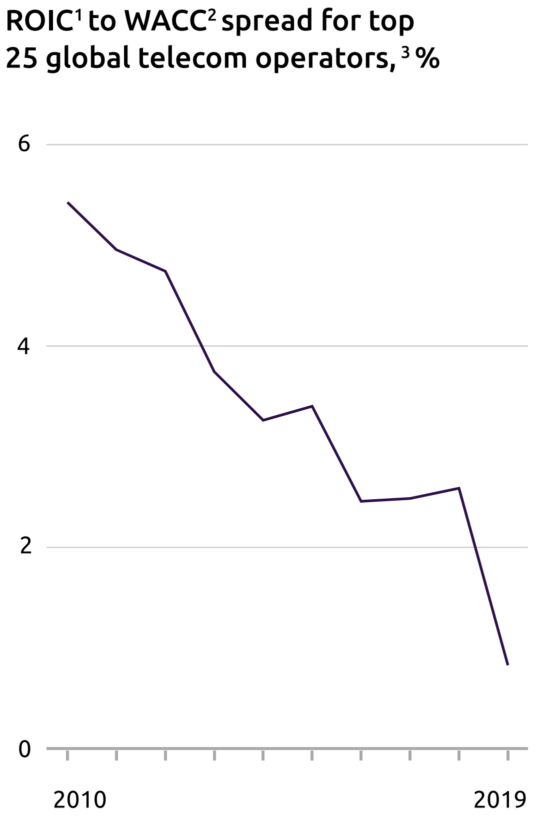
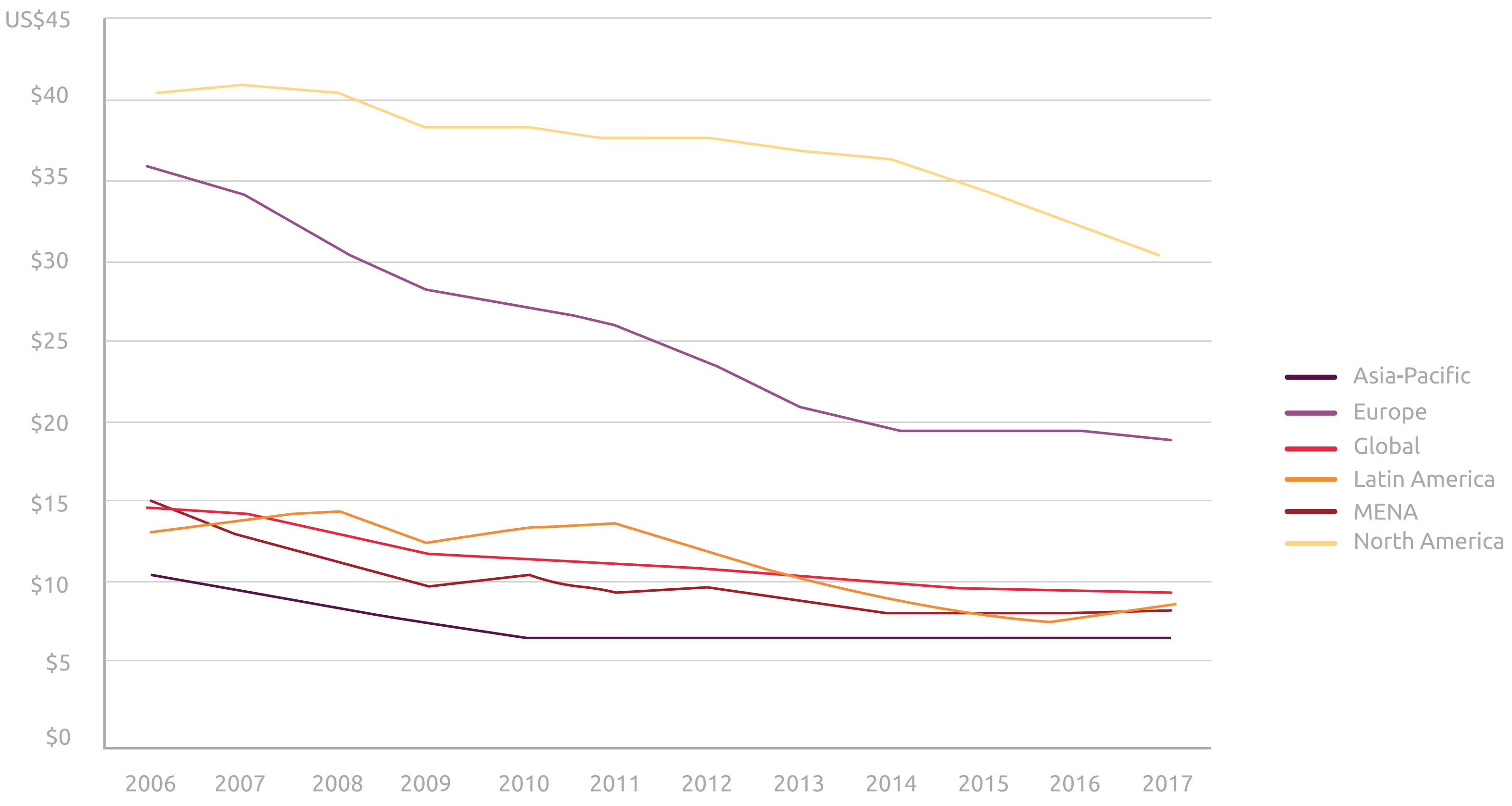


**FIGURE 5**

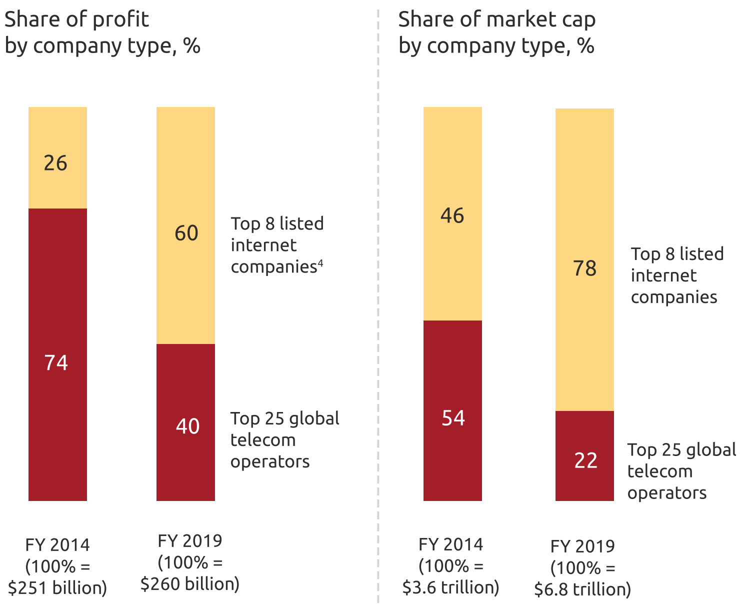
Shrinking ARPU by region, 2006-2017




Source: TeleGeography; Strategy & research and analysis, strategyand.pwc.com/ wirelesscommoditization

FIGURE 6

Share of profit and market capitalisation, by company type
McKinsey, A blueprint for telecom's critical reinvention, 2021




Source: 2023 Lazard's Levelized Cost of Energy Analysis

## How the telecommunications sector tried to adapt

To address the increased churn and reduction in ARPU, communication service providers (CSPs) have been forced to look at how they can improve their customer experience and stickiness by unlocking new sources of revenue outside their core business. These have included forays into financial services, television, IoT and many others to try and generate increased ARPU and stickiness with their customers.

The industry has undergone, and to some extent, is still experiencing a significant transformation. Enormous investments have been made in digitizing their operations, aiming to enhance efficiency and the customer experience. Concurrently, they've also dedicated resources to creating a plethora of entirely new services, such as BT TV by British Telecom.

In many ways, considerable improvements have been achieved, including the implementation of omni-channel and self-care solutions. Moreover, there is now a heavy focus on customer experience supported by the highly advanced analytics of customer interactions. These analytics help identify opportunities for increasing sales and gaining valuable insights. In fact, in certain instances, the insights derived from data analytics have prompted CSPs to introduce secondary digital-native brands featuring more affordable and simplified offerings tailored to specific customer segments, especially younger customers who were previously underserved.

The CSPs have increased the breadth of services offered, including new products and services not always directly linked to their core activities. Some operators proposed bundles with access to media and entertainment platforms (for instance, BT TV in the U.K. or OCS by Orange in France), gaming bundles with fiber connection and a game console, or even energy bundles.

However, in many cases, the resultant revenue and profit increase did not meet expectations and many services have since been retired. Indeed, Arthur D. Little's benchmark of telecom diversification initiatives shows that less than 15% of initiatives generate sizable revenue 24 months after launch. In many cases, new services never really got beyond the trial stage. In many cases, new services never really got beyond the trial stage. Many CSPs miscalculated the strength of their brand. While existing customers trusted them with their core services, they often did not when it came to newly created products.

Now, when we look back at what the industry did, we can say that, in many ways, the changes undertaken were the right ones. However, these companies did not transform their culture and business approach. They simply transformed their technology, still operating as CSPs and providing additional services without creating brand alignment for those services. They should have transformed their business – and the technology should have been a consequence of that transformation rather than the goal.

## What are the learnings that could be applied to energy retailers?

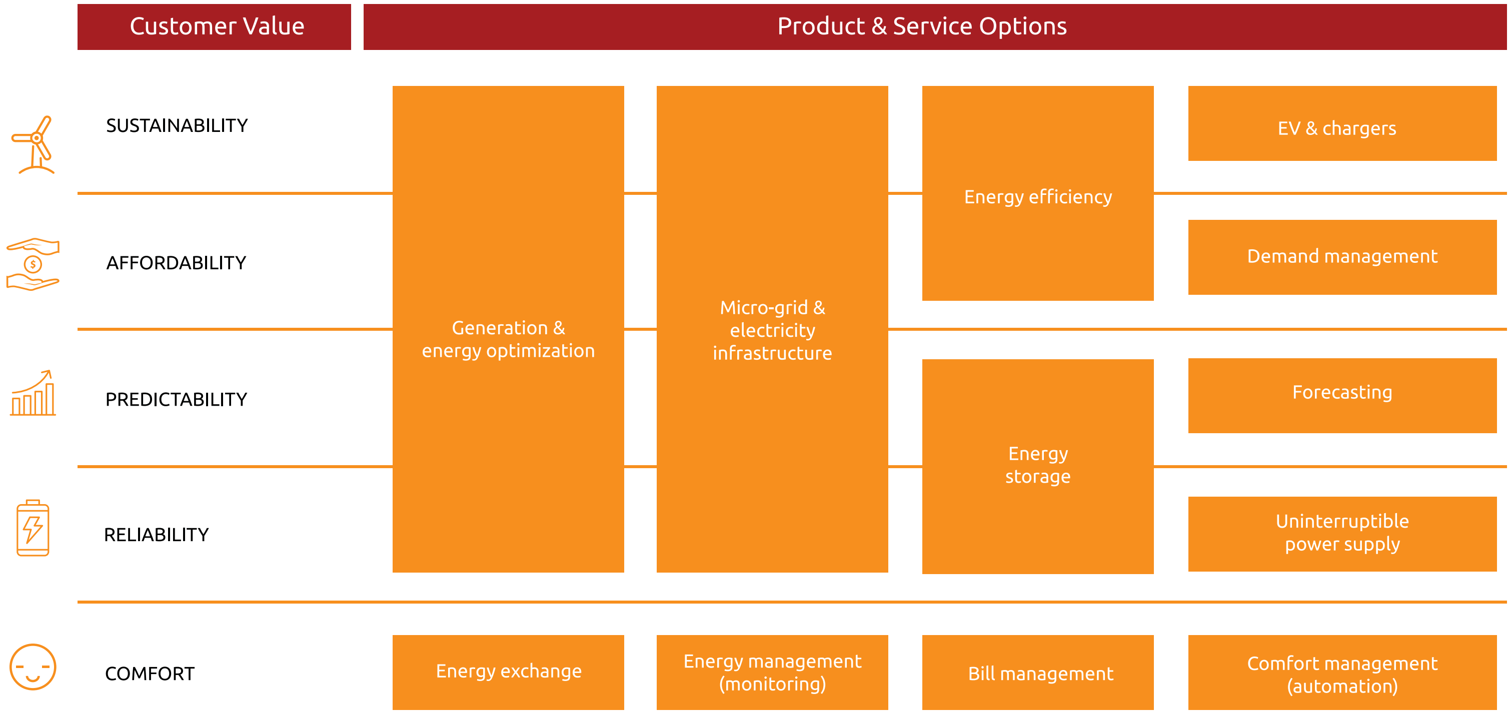
A vital lesson from this sector is that technology upgrades and the introduction of new services, while needed, are insufficient to truly transform your business. There is a need to transform your brand, business processes, and culture. The services delivered were often viewed as an addition to the core business rather than a fundamental change in the business approach, resulting in a lack of significant improvement in their business

Energy retailers have gleaned valuable insights, indicating they can diversify into new markets. This could encompass telecommunications services, as some have already done. Yet, to undergo a genuine transformation, they must prioritize investments in reshaping both their business and corporate culture. Subsequently, they can embark on the technological changes required to support their revitalized business approach.

The Telecom sector has undergone persistent transformation over the last 30 years following the widespread privatization of many of the world's incumbent service providers. However, the transformation over the last 15-20 years is primarily due to the emergence of global technology companies, who rely on the underlying infrastructure of the telecoms service providers but have managed to claim the lion's share of the value. This period coincides with an era of cost-conscious, savvy consumers.

**FIGURE 7**

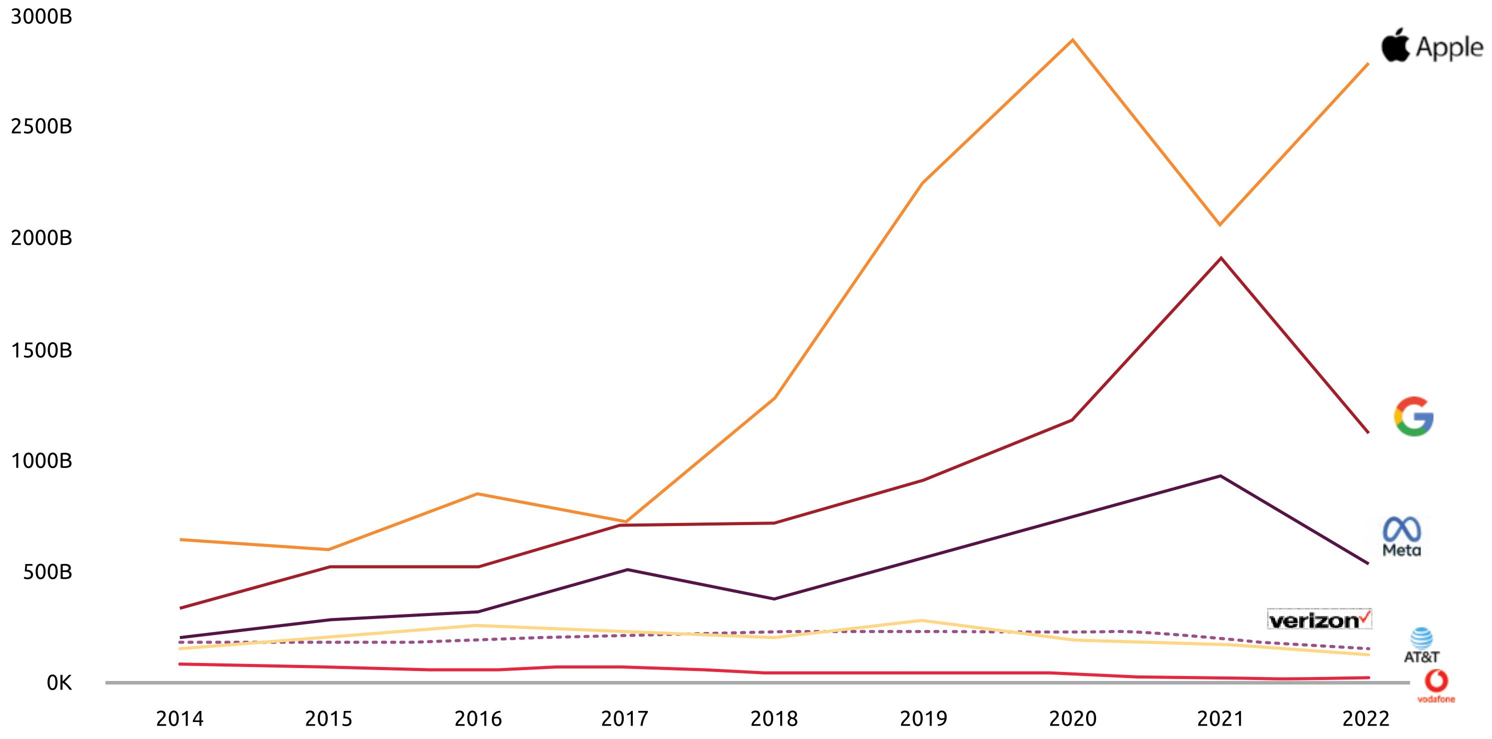
Energy products and services' response to today's customer challenges




Source: Arthur D. Little

**FIGURE 8**

End of year market capitalisation




Source: https://companiesmarketcap.com/

## What telco has done well (... and not so well)

- They have tried to expand into different domains. However, if you look at their revenue, the vast majority is still from core services – the new services have not been successful.
- Why is this the case? Their systems are set up to support a small number of products that have a long lead time – telcos typically take 18 months to bring a new product to market.

Telcos have undergone digital transformation, but the resulting systems support processes similar to the original services.

The transformation has not yielded the substantial efficiency savings that were promised, even though the technology has the capability to deliver them. The challenge lies in the lack of transformation within businesses. A key takeaway for the energy sector is the importance of prioritizing business transformation over technological advancements. Technology changes should only be considered when they align with the specific needs of the business processes.

## Similarities and differences

- Mobile virtual network operators (MVNOs) are the same as retail energy providers in that they do not own the infrastructure that provides the service.
- The telco industry leveraged technology to reduce costs and increase efficiency (including AI).
- The telco industry  is utilizing big data to enhance the customer experience (personalized services such as customized smart home solutions lead to increased customer satisfaction and loyalty).
- Telcos took advantage of service-as-a-platform to provide enhanced services.
- Telcos tapped into opportunities by identifying emerging technologies and trends. For example, they already use blockchain technology and AI.
- Telcos have transformed products and services by offering all-inclusive bundles – not just broadband or voice, but also media and other services.

## Conclusion

If energy retailers truly desire to transform their business away from providing energy, they need to explore what other services could be appropriate for the brand. They should determine whether they must create a new brand to support the new offerings, identify necessary business processes and cultural changes, and define the technology changes required to support these shifts.. Technology change is often mistakenly seen as the critical feature of transformation. Instead, it should be the business change that is the crucial feature that technology supports.

# CUSTOMER BIG BETS: WHAT ARE THE PAYOFFS?

VINNIE NAIR, AUSTRALIA

GAUTAM GANDHA, AUSTRALIA

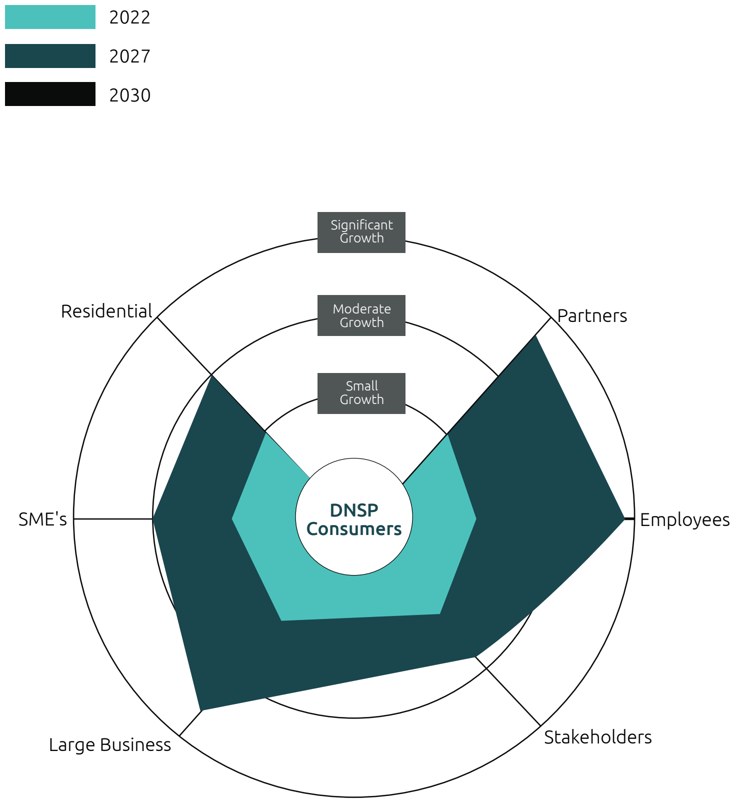
## Who are the customers?

**With the changing demands, compounded by market shifts and innovation, engagement with different groups will change in the lead-up to and beyond 2030. But before we dive into those changes, who are the customers we're talking about for a typical Distribution Network Service Provider (DNSP)?**

1. **Core Customers:** Core Customers include those who are the direct recipients of the electricity and energy a DNSP distributes and are the end users of the power grid services.
2. **Employees:** Employees of the DNSP that ensure the organisation effectively delivers its services, maintains and improves upon the grid, and provides value to customers.
3. **Partners:** Partners include individuals and groups who assist the DNSP to provide services and maintain the grid to ensure each partner can service their customers efficiently.
4. **Stakeholders:** Stakeholders, whilst not direct customers, have a direct interest in the organization, including, interest groups, board members, regulators, and others.

**FIGURE 1**

Indicative Rates of Customer Growth



## Where is the growth occurring?

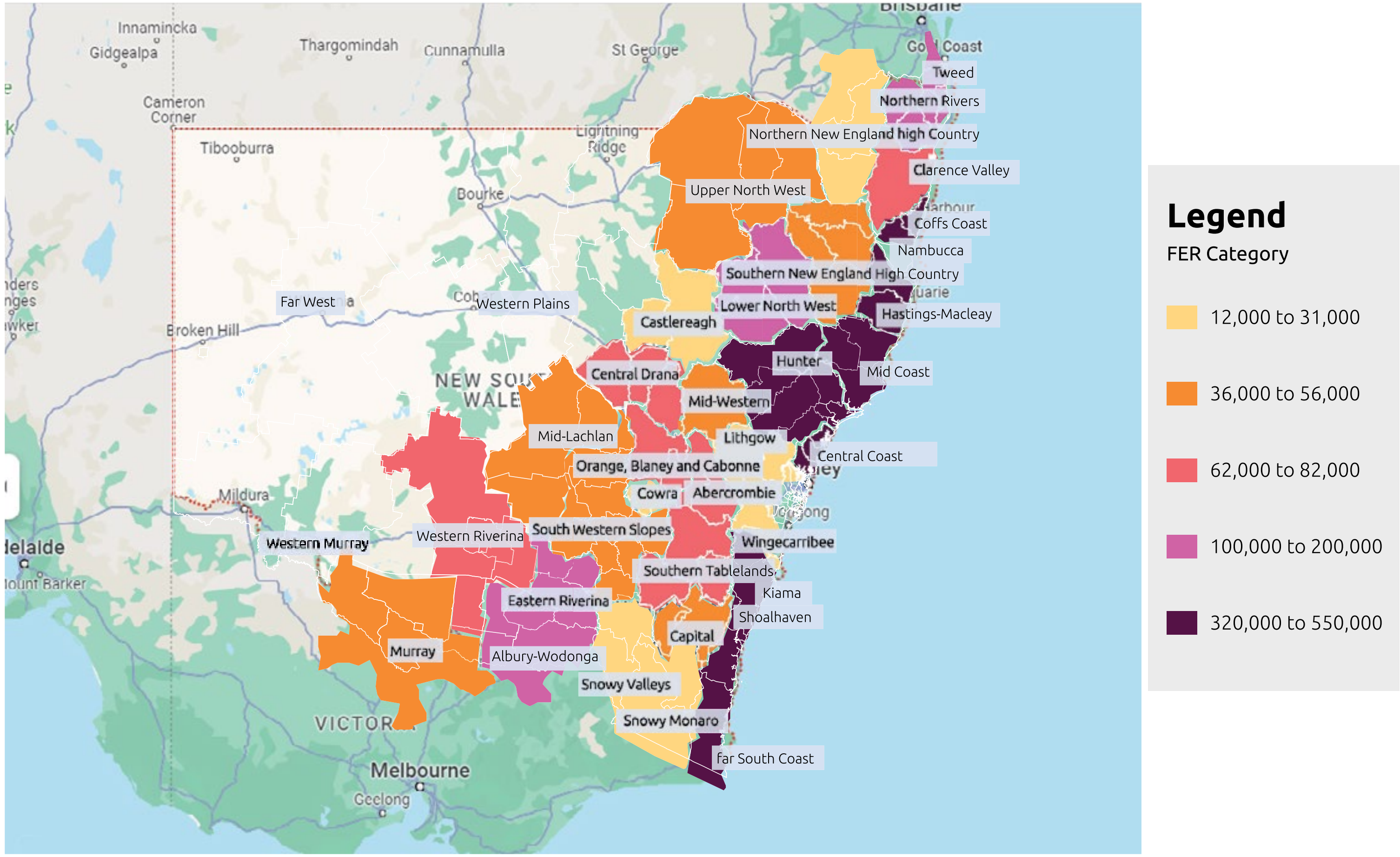
Interestingly, the numbers show that while businesses make up a much smaller percentage of the total customer pool, their impact on consumption and revenue is outsized. This will continue to gain strength over the coming decade.

## Renaissance in manufacturing?

We also predict there will be substantial growth not only in regional corridors around most states in Australia, but also a huge boom in the C&I sector due to a renaissance in the manufacturing sector. Above figure represents the projected population growth across all regions in the state of NSW.

**FIGURE 2**

Projected population 2038



## Revenue per customer segment type

Utilities therefore need to consider the full spectrum of their customer base, not just their residential customers who, in numbers, make up the bulk of their constituents.

Consumption by business will make up 65% of total energy consumed on the network, and NUOS (Network Use of System) revenue - the revenue derived from the tariff applied to energy delivery - will reach 54% of total revenue derived for DNSPs.

## The case for an increase in the regulated asset base over the next two decades?

The energy volume to be served by electricity distribution networks evolves and space as presented in the figure. Electrification of the building and transport sectors translates into higher annual electricity demand for all net-zero scenarios, as compared to the reference case, REF.

For the E+ Scenario, the volume of electricity delivered through the distribution network more than doubled between 2020 and 2050, from 230 to 482 TWh/year. This signifies an exponential growth in the RAB across most DNSPs.

**FIGURE 3**

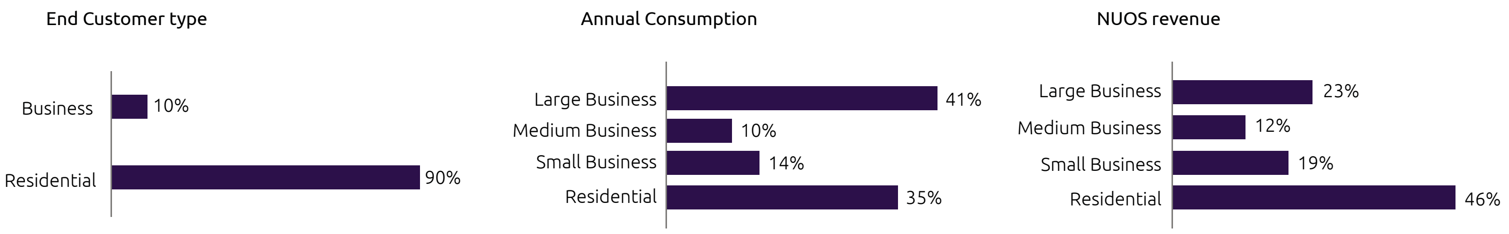



**FIGURE 4**

Time and space evolution of electricity demand to be served by electricity distribution networks.

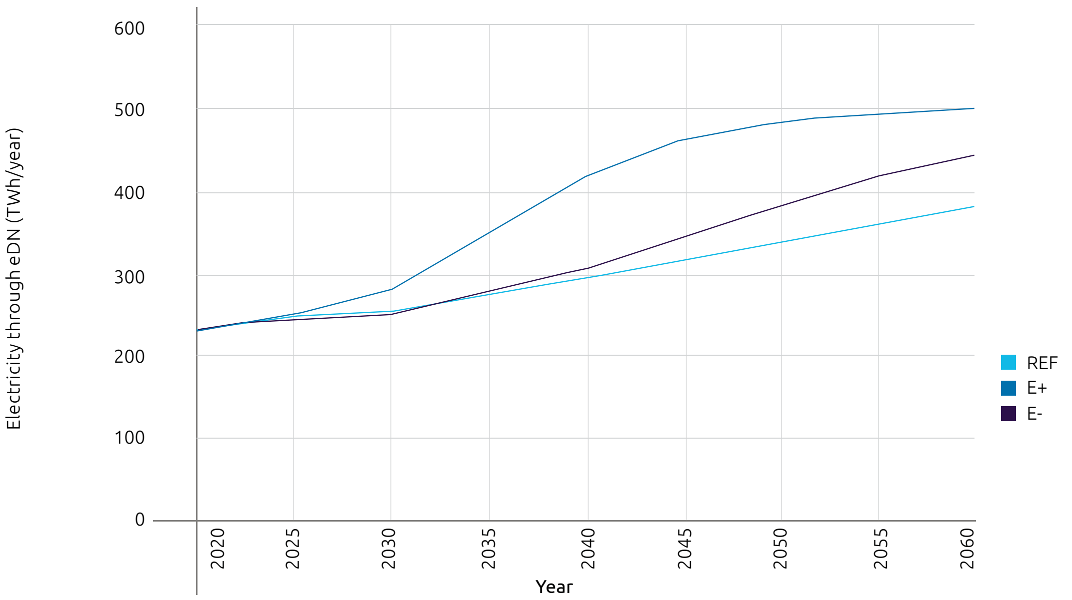
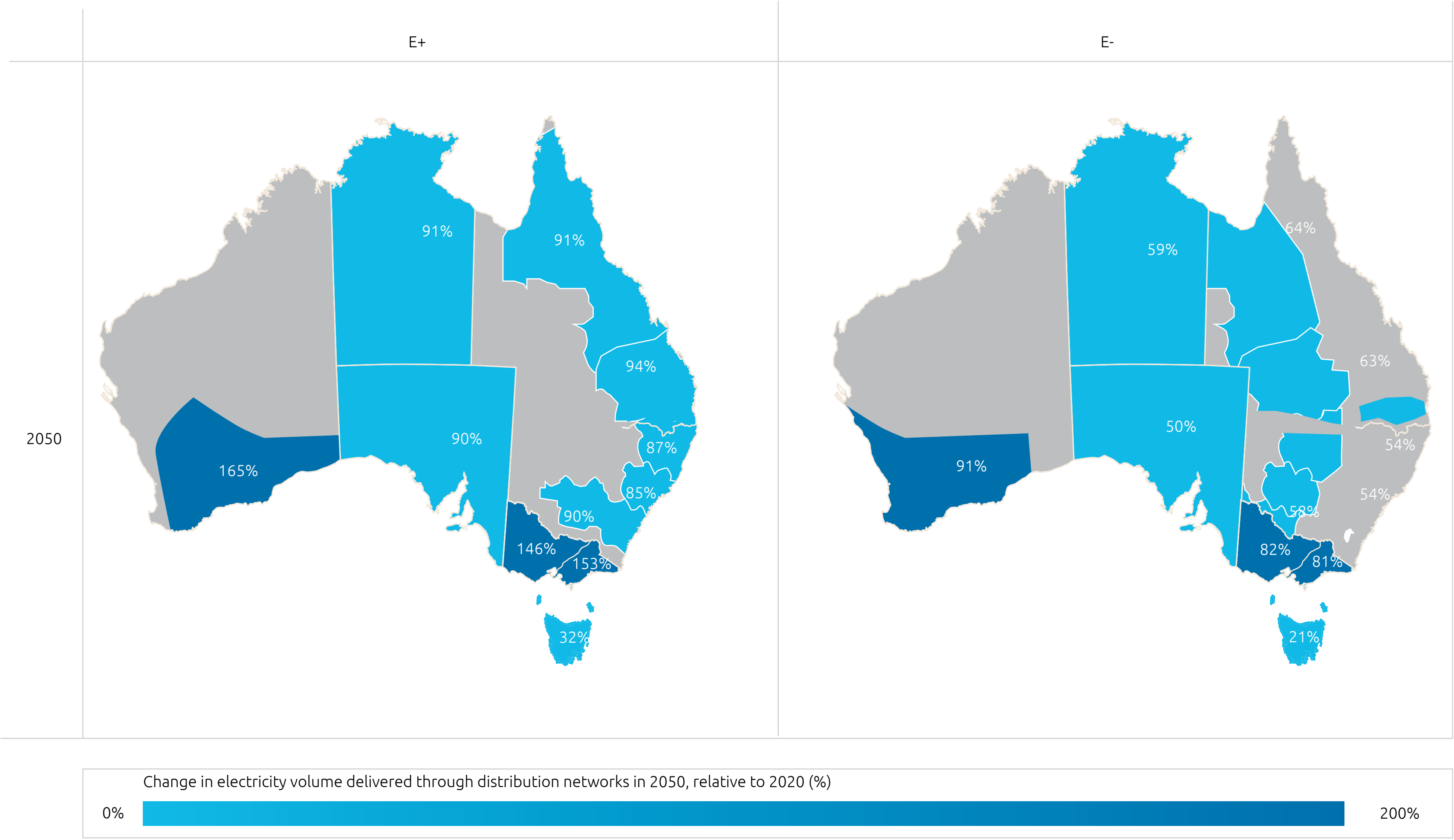


**FIGURE 5**

Change in electricity volume delivered through distribution networks in 2050, relative to 2020 (%)



## What investments do utilities intend to make to tackle this growth?

For any utility of the future, there are several investments they could potentially prioritise in the customer space . These investment areas represent "customer touchpoints" i.e., where the customer domain intersects other areas within the business.

**There are 4 key areas where due to rapid growth, we see consequent investment:**

1. **Connections:** There is a significant pipeline of major projects which will need to be connected to the grid, additionally the time taken to complete large DER connections can be up to 24-60 months. Given the expected backlog, and future importance of successfully connecting DERs to the grid, investment in tools, platforms and digitising the value chain is critical. This is now emerging as one of the key risks of energy transition not just in Australia but across the world.
2. **Call center Automation & Optimisation:** Digital tools and access to data have improved significantly, hence there is more scope for automating and optimizing call centers. Use cases can range from customer sentiment analysis, improved average handling time, and better workforce planning and sequencing. With the advent of generative AI and associated large language models there is merit in examining investment in conversational AI-like tools in a call center environment to increase efficiency gains.
3. **Omni channel:** With the growing number of customers needing to interact with utilities, introducing omnichannel capabilities will provide increased options for interaction. Given utilities need to interact with a multitude of customer types there is benefit in exploring one landing platform for all customer interactions.
4. **C- Data ,CRM and API:** Investing in customer data, a CRM platform and APIs to draw data from separate sources will enable utilities to better segment their customers, hence enabling a single voice of the customer from a platform perspective. For example, a query run to look up the list of life support customers will yield different results each time due to the disparate nature of systems. The cost of regulatory burden is exponentially increasing, and it is imperative that utilities employ innovative methods to manage their ever-demanding customer base.

**FIGURE 6**

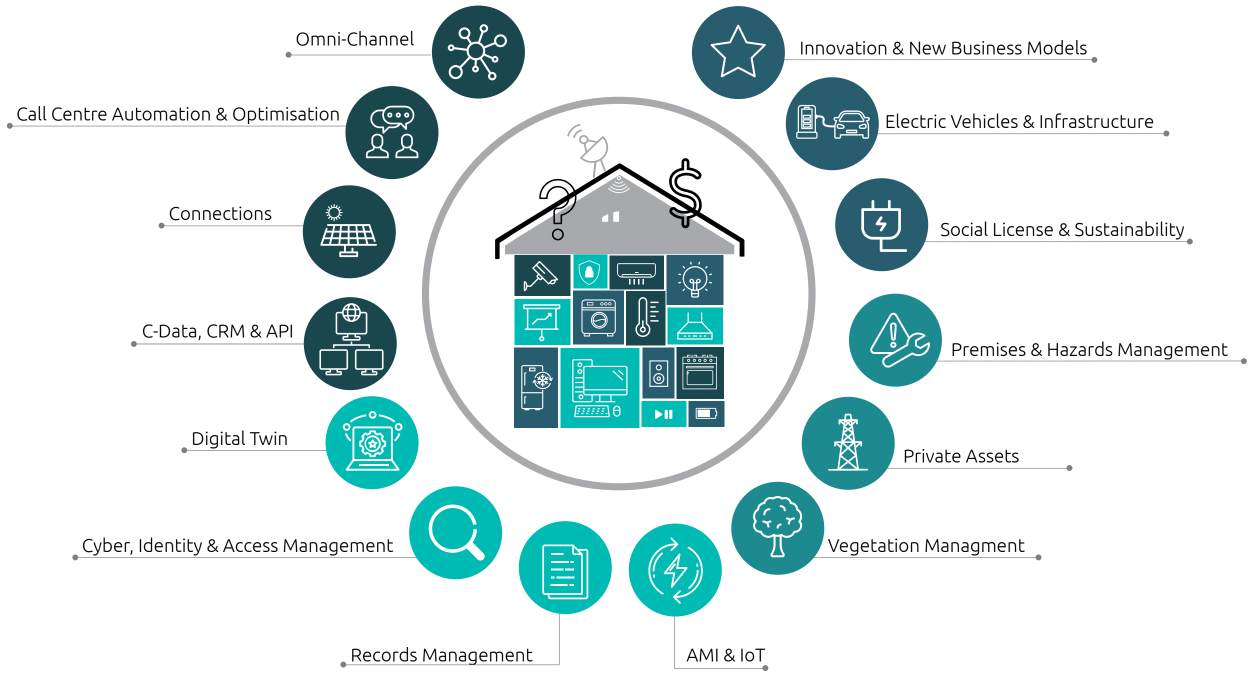
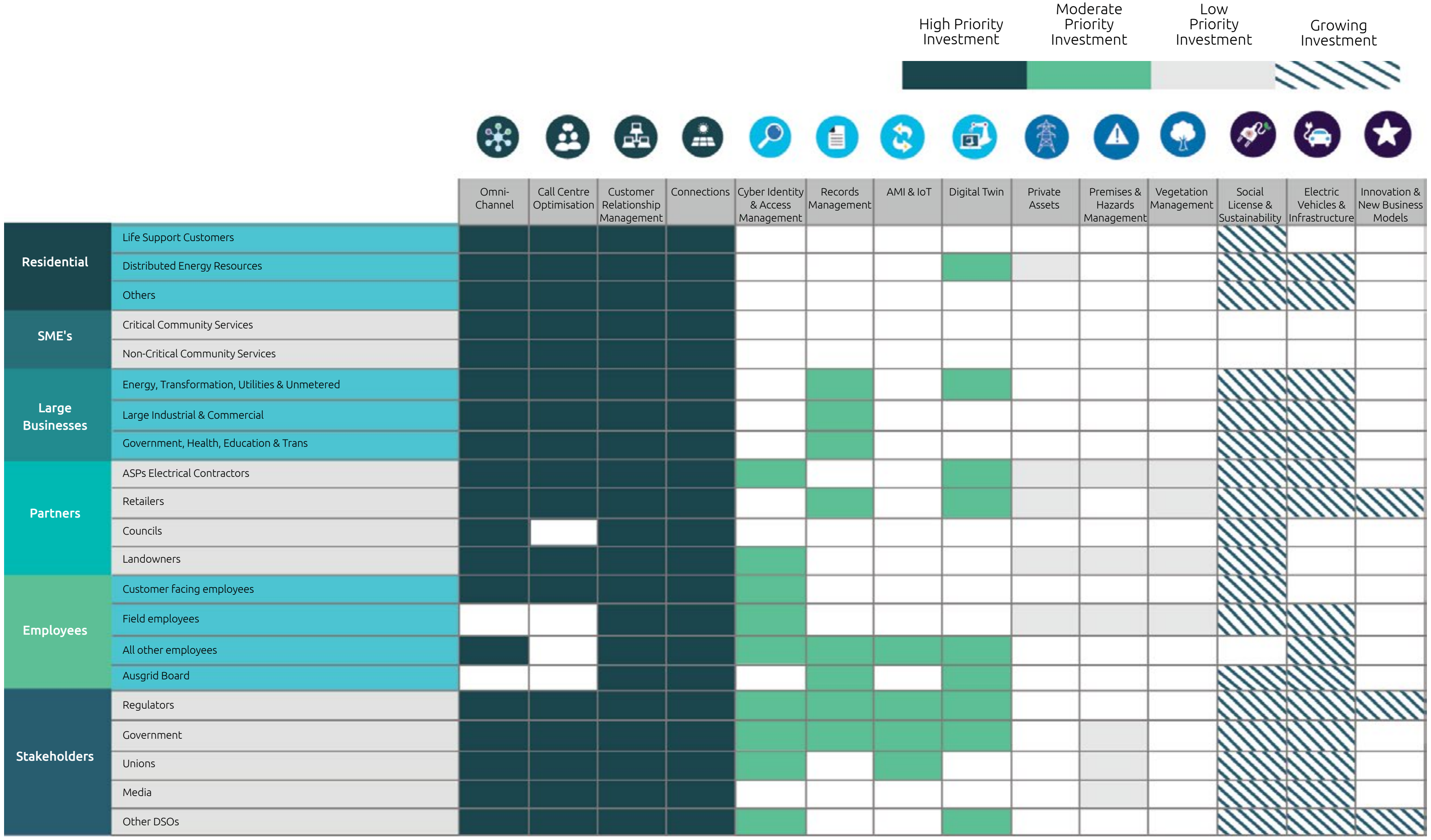


**FIGURE 7**


High Priority Investment
Moderate Priority Investment
Low Priority Investment
Growing Investment
Omni-Channel
Call Centre Optimisation
Customer Relationship Management
Connections
Cyber Identity & Access Management
Records Management
AMI & IoT
Digital Twin
Private Assets
Premises & Hazards Management
Vegetation Management
Social License & Sustainability
Electric Vehicles & Infrastructure
Innovation & New Business Models
Residential
Life Support Customers
Distributed Energy Resources
Others
SME's
Critical Community Services
Non-Critical Community Services
Large Businesses
Energy, Transformation, Utilities & Unmetered
Large Industrial & Commercial
Government, Health, Education & Trans
Partners
ASPs Electrical Contractors
Retailers
Councils
Landowners
Employees
Customer facing employees
Field employees
All other employees
Ausgrid Board
Stakeholders
Regulators
Government
Unions
Media
Other DSOs

# Deep dive on investments & their priority to utilities

| | OMNI-CHANNEL | CALL CENTER AUTOMATION & OPTIMIZATION | CONNECTIONS | C-DATA, CRM & API |
|---|---|---|---|---|
| DESCRIPTION | • The uplift and consolidation of multiple channels (website, call center, email, etc.) through process automation, customer sentiment analytics, self-serve, customer-centric language and post-interaction surveys to enable customers and partners to utilize a single source of truth for their needs whilst iteratively improving and streamlining the overall experience. | • Uplifting, optimizing, and automating processes and technology to improve the call center experience before, during, and after call center interactions along with improved workforce management, modernized training, accurate forecasting, scheduling, and workload management. Enabling call center staff to ensure customer satisfaction with minor manual effort. | • Prioritizing improvement to the end-to-end connections process through automation, manual effort removal, safety risk reduction, digitized forms, efficiency management and reduction of cycle times to improve the customer experience and move customers forward. | • The consolidation of direct and related customer data in a singular digital platform used to manage customer and stakeholder relationships, interactions, data and requests. Enabling a CRM system with an API infrastructure to create a single view of customers and bring together the necessary data with a clear understanding of the customer journey. |
| TRENDS | • Deploying chatbots and other automated services to provide 24/7 support available for customers and facilitate faster response times.<br>• Enabling automatic payment options and receipt generation. | • Machine learning to develop consistent, programmable answers to FAQs, freeing employees to focus on more high-value queries.<br>• Operationalising real-time data analytics to send context-appropriate auto-recommendations and notifications to customers. | • Many Australian distributors are prioritizing improving their connections process due to renewables, EVs, and 2-way energy.<br>• Utilizing new technology to optimize and automate parts of the connection processes to increase the speed of connections setup and operational safety. | • Connecting the CRM to different systems using APIs within a strategic API architecture means getting access to the right data via automation with reduced manual handling<br>• Proactive notifications and service requests |
| EXAMPLES | • The Australian Gas Light Company (AGL) is using full Khoros Platform (digital customer engagement platform) to plan content on social media, respond to customer concerns, and deflect volume from their contact center. **AGL responds to 72% of inquiries within an hour and has a calculated ROI of over $1 million in just one year of partnership with Khoros.** | • Origin Energy has deployed Amazon Connect, a cloud-based contact center platform that will provide smart interactive voice response (IVR) capabilities for the company.<br>• Origin, in partnership with UK's Octopus Energy developed Retail X in 2020 for the rollout of Octopus' cloud-based platform 'Kraken' across Origin's retail business to improve the customer experience. **The company in February 2022 said, the Kraken platform saved $70m to $80m.** | • In February 2022, Evie Networks selected Sitetracker for rapid push towards Nationwide EV charging network. Sitetracker will provide Evie Networks with a cloud foundation for their rapidly scaling business, managing their increasing **volume of sites and ultrafast chargers with intelligent project templates, access to real-time data from the field, and financial data and asset management in a single platform.** | • In June 2023, AGL switched its **CRM platform to Salesforce** as they intend on improving CRM interface and the user experience for the frontline staff. Further AGL is implementing Appian for low-code process automation as part of the same retail transformation effort. |

# COMMODITY TO SERVICES – HOW THE MARKET CHANGES ARE POINTING TO A VERY DIFFERENT PLAYBOOKS FOR UTILITIES.


HARI KRISNAMURTHY, USA


DRAKE RYANS, USA


ALEXANDER HOWARD, USA

## What role are you going to play?

**As the utilities industry confronts the necessity to move toward a net zero future, the law of conservation – that energy can neither be created nor destroyed – becomes even more relevant. In the context of the electricity market, the forces of decarbonization, decentralization, and digitalization, are analogous to energy forces. Then, the question in the U.S. market is: How long do market leaders have to respond to these forces? As we recognize that these market pressures will not disappear.**

While U.S. utilities have been navigating deregulation for over two decades, it has primarily affected the demand side of the value chain. So, vertically integrated utilities have been insulated as owning transmission and distribution lines protects their market position. Compared to the rest of the world, the rhythm of the U.S. market is different for this reason. However, the energy transition could create a dynamic where these leaders cannot lean on their infrastructure as a form of protection.

Decarbonization has introduced a new market segment in the utility space where status quo advantages might not prevail. It is creating a new rhythm in the U.S. utilities market: new services, a new class of players, and a different class of investors. Technology companies with battle-tested engagement models, leveraging ioT infrastructure to enter the space, are working to position themselves as a layer in between customers and their electricity providers.

Automotive companies can also not be ignored. More specifically, electric vehicle manufacturers as they have the potential to accelerate energy disintermediation. In a not-too-far-away future, electric vehicle owners will be less dependent on their utility company as the singular source of electricity. Venture capital firms are also entering the utility industry, via energy management startups – ready to capture the deregulated, energy services market segment. The barriers to market entry have been lowered by energy management and electrification.

There will also be competitors that market leaders could not have predicted. Just look at what happened in Sweden, where IKEA sells renewable energy directly to consumers. But as we previously mentioned, the U.S. market is different from the rest of the world, so the change will not be as severe, and competition will not come from as unlikely places. Still, change is inevitable. In the next era of the utilities industry, market leadership will be defined by adaptability. While there will always be a role for a Utility to play, what is will be determined by how they respond to market changes.

## Market value follows the technology.

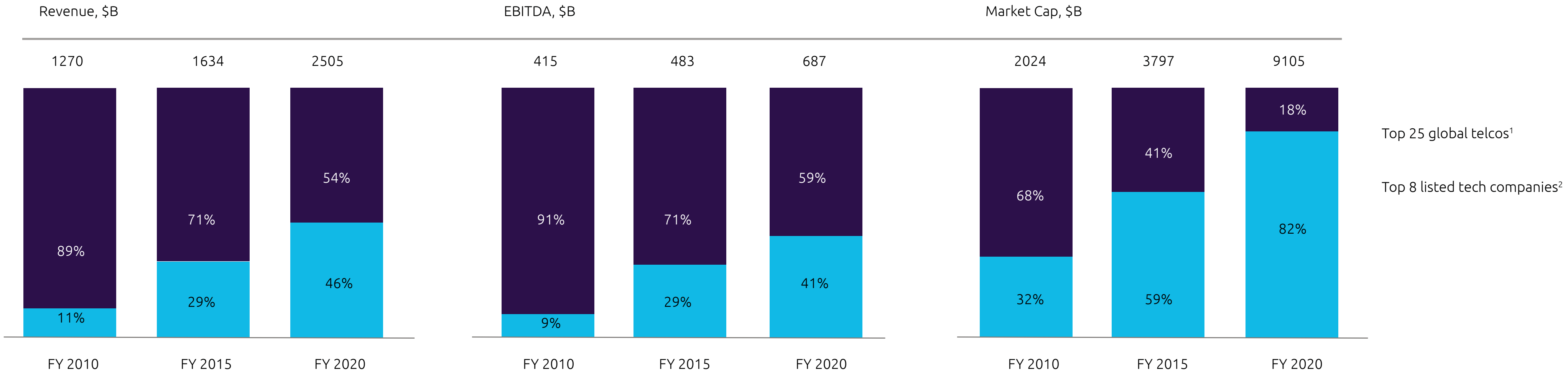
Leading utilities must acknowledge the transformative power of technological advancement. And the utilities market could learn from the recent experience of legacy telecommunication providers, where the proliferation of new services and applications upended market dynamics.

Despite relying on telecommunications infrastructure, companies like Apple, Google, and Facebook– technology companies focused on products and services that connect with consumers emotionally and improve their lifestyles – have emerged as market leaders over the last decade.

### On several measures, the growing performance gap between telco and big tech companies is stark

In the utility industry, with distributed energy resources and AMI bi-directional communication, new firms could emerge as leaders by using existing utility infrastructure to generate enormous value and opportunities.

**FIGURE 1**



## Shareholders, regulators, and moving toward the future.

Historically, utilities have succeeded by playing it "safe." Unlike, other industries, where companies flourish by innovating to meet the needs of their customers. In fact, investors expect utilities to exhibit signs that resemble bonds more so than a technology company

It's not just conservatism that's at odds with technology-driven business model innovation, it's the profit structure of the traditional business model. Rather than adapt to a changing landscape and innovate on behalf of consumers, investor-owned utilities are required to maximize shareholder value through infrastructure investments. Under cost-of-service regulation, utilities are expected to stay the course and introduce improvements via centralized capital expenditures instead of developing a technology ecosystem that could better meet the needs of customers.

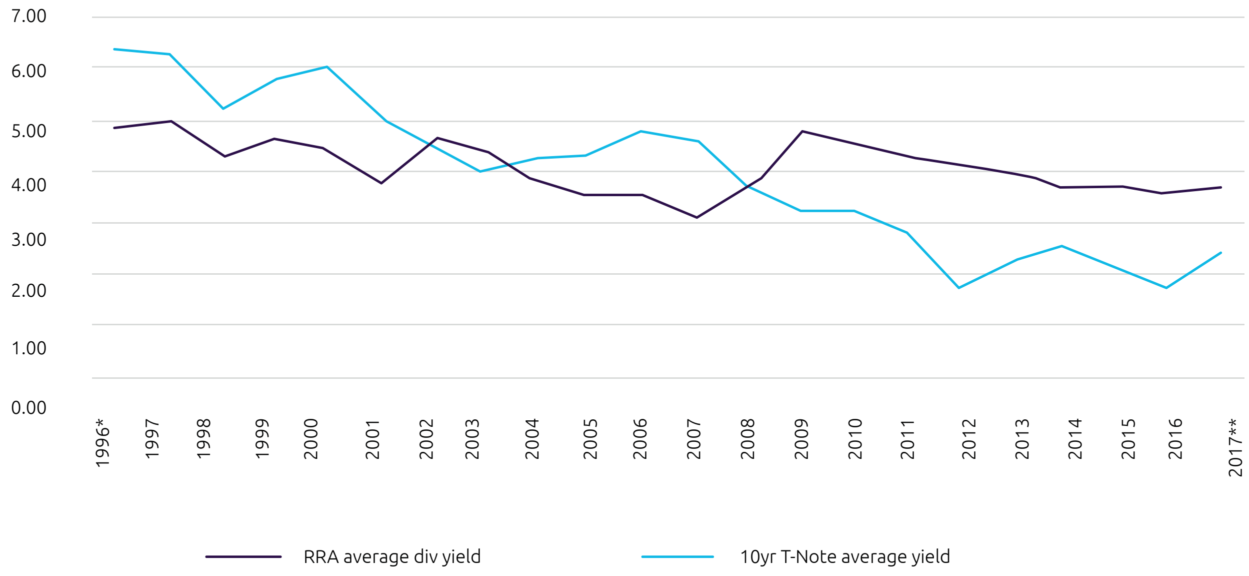
Despite the concentrated market power of investors, services and applications are still on course to transform the utilities industry. Because this market disruption exists beyond the control of shareholders, a different governing force is evolving to accommodate this structural change: regulation.

Policy changes are unfolding alongside these technical developments. Overall, changes in technology and policy operate symbiotically, with grid advances driving changes in policy, and the grid evolving with new policies.2 What we're witnessing today with the growing adoption of renewable resources, DERs, and grid modernization technologies is the interconnectedness between technology and policy.

While policy intervention could enable market changes that help advance socially beneficial innovation for investor-owned electric companies, they could also create an environment for utilities to adopt a new playbook.

**FIGURE 2**

Average Utility Dividend Yield vs 10-year Treasury Yield 1996 - 2017




Source: SNL Energy, an offering of S&P Global Market Intelligence

# Transportation electrification accelerating industry transformation

A new dimension is being ushered into the utility sector due to the electrification of transportation and the growing adoption of electric vehicles (EV): services that create a multibillion-dollar opportunity for individual utilities and third-party companies. If utilities don't evolve their service model, they could cede the opportunities created by EVs not only to energy-as-a-service startups but also to the technology industry and car makers.

## The Tipping point

By 2030, EVs are projected to represent 53% of the transportation market3, and the scale of impact will be unprecedented. The electrification of transportation provides consumers with flexibility and monetization opportunities to become prosumers and redefine their relationship with electricity providers and the grid. This paradigm shift will accelerate the industry's transition to a consumer-centric model, meaning consumers will start having a different relationship with their traditional electricity providers.4

*"Utilities will eventually not be so much control anymore as they used to be in the past."*

## Time to Change

The commercialization of new services means traditional investors and utilities cannot rely on the predictability and comfort that comes from their current positioning. As these changes develop, this deregulated segment of the utilities industry could reflect the governance seen in other industries, where customer expectations are the guiding force. While the timeline of technology maturation and regulatory changes is uncertain, what is clear is that the electricity sector is overdue for transformation, and maintaining market leadership will require customer-driven service model evolution.

Technology-driven transformation also attracts the venture capital ecosystem. Early-stage venture capital investments in startups developing solutions for distributed energy resources (DER) and grid management have more than doubled since 2015.2 In contrast to traditional utilities, these software-based organizations operate have digital business models, and this provides them a strategic advantage when it comes to designing intuitive and desirable experiences for end-customers.

## Finding a north star in shifting market dynamics

In this changing environment, there will be constants and optionality, the constant being that utilities must change fundamentally, the optionality being that there are many viable paths forward.

### Ecosystem services

Octopus Energy, one of the fastest-growing companies in Europe, evidences the power of pairing a customer-centric software-enabled business model with clean energy products and services.

To support electric vehicle owners, Octopus Energy partnered with leading automakers to create Intelligent Octopus. This service helps consumers optimize their charging time and save money on energy bills. By building an ecosystem of products and services on the foundation of its software model, Octopus Energy has gained an 18% share of the U.K retail energy market.3

### Strategic partnerships

Green Mountain Power has taken the partnership approach to developing cutting-edge DER services for its customers. Its collaboration with Tesla should serve as an example of the potential of cross-sector partnerships.

Green Mountain Power allows its customers to acquire a Tesla Powerwall through the utility's power-sharing program, and in 2021, this program saved the utility over 3 million dollars. When taking into consideration, the size of Green Mountain Energy's customer base, 270,000 residents, it's an impressive result.

### Innovation from within

Duke Energy and National Grid, represent two examples of efforts made by traditional utilities to pursue customer-centric innovation and industry disruption, from within, albeit with different risk profiles.

Duke Energy's Lighthouse, a digital transformation program, accelerates innovative solutions across the enterprise and challenges the status quo with smart solutions for customers. National Grid's National Grid Partners is its corporate venture and innovation arm, and today it is the only VC with a global network of over 100 utilities. The way it got there was by building a portfolio of startups that focus on the end-customer of utilities.

### Utilities as a platform

The platform model approach could be the revolutionary opportunity that enables utilities to pioneering cutting-edge service offerings. In the context of the utility industry, the concept of a platform business model should be interpreted as defining new methods for how market participants meet and exchange value; one key implication of this model is that business success is not completely dependent on the traditional economies of scale utilities have relied on in the past. Still, they can achieve a different form of scale by playing the role of the orchestrator: connecting various stakeholders and third parties to deliver a compelling energy management value proposition.

Utilities in vertically integrated markets are exploring the concept, and the distributed system platforms proposed under New York's Energy Vision provide one of the most visionary examples.

New York's Reforming the Energy Vision initiative is catalyzing a shift away from the traditional utility model to innovative business models compatible with a more distributed energy future. A core tenet of this effort is to focus on market-based solutions as they enable utilities to diversify their revenues and become less dependent on the rate base for profitability. What this program and other similar initiatives are trying to overcome is the underlying reasons why utilities don't pursue innovation.

What differentiates this approach is that utilities could establish new revenue streams through the value they help each ecosystem player generate for end customers.

## Are market changes pointing to a different set of playbooks for utilities?

Over the next ten years, the nature of the utility sector will continue to evolve as new dynamics will introduce competition across the utility value chain and spur more demand for services.

Several types of industry leaders are poised to deliver these key services: innovators at scale, integrated electrification companies, and digital utilities. We can briefly examine three companies that embody each persona.

### Innovation at Scale

NextEra Energy is positioned for continued success in the utility industry. The company's advanced software system and energy storage solutions not only improve the reliability of its operation but have also made it possible for the company to deliver outstanding customer value and shareholder returns. Services that create that value include allow their customers to integrate DERS into their infrastructure, while also allowing their customers to engage with a wide variety of renewable generation sources. NextEra's services align with the environment, customers, and shareholders, creating a powerful combination for value creation. It also is evidence that just the electricity commodity is no longer enough. As the industry-leading company, their willingness to push the needle and pursue renewable service innovation has resulted in a 17.4% 10-year Avg. Annualized Return.1.

### Integrated Electrification

Tesla is leveraging battery storage, generation assets, software, and complementary energy management services to build a vertically integrated electrification company that gives customers unprecedented transparency to their own generation and energy consumption. As the world's only major integrated energy storage provider, Tesla's vast software offering integrates with its hardware to deliver a seamless experience for its customers across variety of services including energy storage solutions, virtual power plants, and smart grid integration. Tesla's rise also evidences the role virtual power plants will play in the future as the company is building a compelling retail energy services business without massive infrastructure investment. According to Elon Musk, his vision is for Tesla Energy to become a distributed global utility that could outgrow the company's automotive business.2

### The Digital Utility

TOctopus Energy owes a great deal of its success and meteoric growth to its proprietary Kraken Software System. In 2022, the Kraken Software platform expanded to become Kraken Utilities, the first all-service dedicated technology platform for the utility industry. This model enables the company to innovate rapidly, integrate with third parties to expand its service value proposition, and provide a consumer-centric electricity experience that is transparent and continuously improving. While still in its first year since inception, experts believe that a digital utility could one day be valued at more than $200 billion and deliver top-quartile reliability and customer experience while keeping customer rates among the lowest in the industry. 4

### Conclusion:

The utility industry's future will be defined by players who adapt their operating models and adopt playbooks that chart a path beyond pure commodity, toward a suite of services. As a result, they will remain strategic partners to their customers as their needs and expectations evolve. Shareholder returns and market value will follow technology, which continue to be even more interconnected with policy and customers. So, services are the future of the utility relationship between consumers and electricity providers; the companies that will succeed and emerge as market leaders amidst the energy transition will be the ones that provide them.

# 03

# ENERGY FLOWS

# CAN WE MAKE THE SHIFT?

**PETER KING**
Global Head of Energy
Capgemini Invent

**MARISSA PAPAS**
Director, Energy
Transition and Utilities

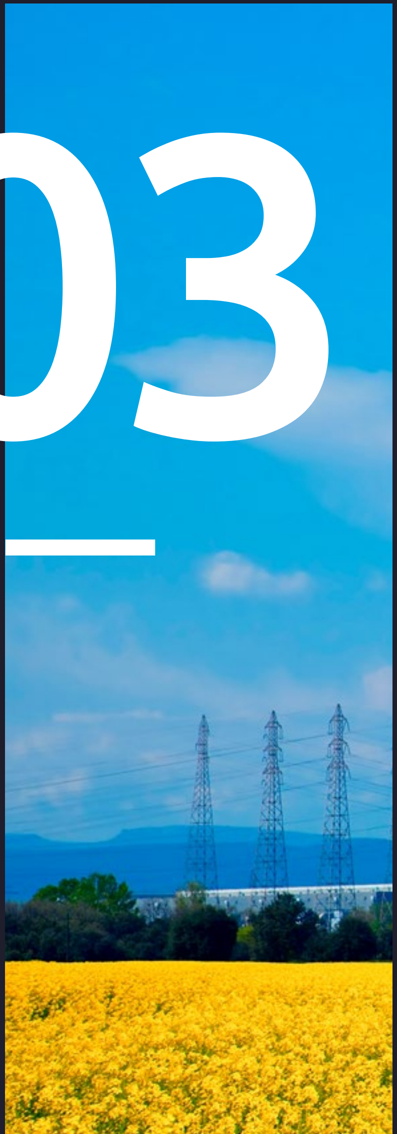
In this chapter we explore how fundamental changes to the way that energy is produced and used will be needed to hit Net Zero targets. With energy production and use as the primary cause of $CO_2$ emissions, this is the first place that the world looks for decarbonisation.

I chose to focus on the flow of energy as I feel this is fundamental to our understanding of the operation of the energy system. Using the flow concept we can better understand how the whole system is interconnected. How gas becomes electricity for lighting, how oil becomes petrol for cars to move people, and how trees in Canada become biomass in a power station in the north of England.

Across these articles we cover topics as diverse as energy can be – how the various technologies will play a role and how we can overcome the challenges of decarbonisation.

This chapter includes:

1. A huge shift in how energy flows - an overview of the challenge
2. Energy transition in oil and gas companies
3. Renewable tech at scale
4. Nuclear tech
5. Electric vehicles
6. Gigafactories supporting the energy transition
7. Future reform of electricity connections (UK)
8. LCOE comparison
9. Energy networks are the pace setters for net zero



# 03

# A HUGE SHIFT IN HOW ENERGY FLOWS

PETER KING, UK

## A daunting task

**Huge changes to the way that energy flows through our systems are needed to achieve Net Zero. We need to shift from roughly 75% of energy coming from fossil fuels to close to zero.**

The task is daunting. Every year we consume 35 billion barrels of oil, 4 trillion cubic metres of natural gas, and 8 billion tonnes of coal. These are more than sources of energy; they are woven into the fabric of our ways of living and our economies. If we switch them off the consequences won't just be the lights going out or queues at petrol stations, economies will collapse, supply chains will fail, food will run out. I read that 50% of the protein in our bodies comes from one of the chemical plants where the Haber-Bosch process fixes Hydrogen and Nitrogen to make fertilizer – dependent on fossil fuels.

We have only just started on this generation long change. It's easy to hear that renewables provided 100% of the power required and think that we have made progress, without realising that electricity is just a small percentage of the energy that we use, and that despite the renewables peaks the vast majority of worldwide electricity is still generated from fossil fuels.

This will require electrification of almost every aspect of our daily lives, and for a few hard to electrify processes deeper technology solutions will be needed. We will need electricity grids that are many times larger than today's, they will need to be smarter, easier to connect to, and will have moved away from centrally driven systems to energy meshes.

## Energy Technologies are key. We know which we need – the big 5 of the transition are:

**Technology #1:** Wind onshore wind is one of the cheapest sources of electricity, whereas offshore can help overcome residents' fears. In development wind requires a complex supply chain, in operation it needs careful planning to manage the intermittent nature of the weather.

**Technology #2:** Solar according to the International Energy Agency PV is the cheapest form of electricity generation with hydro. There are huge parts of the world that combine consistent daily sunshine with large areas of unused land. The supply chain for solar panels has become concentrated in China and this needs to be addressed. But solar in shining only during the daylight…

**Technology #3:** Nuclear hugely complex, expensive, and sometimes dangerous, but today this is the only low-carbon always available at scale option. Decarbonising a major industrial economy does not look possible without using nuclear. New reactor designs offer greater opportunities for decarbonising hard to abate industries like steel and mining.

**Technology #4:** Batteries whilst they are expensive, and the economic case is not always easy to make, it is hard to envision a future highly complex energy system without significant amounts of energy storage. Just as petrol tanks will be replaced by EV batteries, oil bunkers will need to be replaced by Gigawatt scale batteries.

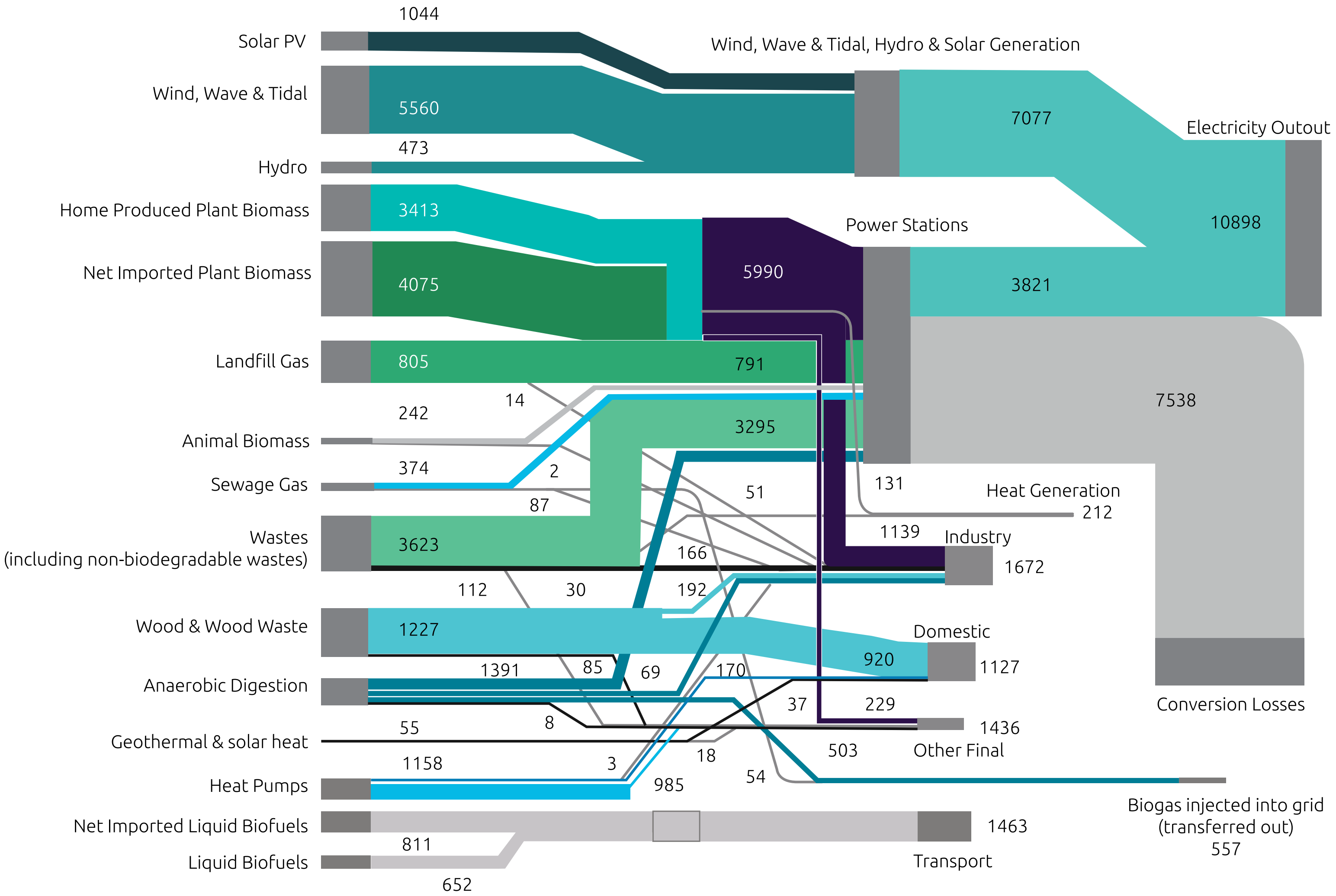
**Technology #5:** Hydrogen whilst the case for widespread use of Hydrogen is far from clear, there are enough potential roles to make it a major character in our decarbonisation story. Green steel, fertilizer and ammonia, shipping, long distance haulage, are some initial cases. Unfortunately, progress with Hydrogen trials for domestic heating have not gone well which leaves its future in this space in doubt.

## To put scale to this challenge, a set of rough calculations shows:

- We will need 3 million wind turbines to be installed by 2030– compared to 340 thousand today, which is a 9 times increase in capacity 6 years.
- The areas of land needed for solar are vast – the solar equivalent of a EPR2 station producing 3.2GW would require approximately 17 square kilometres of panels. For comparison a large city like Paris covers 40 square kilometres. 2050 estimates of requirements approach the area of the earth currently covered by roads.
- Between 800 and 1,200 nuclear power plants – compared to 440 today. With almost all current plants needing to be decommissioned in the period to 2050 means building 25 – 40 new plants every year.
- Battery capacity requirements are hard to estimate, adding up the battery needs for grids, vehicles, industrial plants, and businesses results in a vast number. Capacity for all energy use for 2 days of world energy use would be around 900 GWH – which is many years' worth of current battery production capacity.
- The required increases in Hydrogen production are so large that comparison with current production levels is almost meaningless. A whole new industry will need to be built.

**FIGURE 1**

Renewable energy flow chart 2021

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# ARE OIL AND GAS COMPANIES TRULY COMMITTED TO THE ENERGY TRANSITION?

ALEJANDRO BENGUIGUI, UK

## Energy Transition in oil and gas companies

**As the world seeks to combat climate change and reduce GHG emissions, the choices made by O&G companies today will be critical to shape the energy landscape and society for generations to come. Disparity among O&G players means decisions are not consistent across the sector, but the energy transition is gaining momentum. Some players have started major overhauls of their businesses, betting heavily on a transition to less carbon intensive revenue streams. Renewables, lead by wind and solar, remain key alternatives to move away from fossil fuels, but new choices may yet disrupt the O&G industry in the longer term.**

A report receiving a considerable amount of attention in 2017 (Carbon Majors Report, CDP), found that around 71% of worldwide GHG emissions between 1988 and 2015 could be traced back to 100 fossil fuel companies – that is considering Scope 1 & 3 – and more strikingly still, only 25 were at the root of half emissions. Although shocking, particularly to the public, instead of proving O&G companies are exclusively to blame for climate change, two key insights are truly at the heart of these figures. First, society at large has a high demand for energy which has, so far, mainly been met in an economically and technically viable way through fossil fuels. Second, the energy industry is marked by the fact that, at its core, it is dominated by giant players. These include state-owned National Oil Companies (NOCs), private and public investor-owned International Oil Companies (IOCs) and Independents, mainly focused on upstream Exploration and Production (E&P).

It is therefore key to the struggle against climate change and the reduction of global GHG emissions that these key players lead the energy transition. The size of these companies and resources at their disposal, consolidated by record profits in 2022, together with first-hand influence on how energy is supplied to society, put them in a perfect position to act and have meaningful impact on the short and long term.

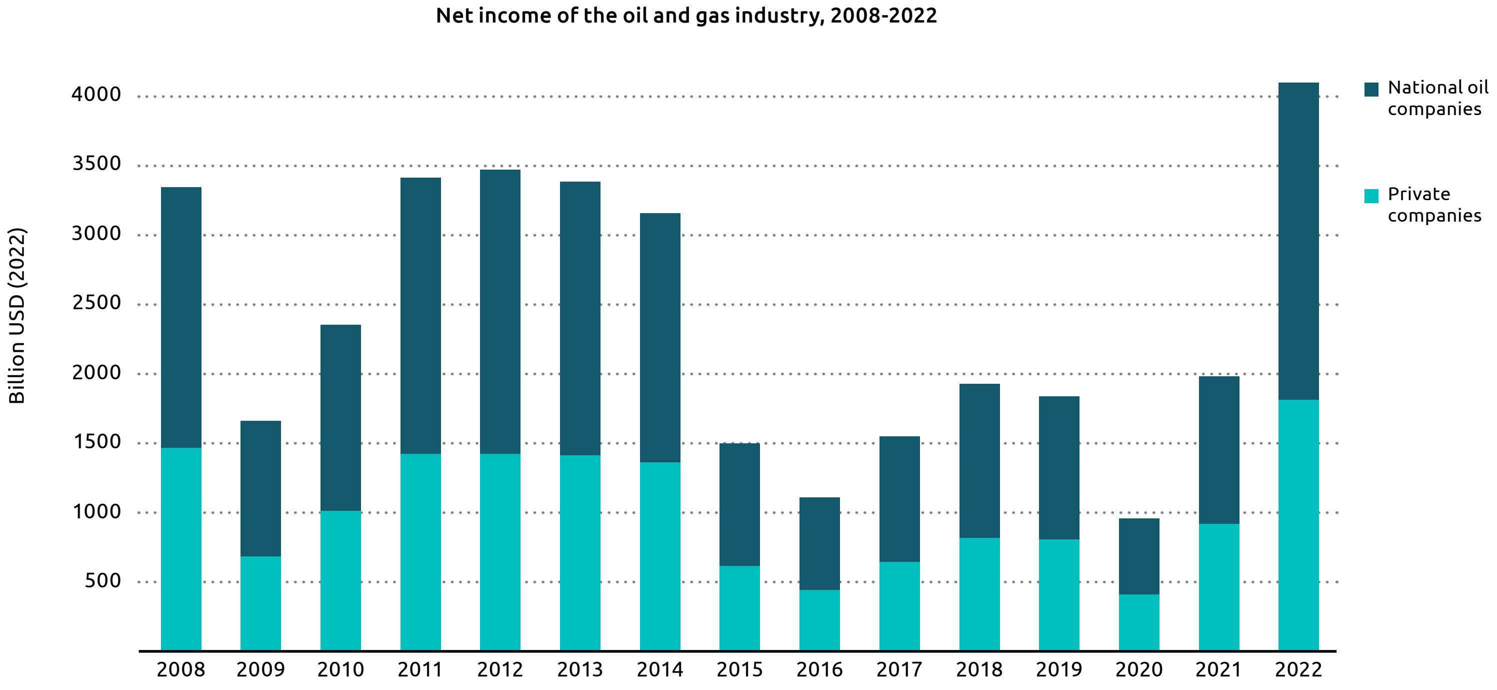
In recent decades, over 70% GHG emissions could be traced back to 100 companies

However, their interest and understanding on the best way forward to move away from hydrocarbons is different for each company, given their distinct origins, business models, shareholders' interests and government policies from the countries in which they operate. As of now, governments and policy-makers have, with mixed results, increasingly put together incentives, penalties, and investment in infrastructure to support the transition to alternative clean solutions (renewables, electrification, biofuels…). Public opinion is increasingly shifting towards sustainability and acknowledging the effort required to ensure a liveable tomorrow for future generations, particularly in Western societies. The general public widely considers fossil fuel companies to lag behind and be more of a hindrance than a catalyst for change. Albeit intentions, Net Zero targets, and actions are not uniform across the sector, such companies are all connected by the same truth: it is essential that all O&G players accelerate and deepen their commitments to reduce GHG emissions for the energy transition to occur and succeed in time.

Despite the ambition to reduce reliance on hydrocarbons, demand for oil and gas remains strong. Post pandemic economic recovery and geopolitical instability – particularly the war in Ukraine – have led to rising prices in 2021 and especially in 2022. In stark contrast to a difficult 2020, businesses have been exceptionally profitable in 2022, offering an appealing incentive to remain focused on fossil fuels. IEA data shows net income from the O&G industry soared last year, doubling 2021's results and reaching up to US$ 4,000 billion, a historic figure, with NOCs accounting for more than half of the sector's earnings. However, windfall profits also present companies with an opportunity to shift capital investment towards more sustainable and future-proof businesses. Yet from a global perspective, low-carbon capital expenditure still represents a minimal part of O&G profits reinvested. Although it has seen significant growth in 2021 and 2022, clean energy investment remains 1% of cash spending after two years of record income. Alternatively, these companies have seized the opportunity to pay down net debt and Globally, 2022 O&G's record profits have not translated into a meaningful increase in appetite for low-carbon investment noticeably increase dividends to shareholders. Still, only a fraction of these companies' capital investment can have a profound impact on the development of low-carbon technologies. In this context, investment portfolios underline their short and medium-term vision, as well as the role they expect to take in the energy transition.

**FIGURE 1**

Net income of the global oil and has industry reached a record high of USD 4 trillion in 2022

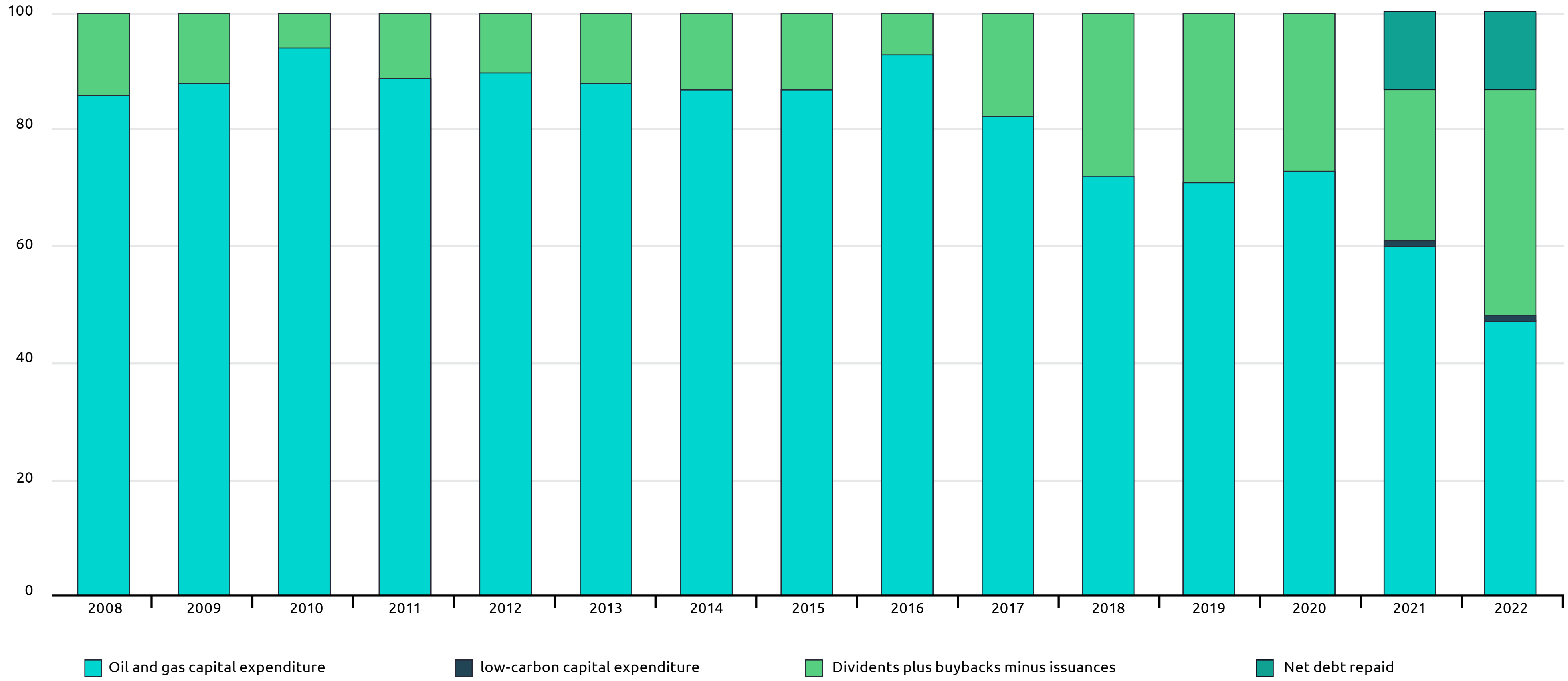



Notes: Net income is calculated from oil and gas production at prevailing oil and gas prices (including subsidies) after operating costs but before taxes: "private companies: here includes listed and non-listed companies.

Source: World Energy Investment 2023 Report, IEA

**FIGURE 2**

Distribution of cash spending by the oil and gas industry, 2008-2022



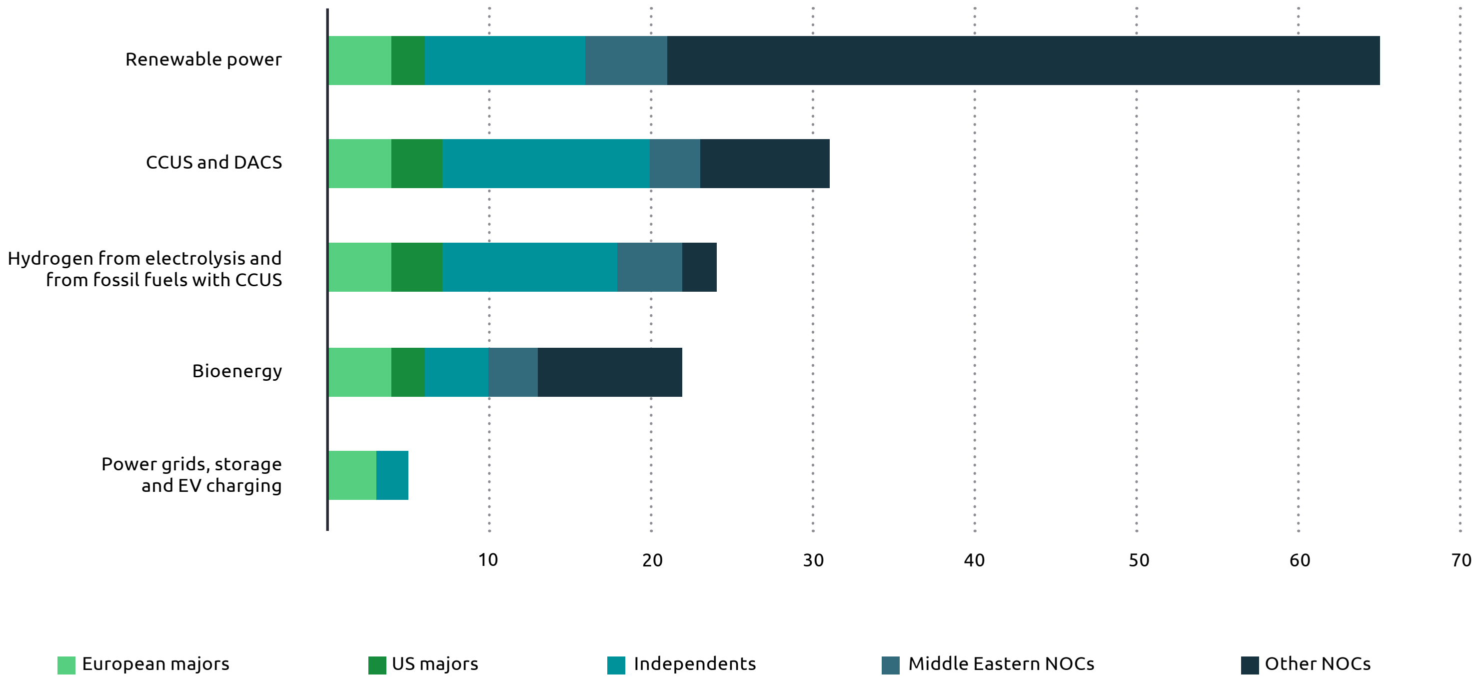

Source: World Energy Investment 2023 Report, IEA

A key insight to understand companies' vision to reduce emissions is analysing how they diversify their business, as they explore other sources and means of supplying energy. IEA's 2023 World Energy Investment report found renewable power to be the main option pursed by most O&G players. This includes a staggering number of NOCs across the globe, which usually see their businesses less inclined towards new ventures. Given their largely exclusive position in E&P within the O&G value chain, independent companies are naturally drawn to Carbon Capture, Utilization and Storage (CCUS) technologies to decarbonise their core activities, and yet less expectedly, many also turn to invest in renewable power and hydrogen.

European IOCs have generally taken more substantial strides towards a diverse portfolio of low-carbon investments, aiming to align with the European Union's ambitious climate targets and public sentiment. European majors such as Total Energies, Equinor, bp and Shell are generally considered at the centre of the transition to fossil fuel alternatives, with substantial investment in bioenergy and EV charging, as opposed to most companies worldwide.

**FIGURE 3**

Number of oil and gas Companies with Strategic Plans and Realised Investment in Key Low-Carbon Businesses




Source: World Energy Investment 2023 Report, IEA

American IOCs have instead favoured solutions to decarbonise existing business through CCUS, as well as investing in low-emission hydrogen production. Renewable power and biofuels are also considered by some American players, however none of them have shown meaningful interest in entering the EV charging or networks markets. All in all, investment from majors like Chevron and ExxonMobil continue to prioritise safeguarding conventional business lines rather than open up to new opportunities. Unlike their European counterparts, these companies still see their traditional source of revenue as the core pillar of their future business, so efforts are more focused on decarbonising its operations with new technology in the short term.

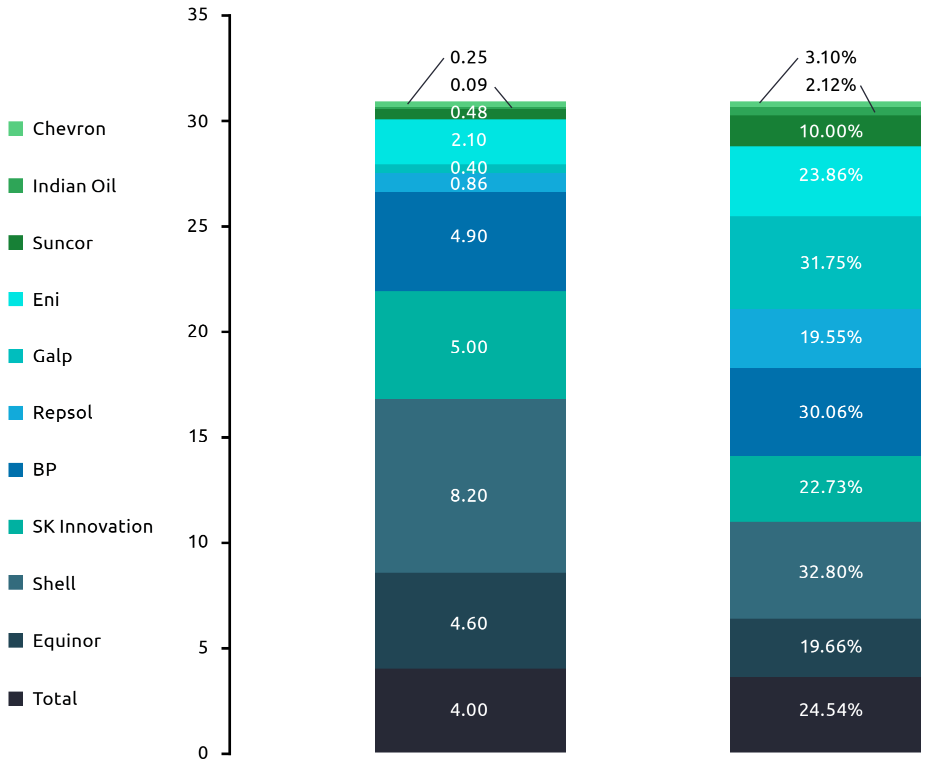
European IOCs continue to demonstrate significant diversification and robust investment in new low-carbon businesses compared to other IOC and NOC competitors

In terms of volume of investment, European IOCs strongly lead the efforts to establish themselves as the main drivers of the energy transition. Our research on selected IOCs shows European majors as the most prominent investors in 2022, in line with previous years. Currently Shell, bp and Equinor have lead the continent in net low carbon investment. However, if clean investment is measured against total investment, Galp surpasses bp, climbing up to a second position behind Shell as the players committing most to the transition. As for Asia, SK Innovation is a clear outlier for the region, as the second biggest IOC investor in volume. It is worth noting companies' definition of low carbon investment is at times challenged, with evolving policies in this space also affecting estimations greatly. For instance, Shell has recently been under scrutiny from Global Witness, an NGO, pointing out its clean investments figures could be greatly distorted by a high level of gas expenditure.

Looking closer at some of the low-carbon investment portfolios of major O&G players, it is clear renewable power has become the most frequent and matured opportunity.

**FIGURE 4**

Low Carbon Energy Investment by O&G Company in 2022 (Net Amount in billion US$ and % of 2022 Total Investments)




Source: Capgemini Internal Research

Given the outstanding growth of variable renewable energy sources (VRES) in the last two decades, fossil fuel companies have developed considerable wind and solar PV capacities, both organically and acquiring smaller firms. Total Energies, Galp and Repsol major acquisitions of renewable power producers and retailers, have resulted in high offshore wind capacities in operation as of 2022. The onshore wind spaces is lead by Shell and Orsted, while Total Energies dominates the solar PV landscape among traditional IOCs.

Moreover, hydrogen electrolysers, requiring renewable power to produce green hydrogen, have only seen prominent growth in recent years with the expectation of decarbonizing hard to abate emissions in key industries (e.g. steel, chemicals, agriculture…). Repsol and bp currently operate the biggest electrolyser capacities, however short-term targets from competitors are also quite ambitious.

Biofuel production and EV charging emerge as key opportunities for European IOCs, given considerable synergies with their traditional business lines

Bioenergy has surged in 2022 to over US$ 10 billion in investment from O&G companies (IEA, World Energy Investment 2023), rapidly becoming a new priority to catch up with strict policy in areas like sustainable aviation fuels (SAFs). Shell, Galp and Total Energies seem to be at the forefront of this area.

With regards to EV charging, investment in some cases is held back by consumer adoption and available power grid infrastructure. Nevertheless, companies like Shell, Total Energies and bp have secured a solid footprint in this new market as they transform their convenience and retail stores, going from product-led to service-led businesses.

In the short term, it is difficult for O&G companies to drastically reduce emissions (particularly Scope 3) considering solid demand for fossil fuels worldwide. Swift action is imperative, thus our recommendations for key players are the following:

**NOCs/IOCs:**

- **Investment –** increase efforts to diversify even beyond wind and solar, towards low-carbon solutions such as bioenergy, EVs and hydrogen.
- **Scope 1 emissions –** leverage available resources and know-how to ramp down emissions from traditional operations.
- **Scope 3 emissions –** as key suppliers of fuel for transport and industry sectors, focus on sustainable alternatives.

**Governments/ Policymakers:**

- Make new infrastructure available including enhanced power grids for EVs and H2/biofuel ready pipelines.
- Further develop international climate change policy to narrow disparity on incentives/penalties across countries, thus preventing O&G multinationals from avoiding emission reductions

**High demand for fossil fuels still challenges society's ambition to get rid of them. Choices made by O&G companies to venture into clean energy or reinvest in its profitable business carry huge significance and impact, and will continue to be a turning point in the fight against climate change.**

**FIGURE 5**

Clean Energy Portfolios in large IOCs (in operation or planned in 2022)

| Segment | Total Energies | GALP | ENI | BP | Shell | Exxon Mobil | Chevron | Equinor | Repsol | Orsted |
|---|---|---|---|---|---|---|---|---|---|---|
| Offshore wind | 11 GW | 10 GW | 0.75 GW (onshore and offshore) | 4.4 GW | 2.2 GW | - | 30 GW (2030 target) | 3.3 GW | 7.6 GW | 2.4 GW |
| Onshore wind | 4.5 GW | 0.012 GW | | 1.7 GW | 8 GW | 0.5 GW | - | - | 1087.6 GWh | 3.5 GW |
| Solar PV | 11.7 GW | 1.8 GW | 1.45 GW | 1.6 GW | 1.9 GW | 0.3 GW | 0.02 GW | 1.27 GW | 820.5 GWh | 0.7 GW |
| Hydro | | - | - | - | - | - | - | - | 0.7 GW | - |
| Hydrogen electrolyser | 0.05 GW | - | - | 2 GW | 0.03 GW | 28 million m³ per day (planned) | 150,000 tonnes per year | 1 GW (2027 target) | 2.5 MW | 1 GW (planned) |
| Biogas | 1.1 TWh | - | 50 million m³ | 16,000 boe/d | 3.2 mboe/d | - | 2000 barrels per day | - | - | 730k tonnes (planned) |
| Sustainable fuels (inc. Biofuels) | 500,000 tonnes | 600,000 tonnes | 3 million tonnes (by 2025) | 27 kb/d | 820,000 tonnes | 40 kb/d | 100k barrels per day (2030 target) | - | 250,000 tonnes | - |
| EV charging points | 41,500 | 5,500 | 6,500 | 22,000 | 150,000 | - | - | - | 2,000 | - |

Source: Capgemini Internal Research

# RENEWABLES TECHNOLOGY AT SCALE

DAVID PEREZ LOPEZ, SPAIN

ABHISHEK GOKHALE, AUSTRALIA

**Energy transition is off-track, but there are lights and darks. With a record 30% share renewable electricity generation is driving the shift in electricity supply. However, renewable-based electricity needs to grow much faster more than double to ensure a fair energy transition.**

## Renewables will break records in 2023 and 2024

For 2022 solar PV was the only technology to break a record for annual capacity additions, on the other side wind power additions decreased for the last two years in a row. For 2023 and 2024 is expected another record year for global renewables capacity additions, especially solar PV will continue dominating the growth with onshore wind additions rebounding to break the 2020 record[1].

Global renewable capacity additions is expected to reach more than 440 GW in 2023 setting a new mark, 13% more than 2022. However solar PV was the only technology that broke the last year record with new 220 GWs leading the growth leveraged by the global energy crisis. In 2023 onshore wind additions after two years of decline is expected to rebound by 70% to 107GW with all-time record.

Renewable energy investment reached a record $358bn in 2023 H1, up 22% compared 2022 H1 and 36% YoY.

1 IEA Renewable Energy Market Update - June 2023

Solar PV grew during the 2023 H1 by 43%, especially driven by China which accounted for half of the investment and followed by the US with an all-time record and 75% increase supported by the Inflation Reduction Act (IRA).

However wind power investment decreased by 8% dragged down by onshore although offshore recorded an increase of 47%[2].

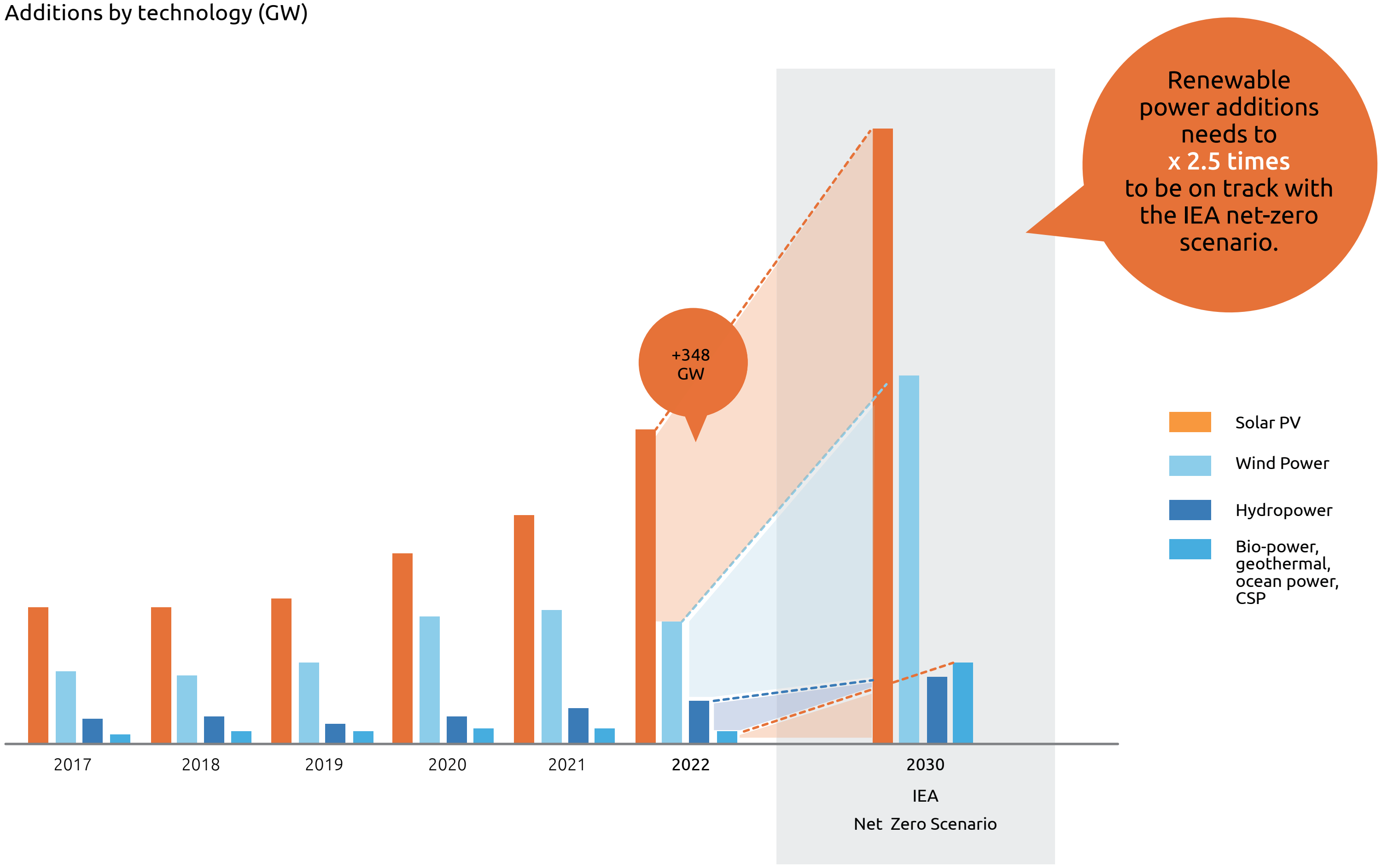
Still renewables investments need to increase by 76% to align with a net zero emissions pathway[3].

Global renewable capacity additions could reach 550 GW in 2024 in an accelerated case[4], since European countries have introduced key policy and regulatory changes to ease fast permitting setting maximum deadlines for granting permits (should not exceed three months for solar energy projects), upgrading renewable power plants (six months for repowering projects). In certain cases, qualifying projects may be exempted from environmental impact assessment and a presumption of "overriding public interest" for renewable energy projects. This will allow renewable energy projects to benefit from a simplified assessment for some environmental.

2 BNEF 2H 2023 Renewable Energy Investment Tracker
3 BNEF New Energy Outlook de BNEF
4 IEA Renewable Energy Market Update - June 2023

**FIGURE 1**

Additions by technology (GW)




Source: IEA Renewables 2023 Gloabl status report

Current annual new renewables capacity addition would need to be accelerated by as much as 2.5 times to achieve the capacity growth required under the IEA scenario for net zero emissions by 2030[5].

The rapid expansion of renewables needs to be accompanied by grid infrastructure, storage and flexibility investments. An increasing amount of electricity generation from wind and solar PV is being curtailed in many markets remaining relatively low ranging from 1.5% to 4%, especially where grid infrastructure and its planning lag behind the deployment of these renewable energies and where there is a lack of storage. IEA estimates that for every $1 invested in renewables, $3 of grid will be required.

5 REN21 Renewables 2023 Global status report

## Energy security concerns is spurring the capacity growth

The global shift towards cleaner energy including solar, wind, hydropower, biofuels and others has been accelerating due to the energy security concerns. This is primarily driven by supporting policies, higher fossil fuel prices, declining costs for solar photovoltaics and wind power. These growth driving factors are outweighing the high investment costs, skyrocketing raw material and transport prices, rising interest rates, and supply chain disruptions.

According to the IEA, globally the renewable capacity additions are expected to reach 440 gigawatts (GW) in 2023 and could reach up to 550 GW in 2024 in a favorable case[6].

This new capacity addition is equivalent to total power capacity generated by Germany and Spain combined. By the end of 2023 an increasing push in new capacity addition is anticipated, which will take the installed capacity to reach 4,500GW by end of 2024, which will be equivalent of combined power output of China and US.

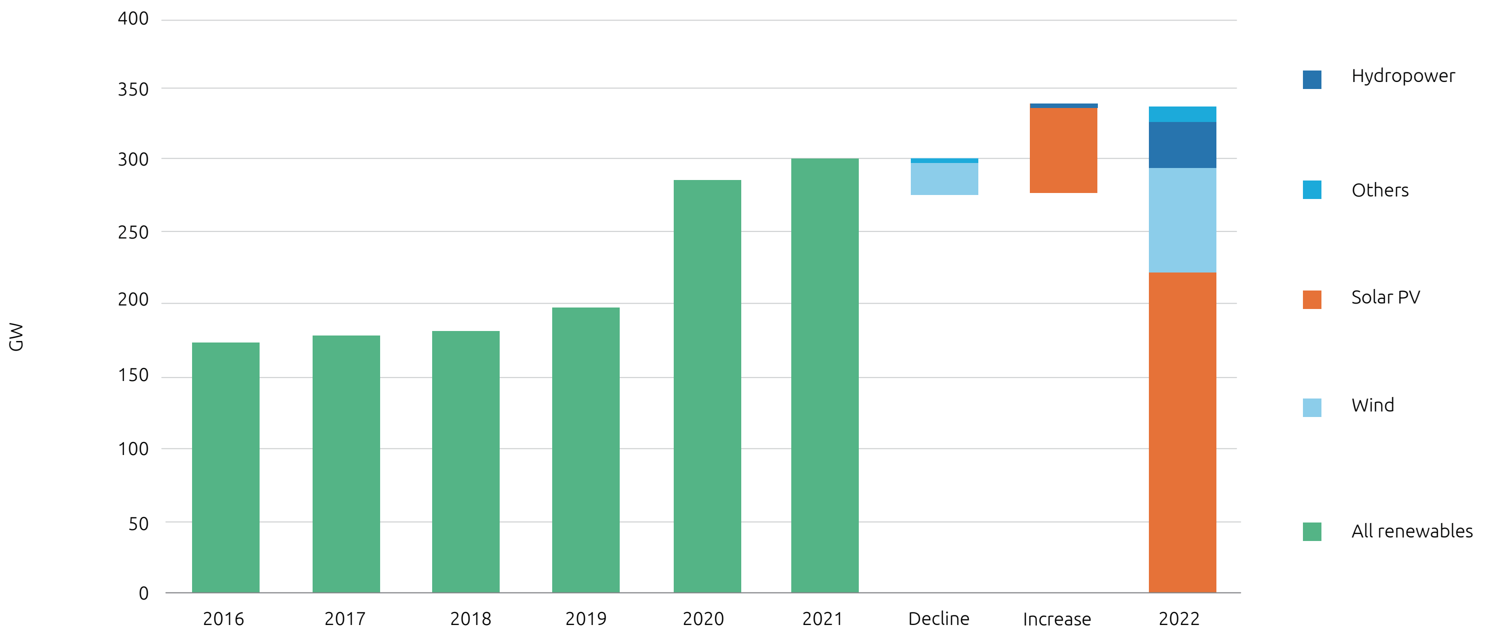
## Renewables, electrification and technology enablers at the heart of Energy Transition

This unprecedented growth needs to be backed by substantial and consistent investments. Scaling up renewables will also demand building new digital technologies that will provide system flexibility.

Economy electrification with renewables and technology enablers such as digitalization of grid, real time smart power plants, AI data-driven, new generation of SCADAs and full IT/ OT integration, advanced networks and communications, and cybersecurity will be needed to achieve the objectives.

**FIGURE 2**

Renewable electricity net annual capacity additions, 2017 - 2022




6 IEA Renewable Energy Market Update - June 2023

## Wind Power

In 2022, 77.6 GW of new installations brought the global cumulative wind power capacity to 906 GW, with a year over-year growth rate of 9%[7] compared to 2021.

The slow growth was due to supply-chain issues, inflation and market uncertainty contributed which lead to a decline of nearly 17% in capacity additions. However, China and U.S. jointly accounted more than 52% of global wind output[8].

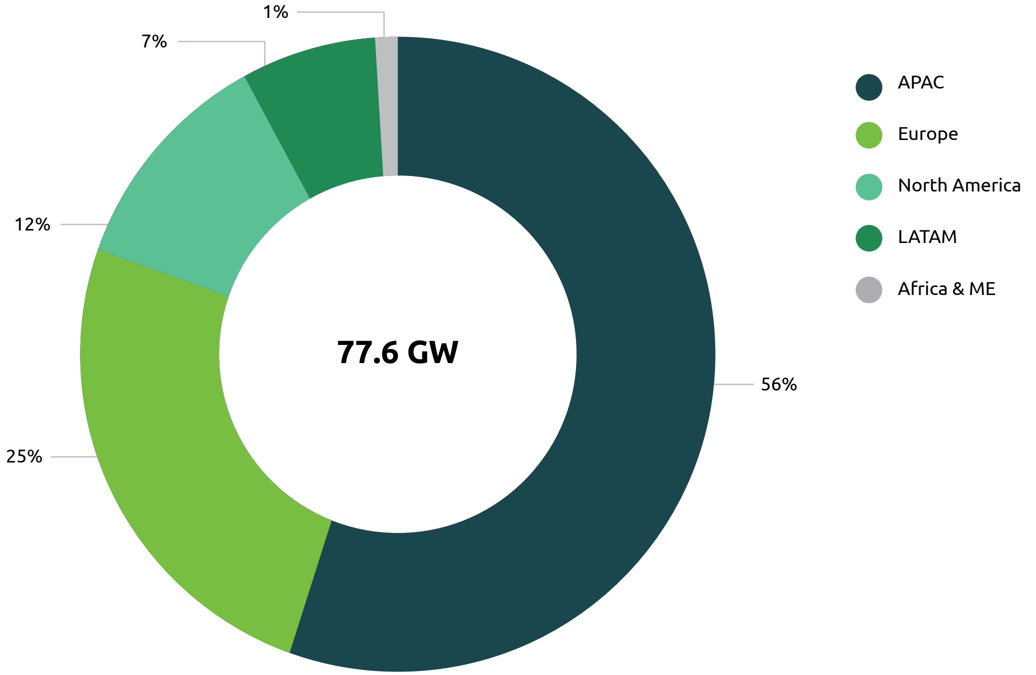
Current rates of installation will have less than two-thirds of the wind energy capacity required to meet the 1.5oC target and achieve a net zero pathway by 2030. The wind market growth rate will need to quadruple to meet net-zero goals.

Lengthy permitting procedures and lack of improvements to grid infrastructure are two main bottlenecks which is slowing down energy transition momentum. This is also posing a greater risk to outlook for developers and investors and potentially disincentivising investment.

Unfortunately the profitability of onshore wind turbine manufacturers has been hampered since several years ago by competition among them, especially in the context of auctions in a "race to the bottom" in costs, even in agnostic auctions against PV, supply chain disruptions, rising and scarce raw material costs, logistical oversight, and for the past year especially by higher inflation, interest rates and capital costs, and quality problems appearing in newer wind turbine fleets. But not only onshore wind turbines, now also offshore are raising alarm bells about a similar situation due to inflation, interest rates and capital costs, and the supply chain.

**FIGURE 3**

New wind power capacity in 2022 by region (%)




Source: Global Wind Energy Council (GWEC) report 2023

7 IEA Renewable Energy Market Update - June 2023
8 Global Wind Energy Council (GWEC) report 2023

## Onshore Wind

In 2022, the onshore wind market added 68.8 GW, making up 88.6% of global wind installed cumulative wind power capacity to 842 GW, with a year over- year growth rate of 8.8%[9]. The global weighted average levelised cost of electricity from onshore wind added in 2021 dropped by 15%

In 2022, Asia-Pacific and North America represented more than two-thirds of global new onshore installations. Asia Pacific lost 3% market share as compared to last year, but Europe saw record installations primarily driven by Sweden, Finland and Poland in 2022 to boost its to 25%. North America retained its third position with growth driven in Brazil and Latin America markets.

## Offshore Wind

The momentum for offshore wind farms stalled in 2022 with new additions reducing by 58% compared to 2021. This was mainly due to end of national feed in tariff in program for China, modest growth in European markets, and the US didn't installing any new turbines.

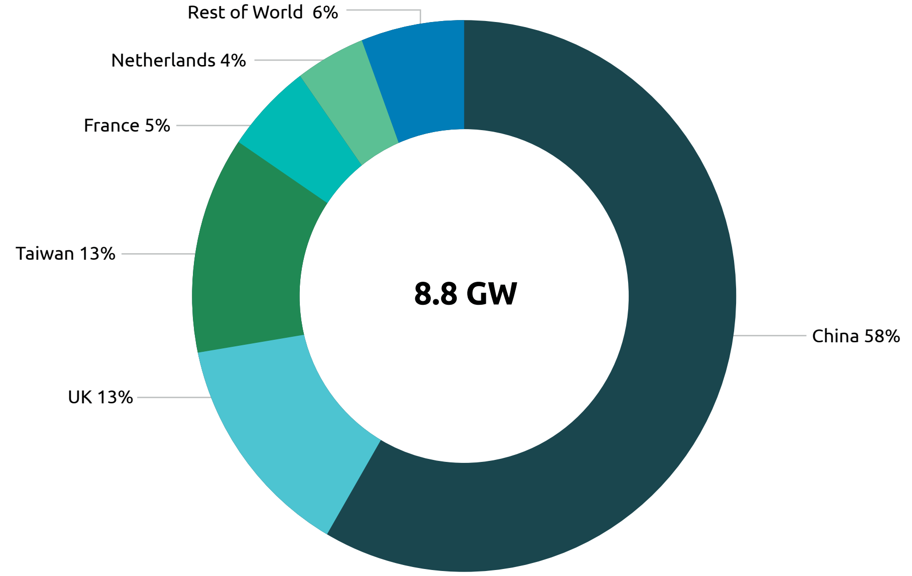
A total of 8.8 GW of offshore wind capacity was commissioned in 2022, bringing total global offshore wind capacity to 64.3 GW by the end of 2022. In 2022, China accounted for 63.6% of the global total offshore wind, followed by the U.K., Taiwan, France, and The Netherlands.

9 REN21 Renewables 2023 Global status report

The offshore wind market continues to be dominated by four main Chinese manufacturers1. The rest of the market is mostly served by two Danish manufacturers and one American manufacturer. Over the next five years, the CAGR for offshore wind is expected to be 32%, while the market share of new global wind installations is expected to increase from 11% in 2022 to at least 23% by 2027. The decline in commodity prices has led to a 2% drop in costs of new offshore and going down the levelized cost of electricity LCoE on par with coal now.

**FIGURE 4**

New installation offshore (%)




Source: Global Wind Energy Council (GWEC) report 2023

Offshore wind projects in particular are facing delays owing to rising input costs, slow permitting processes and an increasing shortage of specialized ships needed to install turbine foundations. Recent alarms has appeared since Vattenfall has stopped the development of the major offshore wind project in the UK and will review the entire 4.2 GW as the average cost of an offshore wind turbine is now ~40% higher than it was 2 years ago, mainly due to higher inflation, higher capital costs, and an increasing of the materials average price by ~90% since then.

## Solar PV

Newly installed solar PV capacity in 2022 reached 239GW, an increase of 35% compared to last year. Solar PV continues to be the main source of global investments for transmission and distribution networks and speeding up also the global energy storage market for a 30% annual growth to 2030[10].

It is to be noted that 65% of new capacity additions was led by distributed applications, including residential and commercial systems which account for almost half of global PV expansion. It is expected that Global installed solar PV capacity of 1TW will be added annually by 2030. Lower module prices, more economically attractive distributed PV system uptake for residential and commercial customers and a regulatory policy push for large scale deployment is expected to push the new capacity addition to 286GW by end of 2023 and 310GW by 2024. Apart from solar PV capacity additions, manufacturing capacity for all solar PV production segments is expected to more than double to 1,000GW by 2024, led by China and increasing supply diversification in the US, India and Europe, having enough solar PV manufacturing capacity in 2030 to meet the annual demand under Net Zero scenario.

From 2021 to 2023, the worldwide weighted-average levelized cost of electricity (LCoE) from concentrated solar power (CSP) and utility-scale solar photovoltaics (PV) has increased after a decade of uninterrupted decline. The mains reasons for this increase is the lingering effect of COVID-19 pandemic, increase logistics or shipment costs and inflationary pressure due to the Russia-Ukraine war; however, this does not pose a challenge to cost competitiveness as solar PV technology remains significantly cheaper as compared to other new fossil fuels and nuclear.

China continues to be a dominant player in the solar PV manufacturing industry with investments of almost $50 billion over the last decade. It also continues to control the polysilicon market with a share over 80% with out of the top 10 PV module 10 companies, seven are from China including the top three.

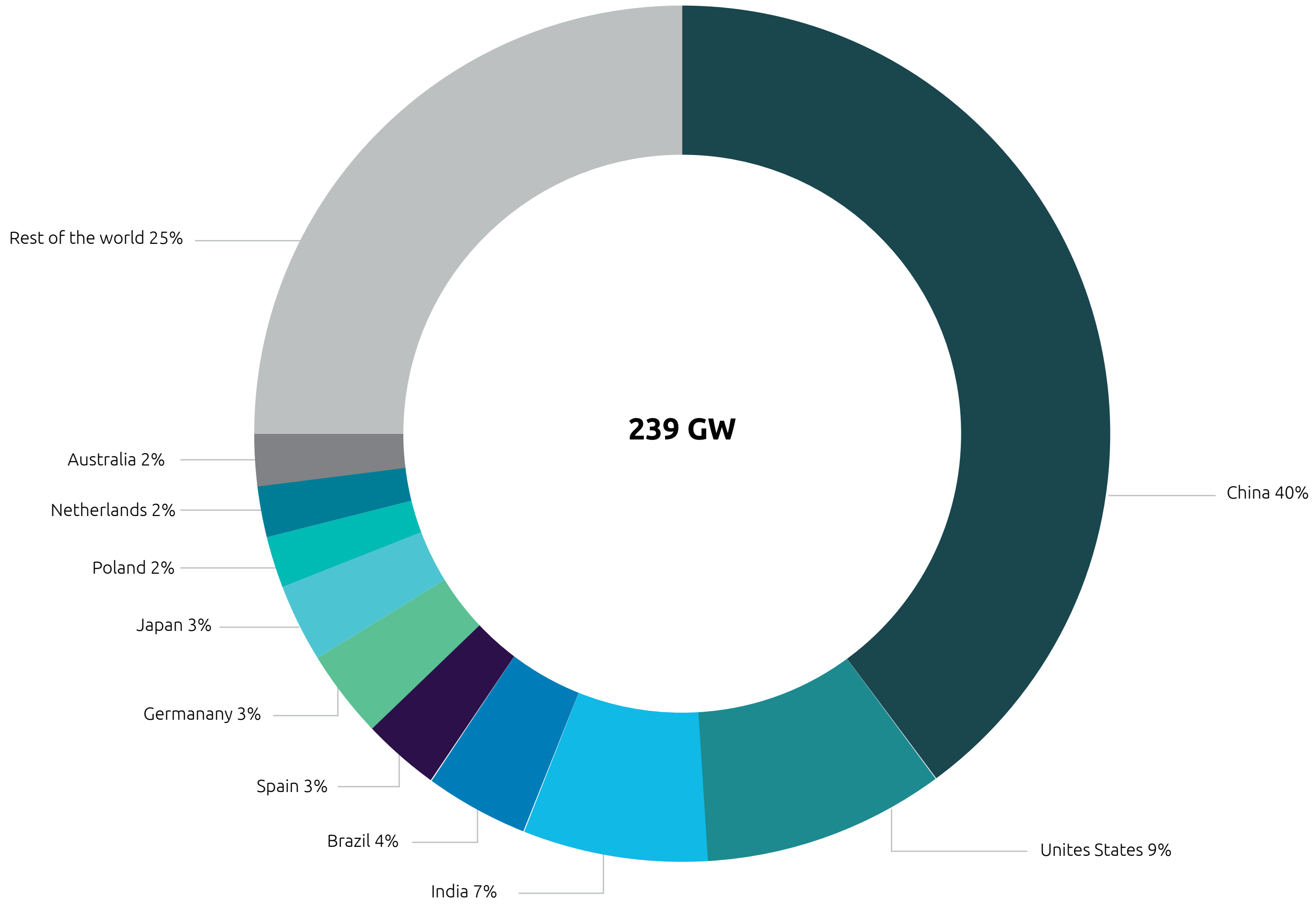
Solar PV panel prices are set to decline for the first time since many months ago for the second half of 2022[11]. A increase in solar shipments due to lower freight costs and increased efficiency in the production of large wafers of 210 mm is also expected to reduce module costs between10% and 15%, with prices dropping.

PV crystalline modules price are declining around 20% for the current 2023 since January to July in all type of modules (high efficiency, mainstream and low cost)[12].

10 Global Wind Energy Council (GWEC) report 2023

11 IEA Special Report on Solar PV Global Supply Chains 2022
12 Price Index - pvxchange

FIGURE 5




Source: Solar Power Europe 2023

## Supply Chain Constraints and Disruptions

Since 2021, market has witnessed significant disruptions in global supply chains, increased shipping costs, and Russia-Ukraine war led inflationary pressure have triggered significant price increases.

The energy sector is emerging as a major force in driving the usage of critical materials such as lithium, graphite, arsenic, titanium, selenium, manganese, nickel, and cobalt are vital to battery longevity and performance. Rare earth elements which is essential for permanent magnets for EV motors and wind turbines, and large amount of copper and aluminium to support electrical technologies.

Todays, critical material supply availability and investment reliability is raising concerns for a more expensive energy transition. There is need for the industry to focus on key questions such as how to reduce the material intensity and what are the alternative or substitute materials. It is expected that there will be shortage of supply of these materials by 2030, and high geographical concentration of supplies from China (rare earth elements), Indonesia (nickel), Democratic Republic of the Congo (cobalt) pose risk to the supply chain.

Critical minerals demand is projected more than double under APS[13] but NZE[13] will require almost quadruple[14].

13 IEA scenarios: Announced Pledges Scenario (APS) by 2030 and 2050 and Net Zero Emissions by 2050 Scenario (NZE)
14 IEA Critical Minerals Market Review 2023 report

The market for critical minerals used for the energy transition reached $320 billion last year has doubled in size over the past five years. In 2022, global manufacturing of renewable energy and enabling technologies grew by nearly 40%: solar PV (up 39%), electrolysers (26%), heat pumps (13%), but wind energy manufacturing grew by an insufficient 2%[14].

The Russia-Ukraine crisis has driven the wholesale and retail electricity price across major markets, including China, the EU, the US and India. Additionally, the permitting challenges, unsubscribed auctions, and long development timelines continue to create hurdles in the utility-scale growth. There are a few promising initiatives and focus on policy frameworks which is expected to tap the huge potential of bilateral solar power purchase agreements.

## Fast-track renewables permitting will have to address balancing social and environmental interests

**The average permitting times in major countries in Europe and United States go from 3 to 7 years[15].**

There is a huge gap between renewable energy capacity being built and average permitting times, especially for wind projects and even grid infrastructure, due to slow bureaucratic processes, environmental issues, grid access and other bottlenecks, with major implications for the pace of the energy transition.

15 IIEA Special Report on Solar PV Global Supply Chains 2022

European countries have been waiting for permits to substantial renewable capacity in the pipeline, a new act was passed enabling fast track permitting process to accelerate renewables development introducing specific policy measures with one-stop shops, overriding public interest, including supply chain criteria in public tenders to favour diversification and local economic value, investment in the European labour upskilling, … ensuring a good balance with societal interests, biodiversity protection and others criteria.

China is the leading global supplier of clean technologies holding around 60% of the world's manufacturing capacity for most mass-manufactured technologies (solar PV, wind systems, batteries, 40% of electrolysers[16].

Global solar PV manufacturing capacity is expected to double to nearly 1,000 GW by 2024, enough to meet annual demand in the IEA's 2050 net-zero emissions scenario. In contrast, wind equipment manufacturing is expanding slowly, and Western wind equipment manufacturers are experiencing financial difficulties and may struggle to keep pace with demand growth through 2030.

16 IEA Energy Technology Perspectives 2023 report

## A new green tech race? US Inflation Reduction Act and EU Net Zero Industry Act

Multiple policy support packages such as the US Inflation Reduction Act (IRA), the Net-zero Industry Act in Europe, Japan's Green Transformation program and India's Production Linked Incentive scheme have aimed to increase domestic manufacturing capacity of renewable energy and enabling technologies as response to the energy crisis.

In the US, the IRA was approved, with a budget of some US$400 billion over the next decade, which will help consumers and companies with a wide range of support schemes, mostly in the form of tax credits. In response to the IRA, the EU articulated the Green Deal Industrial Plan, which will mobilize €335 billion (€110 billion previously committed) with different funds. Although the EU budget is lower than that of the US, comparatively the effort in terms of % of EU GDP is 2.1% higher than the US 1.6%.

In the 12 months since the IRA was signed, the private sector has announced over $110 billion in new investments in clean energy manufacturing, over 75,000 new jobs created in the battery supply chain, over 80 new or expanded electric vehicle plants, and solar power for 12 million new homes[17].

While the EU approach is not so much protectionist as IRA with the privileging of domestic products over imports, and the need to significantly increase the speed of transition implementation including another key piece such as the Carbon Border Adjustment Mechanism with a level playing field for domestic and non-domestic imports.

17 U.S. Department of Energy: The Inflation Reduction Act in its first year. Aug 2023

## Wind and PV generation costs increased for the first time in history but will decline in PV and stabilize in Wind by 2023 being the cheapest electricity source by far

Wind and solar generation costs increased for the first time in history but will decline by 2023 and 2024 remaining 10-15% above their pre-Covid levels in most markets[18] driven by a perfect storm environment in a context of inflation increasing, energy crisis by the Russian gas cut, higher financing costs and interest rates, increasing of raw material and labor costs, and supply chain issues. In spite of it wind onshore and solar PV are the lowest LCoE by far.

Apart from the PV crystalline modules price dropping by 20% since January to July 2023, also a lot of technological progress is taking place contributing to alleviate this situation; renewable technologies are making a great effort in innovation and R&D, improving their final efficiency. PV technology is developing new semiconducting materials for higher efficiency solar cells and larger power panels, using crystalline silicon, CdTe, CIGD, perovskites, multijunction, organic[19]. In the case of bifacials modules new developments based on perovskite solar cells are pointing to higher yields at lower overall costs[20] making solar PV more accessible even.

18 IEA Renewable Energy Market Update - June 2023
19 Fraunhofer ISE and US DOE (Department of Energy) Solar Futures Study report

Another like new generation of power electronics inverters with grid-forming features, synchronous generators and grid frequency control. New uses and applications as integrated photovoltaics floating or agrivoltaics uses.

In the case of wind industry bigger and more powerful offshore and onshore wind turbines with new design criteria, smarter control, advanced aerodynamics and aeroelasticity, wakes, materials, digitalization, ….. creating a more efficient technologies and new promising uses as floating offshore wind6. However, looking ahead to 2023, the wind industry is at a particularly complex juncture, as a new generation of wind turbines is facing potential one-off design problems due to new technical challenges and aggressive cost and time-to-market pressures, which could be feared to become a more widespread problem in the industry.

## Digitization of energy emerging a new era will trigger the energy transition at scale

**Energy transition will be digital or it will not be.**

Digital technologies will help increase energy efficiency and smart use from generation to final consumers cutting costs, improving efficiency and resilience, and reducing emissions. In electricity systems, for example, will help integrate higher shares of variable renewables and better match supply and demand from increasingly heterogeneous decentralised sources such as smart charging technologies for electric vehicle and distributed energy resource, or smart and flexibility of demand response requiring a more sophisticated management of electrical grids and final uses in transport, buildings, industry and residential.

Digitization trends are truly dazzling, for example 90% of the world's data has been created in the last two years, growing global investment in software and digital across the electricity value chain by 20% per year in recent years[20].

A new generation of digital technologies (AI for predictive maintenance, analytics, smart self-maintenance, a new generation of SCADAs, full IT/OT integration, 5G, and cybersecurity etc.) are expected to drive the increase in performance and efficiency, resulting in a declines in construction and operational costs.

20 IEA Digitalization and Energy 2023 report

## Pure 100% renewable energy based electric system is possible

An energy system based on 100% renewables has emerged to become the goal of many countries beyond 2030 a really efficient cost mainly based on solar and wind energy, hydropower, geothermal, biomass, short, mid and long term energy storage, sector coupling power-to-X and hydrogen-to-X, and direct and indirect electrification of almost all energy demand.

100% renewable energy with a combination of wind, solar, hydro and storage could be like today's energy costs be reached between 2035 and 2050 in 145 countries creating 28 million net new green jobs and decreasing user energy costs in more than 50%[21]. Australia has announced its world leading transition to 100% renewables with wind and solar to meet all grid demand at certain times as early as 2025[22].

Reaching 100% renewables is not a minor issue that requires a solid plan that analyzes many complex issues and crossroads situations, including economic affordability and competitiveness of electricity considering another investments such as e.g. grids investments, security of supply taking into account the cost of storage, baseload, dispatchability, flexibility mechanisms, readiness of future clean technologies, ....and of course sustainability, decarbonization and climate costs. None of the world's major industries would be profitable if it paid for the natural capital it uses

21 Low-cost solutions to global warming, air pollution, and energy insecurity for 145 countries, Energy & Environmental Science. On the History and Future of 100% Renewable Energy Systems Research, IEEE and Stanford
22 Daniel Westerman, CEO at AEMO (Australian Energy Market Operator), Australian Celan Energy Conference 2023, Sydney July 18th,2023

- **For the last year we are made many progresses but not still enough. Energy transition is off-track with lights and darks.**
- **Solar PV is growing significantly but wind power is tackling many issues, other new emerging ones not being massively deployed as heat pumps and storage, and huge expectation in breakthrough hydrogen and CCUS as corner stones.**
- **Many challenges have to be addressed: permitting processes, shorten projects development, rare earth and materials scarcity, investment availability, grid readiness, there is no time to wait.**
- **Acceleration is absolutely needed. Time is now or never. Act.**

# CLIMATE CHANGE AND ENERGY SOVEREIGNTY ISSUES ARE TRIGGERING NUCLEAR REVIVAL

DAVID STEIGER, FRANCE

## The year 2022 marked the return of nuclear power to favor, thanks to soaring energy prices and the war in Ukraine.

At the end of September 2022, the International Atomic Energy Agency (IAEA) revised its forecasts (in the high case) upwards to 870 GW of nuclear power by 2050. It had previously forecast 790 GW, compared with the current 390 GW.

### A strong political will in OECD countries, with investment decisions slow to materialize.

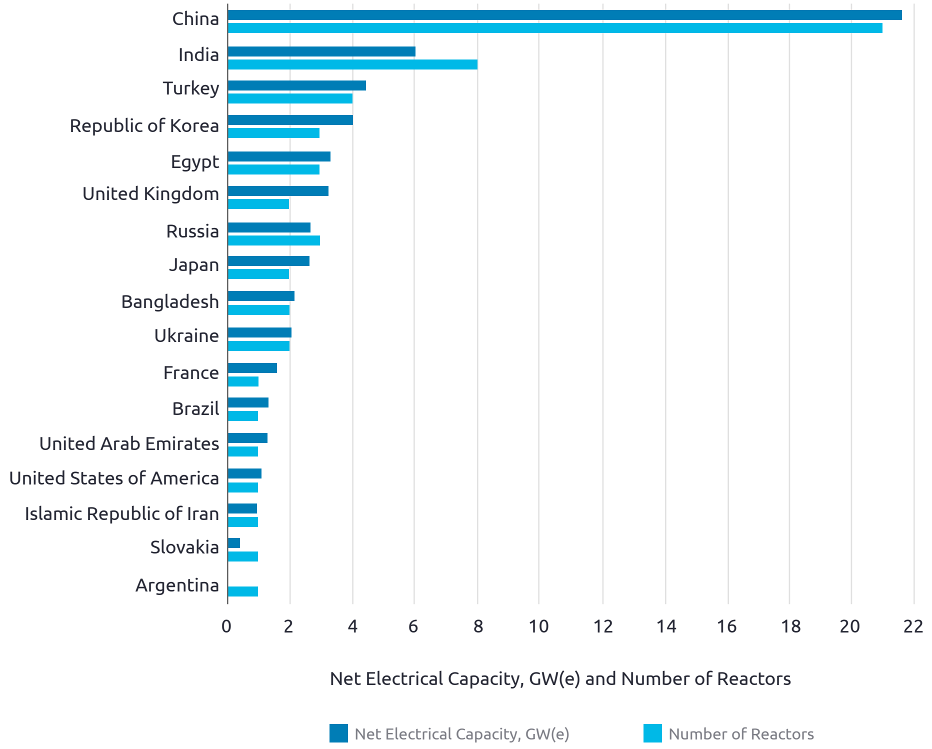
- In Western Europe, the French, British, Dutch and Swedish governments have all taken positions in favor of nuclear power. In some countries, however, investment decisions have been slow to make a clear start to a new positive dynamic. In France, for example, the financing model for the construction of the first 6 EPRs has not yet been decided.
- In Western Europe, the first reactor in 20 years has been commissioned (in Finland) and three power stations are under construction in France and the UK.
- In Central and Eastern Europe, Prague, Bratislava, Bucharest and Budapest, that already operate nuclear plants, have launched new projects. Poland wants to decrease its dependance on coal and is planning to build for the first time, two power stations.
- In Japan, Tokyo adopted a plan in December 2022 to restart its power stations and reach 20% nuclear power by 2030, compared with 7% today.
- In the US, only two units are under construction, with 12 reactors shut down in the last 10 years due to low electricity prices and a lack of political support. However, the government is trying to limit this loss with a €6 billion rescue plan for plants threatened with closure. The inflation Reduction Act (IRA) makes nuclear power eligible for the same tax credits as renewables like wind and solar. A recent report from the Department of Energy (DOE) suggest that America could triple its nuclear power generation, to 300 GW, by 20250, the year by which the Biden administration has pledged to reach net zero carbon emissions.

## The development of nuclear construction in Asia remains steady.

- Moscow plans to build 24 reactors to achieve a 25% nuclear share of its energy mix by 2045. However, Rosatom will only be able to rely on its own revenues following Moscow's decision to end government subsidies.
- In China, the 14th five-year plan aims to build around 20 reactors to achieve 70 GW of nuclear capacity by 2025, compared with 53 GW today. China, which built 35 reactors between 2010 and 2020, is still leading the growth of nuclear power worldwide.
- India remains second only to China in terms of nuclear reactor construction. New Delhi hopes to meet its energy needs, which are growing by 4% a year, notably thanks to nuclear power, which currently accounts for 4% of its energy mix. However, its plans are slow to materialise.
- South Korea is following the same path, with the election in March 2022 of a new president Yoon Suk-yeol who is reversing his predecessor's policy of phasing out nuclear power.
- Central Asia is keen to capitalise on the experience it has acquired in its uranium business. In 2022, Kazakhstan and Uzbekistan have selected the sites for their first power stations.
- Finally, after the successful construction of four nuclear power plants in the United Arab Emirates, other countries as Saudi Arabia have nuclear development plans.

**FIGURE 1**

Reactors under construction



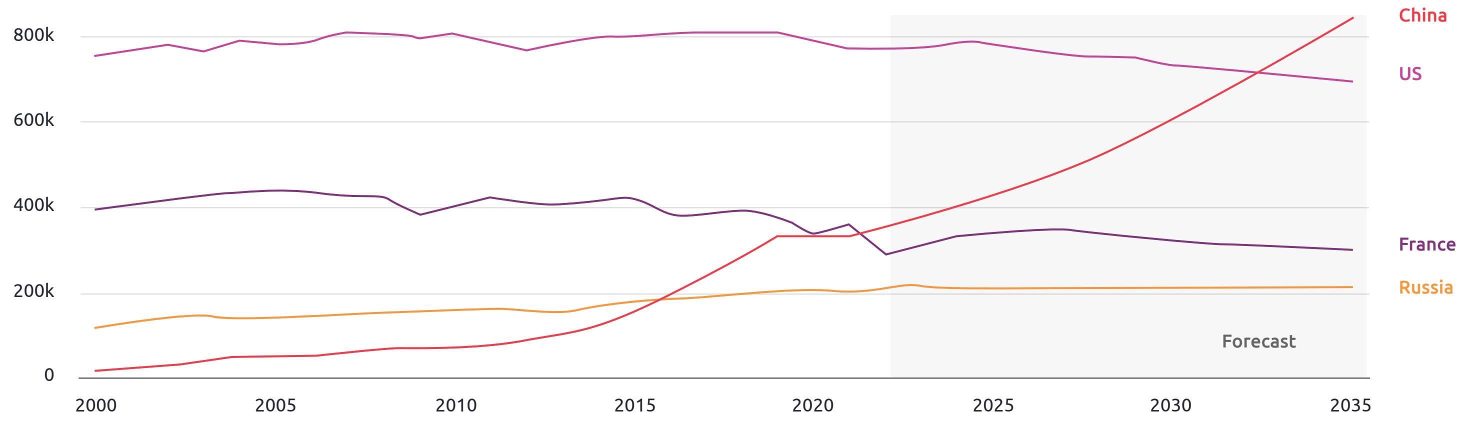

Source: IAEA (PRIS)

## The civil nuclear market still dominated by China and Russia while in OECD countries, new nuclear powers construction is disappointing.

- As at 1 January 2023, of the 59 reactors under construction worldwide, 22 were in China and 43 are based on Russian or Chinese technology. This means that four out of every five reactors under construction worldwide are being built by Moscow or Beijing. The only other two countries building reactors abroad are France (in the UK) and South Korea (in the United Arab Emirates).
- Rosatom is still the world's leading builder, with 25 reactors under construction in 9 countries (including Russia). Moscow controls 10% of the uranium extraction market, 36% of uranium enrichment and 22% of fuel fabrication.
- In China, Beijing has made nuclear power a technological showcase. However, its attempts to develop its technology in Europe via Romania and the UK have not been successful. So far China has only exported nuclear plants to Pakistan. All six units operating in Pakistan are of Chinese design.

**FIGURE 2**

China is set to overtake the US as the biggest nuclear generator by the early 2030s



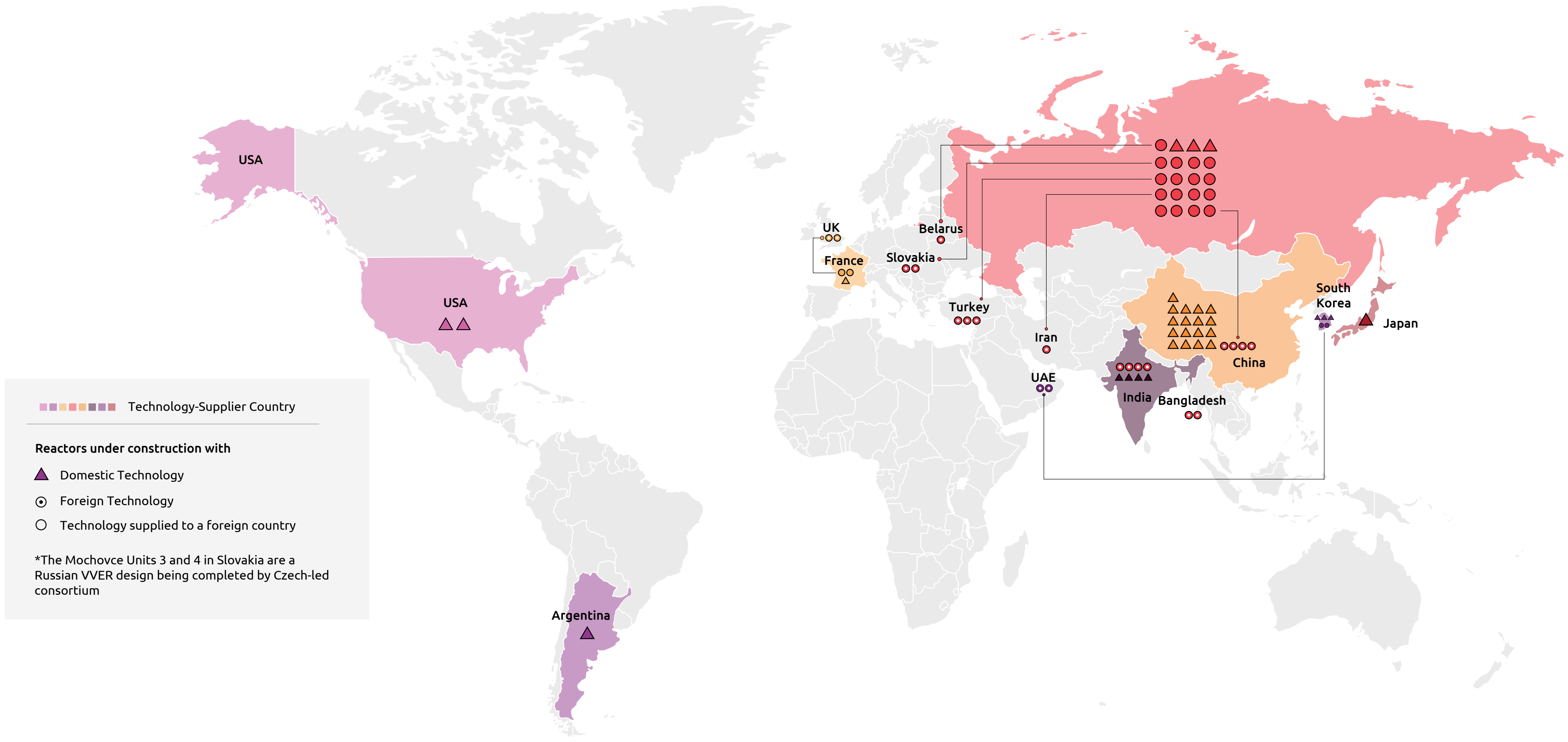

Source: Energy Monitor - Globaldata

- In the United States, Westinghouse's victory over EDF for the construction of a power plant in Poland is evidence of a change of direction, albeit a slight one for the world's leading nuclear power industry. Westinghouse aims to develop in East Europe and notably to take over from Rosatom, the maintenance of the existing VVERs. America’s State Department has set up partnership with more than a dozen countries to help them fund and develop nuclear energy programs and eventually small modular reactors.

FIGURE 3

**Nuclear Power Reactors Under Construction by Technology-Supplier Country**

Units by Technology-supplier Country and Construction County as of 1 July 2022



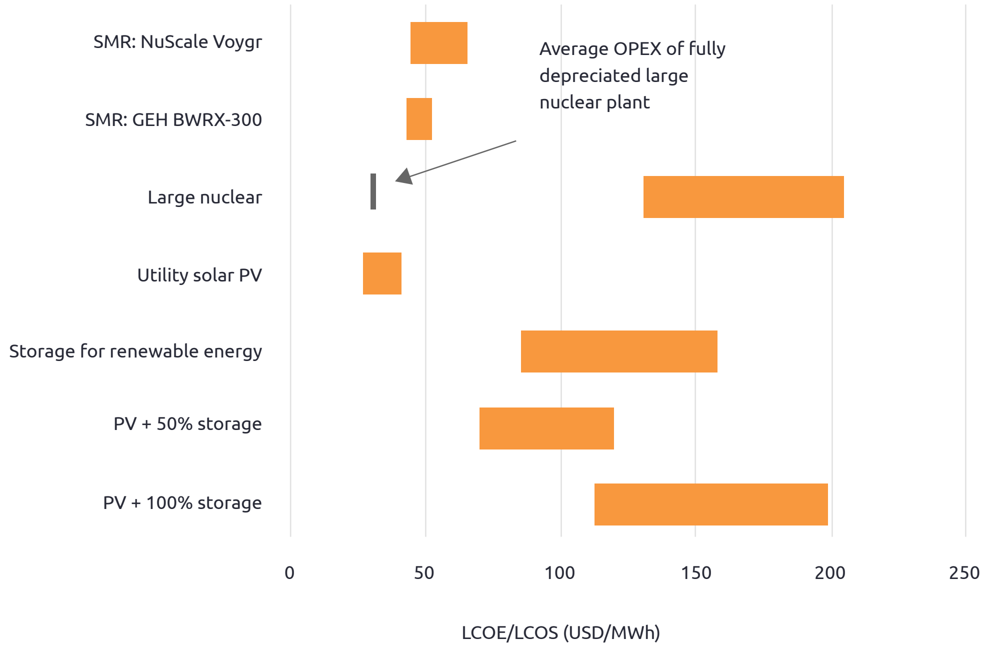
# Technological breakthroughs that herald hopes for a nuclear energy faster development.

## The promise of Small Modular Reactors (SMRs)

- As a possible complement to the large power reactor systems, smaller reactor potentially using new technological approaches (AMR: advanced modular reactors), are emerging and offering new services going beyond the production of carbon-free electricity. SMRs typically generate less than 300 MW, around a third of the capacity of traditional reactors. These reactors are partially factory-built and aim to make nuclear projects cheaper, enhance their safety and open pathways to new business models.
- SMRs are generally much simpler to engineer than large reactors. In addition to their integrated architecture, by using passive safety systems, they offer a higher level of safety.
- They are also meant to require less fuel than traditional reactors. Power plants equipped with SMRs are designed to refuel every 3–7 years, compared to 1-2 years for large nuclear plants.
- SMRs are factory-built, which means that there should be significant economies of scale when it comes to mass production. As they are transported to their place of operation, they do not require large numbers of skilled workers on the installation site.
- Compared with the territorial location constraints of large reactors and renewable energies, SMRs can easily be installed on smaller sites.
- The financing of SMR construction can be envisaged with smaller amounts and over a shorter period, allowing a faster return on investment.
- Finally, their operating cost should be very competitive. In August 2022, GE Hitachi Nuclear Energy stated that modular SMRs can be developed with a LCOE of around $60/MWh and that they will have a longevity advantage over renewables, between 60 and 100 years, compared with 20/25 years for wind and solar.

**FIGURE 4**

LCOE/LCOS Ranges of Nuclear Energy vs. Renewables, Storage.




Source: IDTechEx

## The challenges of SMRs

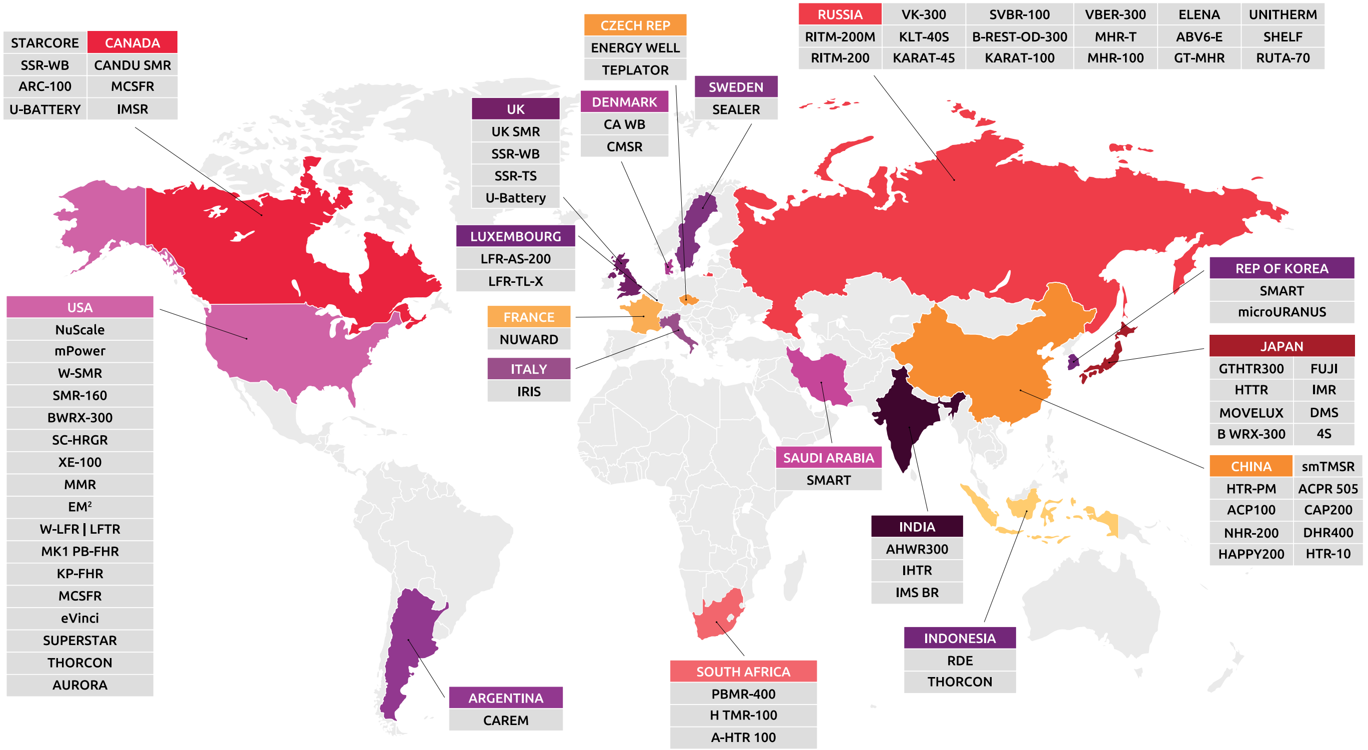
- Despite these competitive advantages, SMRs are still nuclear reactors with little construction experience. However, some small nuclear reactors have been constructed for aircraft carriers and military submarines. In addition, SMRs economic competitiveness is still to be proven in practice once they are deployed at scale.
- Harmonization of regulations and requirements around the world will be essential to support standardization of design, in-factory series production and limited design adaptations to country-specific requirements.
- The next decade is crucial, with some modular reactors due to be commissioned by 2030. Cost overruns, licensing delays and fuel shortages can easily bring construction to a halt. The fate of the NuScale power station in Idaho could be decided this year.

## A very dynamic marketplace opening new market opportunities.

- These new generations of reactors are proving extremely popular worldwide. By 2022, the International Atomic Energy Agency (IAEA) will have identified more than 80 SMR and AMR projects worldwide, notably in the United States, Canada, China, Russia, the United Kingdom and France: For example NuScale and Holtec in the United States, Rolls-Royce in the United Kingdom, the Russian RITM-200, the Chinese ACP 100, the Korean SMR model and NUWARD in France. Most of the projects are in the design or licensing phases.

**FIGURE 5**

Worldwide development of small and medium-sized modular reactors by technology

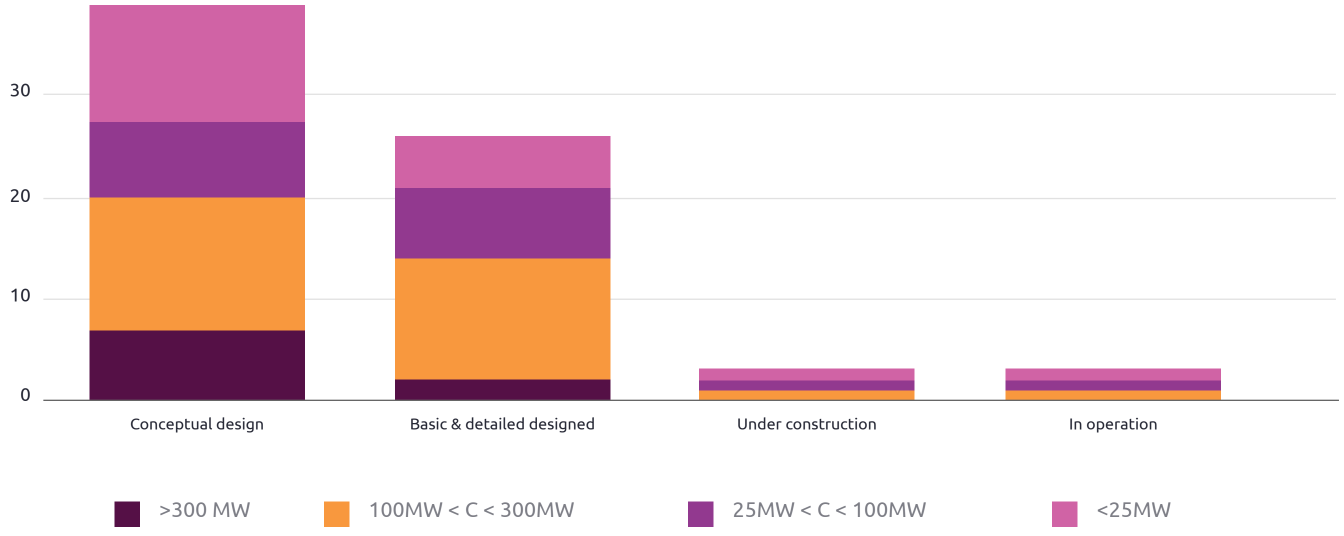



Source: AIEA

- Russia had the first operational SMR, but it is probably China that leads the world in SMR operations, with two SMRs operational on a commercial scale. North America and Europe are other geographical poles of development, although in Europe, projects are at a less advanced stage. Other countries with projects making significant progress are scattered around the world - such as Argentina, which is building the CAREM.

**FIGURE 6**

Global number of small modular reactor projects by development status, 2022

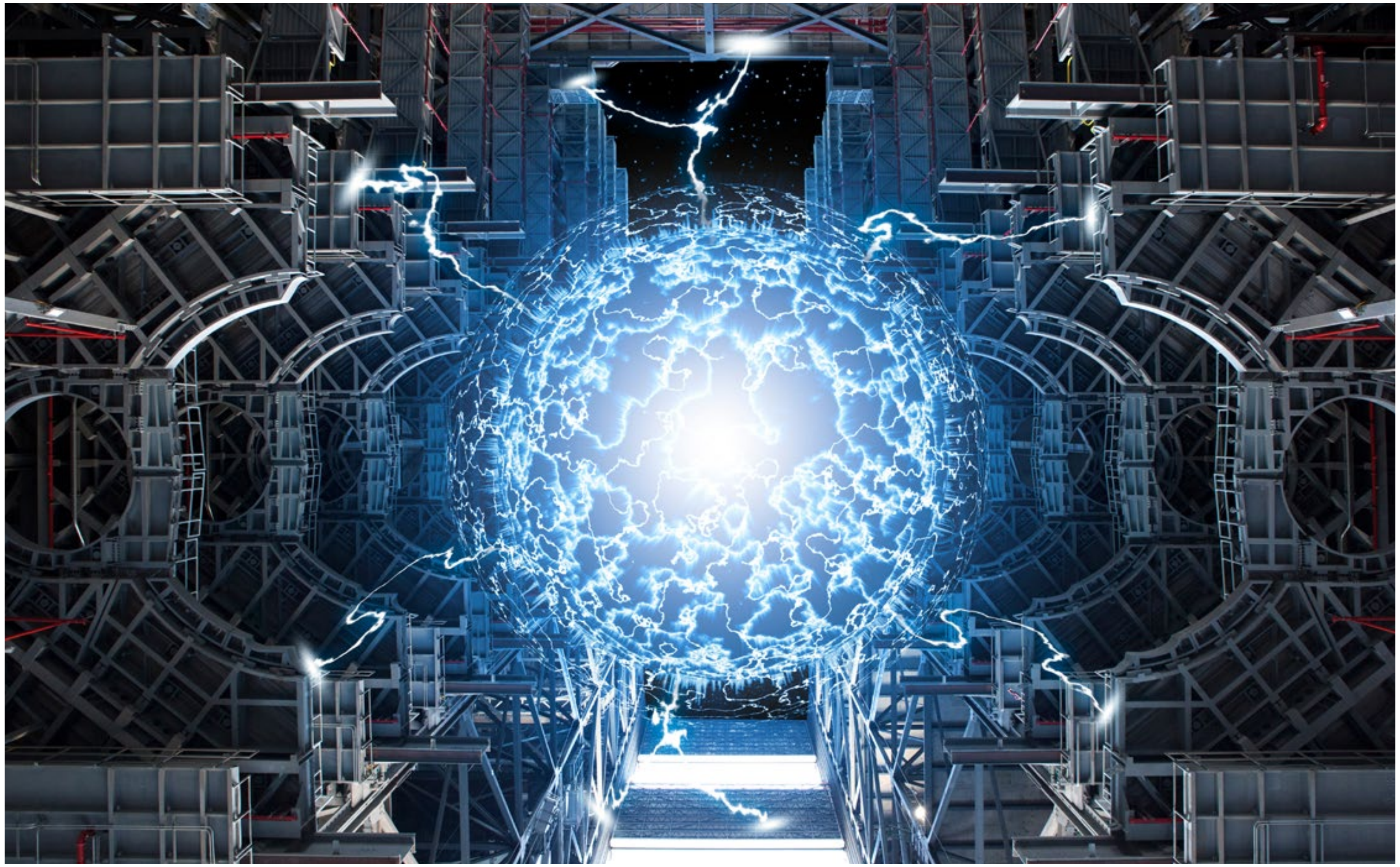



Source: IEA -Energy Monitor

- The market for SMRs and AMRs is huge: in countries open to civil nuclear power, more than 3,300 coal-fired units will have to be replaced by 2050 and SMRs have the right size for that.
- But as well as supplying electricity, these new generations of reactors will have other uses, such as producing heat or supplying electricity for desalination plants, green hydrogen production or synthetic fuels production. District heating is also one of the possibilities offered by SMRs and AMRs, as shown by the studies carried out in Finland to replace district heating networks with SMRs, thereby reducing the use of fossil fuels.
- The first examples of the most mature SMR models, based on 3rd generation technologies, are expected by 2030. Regarding the AMRs, their industrial and commercial availability will not happen before 2040 or even 2050.
- Many start-ups have invested in SMRs and AMRs. Of the more than 70 SMR models under development, 21 are being developed by a new company.

## Fusion is not expected to be implemented before 2050 in the most optimistic scenarios.

- Several projects:
  - Laser-triggered fusion: only 2 places in the world are experimenting with this type of fusion, including 1 based in France (the Laser Megajoule near Bordeaux) and another in the US, where the NIF (National Ignition Facility) laser instrument reached in laboratory the breakeven point on 5 December 2022 proving that controlled nuclear fusion can generate more energy than it consumes.
  - Tokamak: ITER project in France which benefits from international funding, Tokamak EAST in China, which has beaten several records1.
- Still at the experimental stage, nuclear fusion is fueling hopes of large-scale, carbon-free and electricity production with abundant fuel. It should emit little and short lifetime radioactive waste.
- In the same fuel quantities, nuclear fusion could produce 4 million times (versus 1 to 2 million times for fission) more energy than fossil fuels: oil, gas and coal.
- Several technological challenges must be overcome. For example, the tokamak process requires heat confinement of up to 150 million degrees. Reactors must prevent the walls from melting, while maintaining fusion for as long as possible.
- Although nuclear fusion reactors are promising and could hold a key role in our energy future, they are not expected to be in industrial operation before 2050 at the best.



# Main issues to sustain and drive the nuclear development.

## Main issues to sustain and drive the nuclear development.

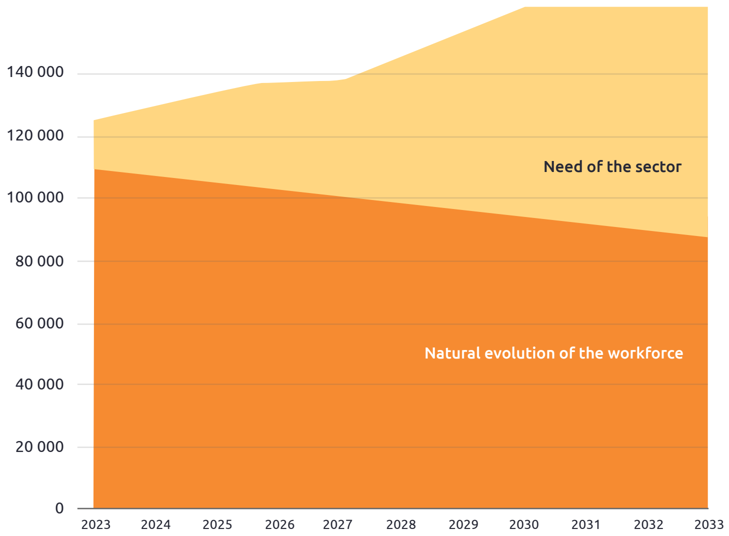
- Because their design is highly technical and safety issues are crucial, it takes years to be get nuclear plants design and construction approved. They are thus expensive to build while their fuel and operation cost are relatively low. The US Department of Energy (DOE) estimates that nuclear reactors should cost around 3,600 dollars per kilowatt to allow quick development in the country. However, the first reactors of this type cost between 6,000 and 10,000 dollars per kilowatt.
- A period of high interest rates will lead to higher construction cost.
- To encourage nuclear development despite these difficulties, innovative approaches to financing and support policies are being pursued, including partial investment or loan guarantees from the government.

## Unprecedented need for workers, a major source of employment.

- Finding enough workers to build and operate new nuclear plants is a real challenge.
- The DOE estimates that US will need an extra 375,000 workers to meet the 2050 target. “The very near term is going to require the skilled trades: electricians, metal workers, fabricators, construction” says Kathryn Huff, the head of the DOE’s Office of Nuclear Energy. The need for reactor operators and nuclear engineers will come later. “This is a blue collar blueprint to rebuild America” said President Biden.
- In France, in April 2023, the” Groupement des Industriels Français de l'Énergie Nucléaire “2(GIFEN) presented the government with the "MATCH" program, which sets out the capacities and requirements of the nuclear industry over the period 2023-2033, as it prepares to relaunch itself. Extrapolated to all 220,000 jobs in the nuclear industry, the foreseeable need would be around 100,000 full-time equivalent recruitments.
- But in a tight labor market it is unclear where all those workers will come from.

**FIGURE 7**

Estimated FTE requirement (French nuclear field)



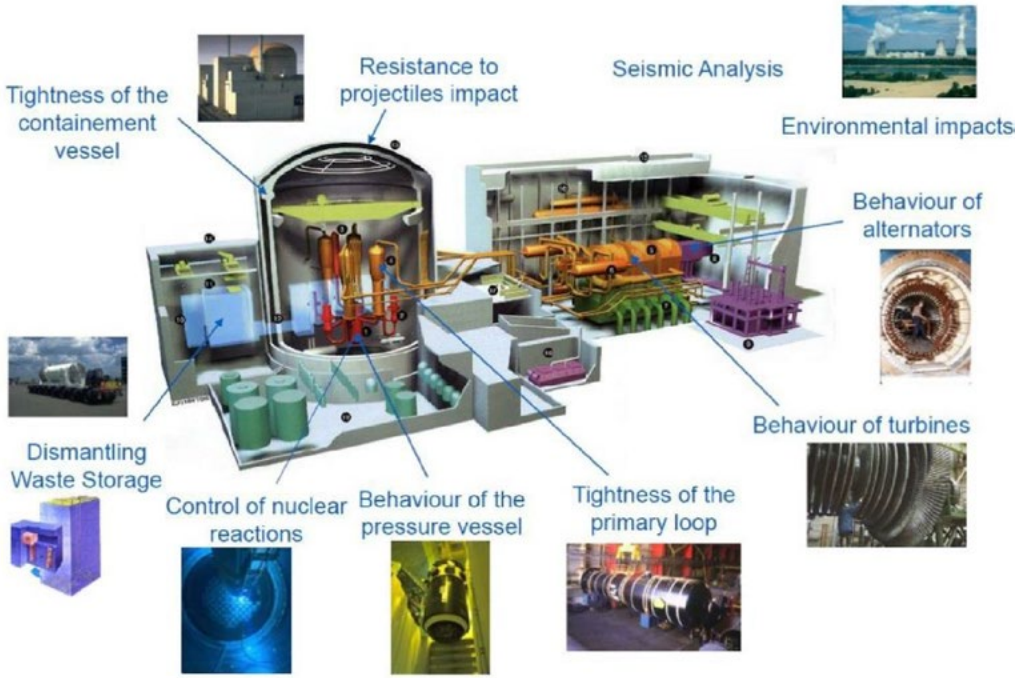

Source: Match Report

## Digital technologies are a strategic lever for productivity, performance, quality, and nuclear safety.

- Digital technologies are now reaching maturity and are considered as key enablers. Numerous initiatives by companies of all sizes, including startups, are now underway at every stage of the life cycle of nuclear facilities, including design and simulation, construction and manufacturing, operation, and maintenance, dismantling and waste management, and safety.
- Like EDF, the nuclear industry has embarked, at a more or less sustained pace, on an in-depth transformation that requires joint improvements to material flows (industrial processes, management of manufacturing deviations, etc.) and information flows (document exchanges, fault analysis, widespread use of 3D models, etc.), all supported by digital transformation (PLM, MES3, etc.).
- Ultimately, these investments will enable to control safety requirements, costs and "lead times."
- They will go hand in hand with the standardization of components and processes and contribute to better management of equipment performance.
- They will also enable each country to strengthen its competitiveness and win export contracts - with major benefits in terms of the balance of trade and high value-added jobs.
- Digital technology can make a major contribution to sharing the information needed to carry out security checks in a way that is both safer and more efficient, or to supplement these checks with artificial intelligence tools.

**FIGURE 8**

EDF has developed for 30 years its advanced simulation capacity, methodology and in-house software.




Source: EDF

# Conclusion

- The growing urgency of the climate change impact and, more recently, the energy crisis has wakened-up a global interest in nuclear energy.
- China is still leading the construction market with by far the most reactors under construction. However, Chinese companies are currently not building reactors outside their country. Russia is still largely dominating the international market as a technology supplier.
- In the OECD countries, more and more countries are announcing the launch of new programs or the desire to relaunch the nuclear industry. Beyond the challenges of decarbonizing society, these programs also aim to re-industrialize countries and consolidate their energy sovereignty.
- To that end, there are many challenges to be met, particularly in terms of resource requirements, financing in an era of increasing interest rates and controlling costs and deadlines.
- Industries have embraced the issue and are using digital technologies (typically digital twin programs) throughout the lifecycle of a reactor to improve performance and safety and reduce costs and lead times.
- There is much expectation surrounding the SMRs development, a new generation of nuclear reactors that are being marketed as the solution to nuclear power's previous shortcomings. The proliferation of initiatives worldwide, the unprecedented volume of investment and the competition between developers will lead to technological breakthroughs and a possible acceleration of the design and development phases.
- In addition to technology improvements a successful nuclear renaissance implies: a strong political will, available financing, public opinion (national and local) acceptance and approval processes acceleration.

# IS THE BATTERY INDUSTRY READY TO SUPPORT THE ENERGY TRANSITION?


TIM GERKENS, GERMANY


SIMON SCHÄFER, GERMANY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## Batteries are key – can they deliver?

**Electrification, combined with the usage of green energy, is a key lever to meet future $CO_2$ targets and transform industries towards climate neutrality. The expected growth of green technologies, such as electric cars or trucks, is extremely high and rapid. The fluctuation in renewable energy generation requires ramping up stationary battery energy storage systems for grid stability.**

**This shift causes the need for a significant increase in battery production. Can we meet the demands in time? Will the costs be bearable? Is the supply chain sustainable? Is there enough raw material accessible? Can the industry deliver what is needed?**

### The battery race is on

The race is on for the gigafactory and battery industry. The key to success is providing the required number of batteries quickly, at competitive cost and at scale.

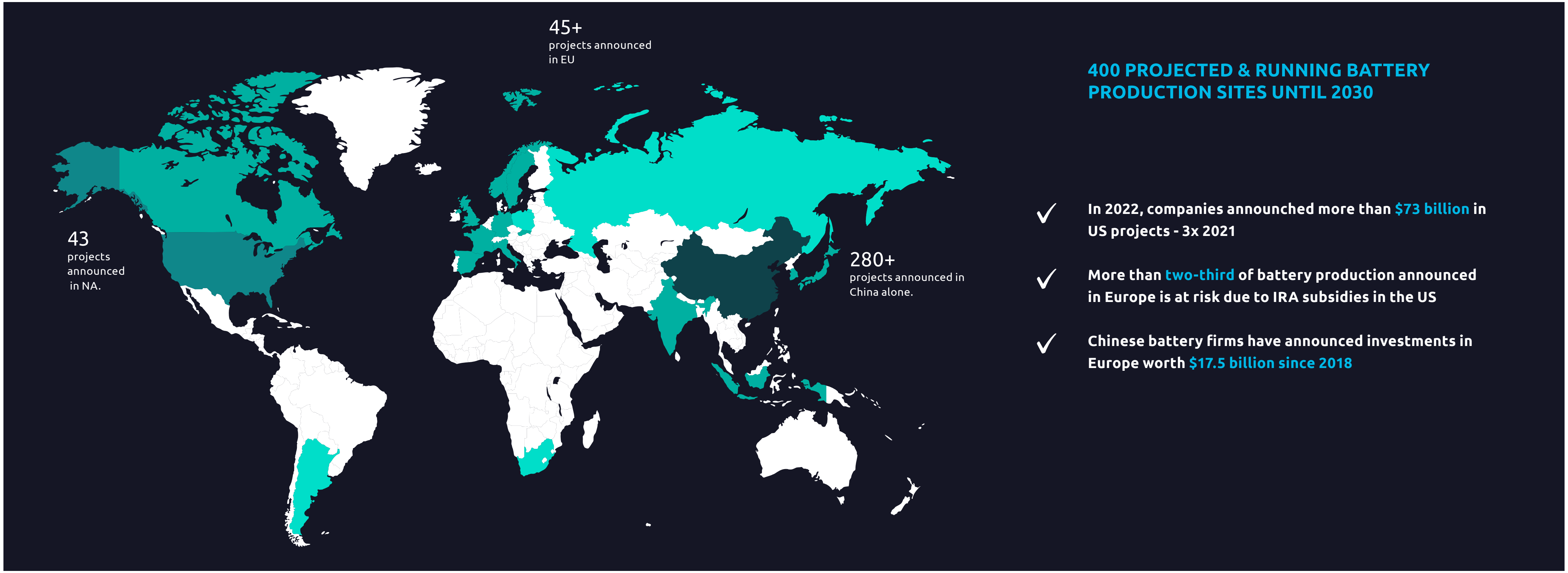
Major challenges in the battery industry include rapid scrap rate reduction, high and consistent quality, and increased throughput on the technical manufacturing side. But also, the war for talent, the need for sustainability across the entire value chain, and traceability to meet regulations are equally important. It is crucial to foster data for product and manufacturing improvements, as well as to successfully create new services and business models in order to remain competitive.

More than €300 billion in investments into gigafactories have been announced until 2030 already. More than 6.8 TWh are currently announced for 2030, covering the need of 3.5 TWh (APS scenario), which is six-fold today's capacity. However, being on the edge of meeting the net zero emissions (NZE) scenario requires 5.5 TWh if an 85% utilization is considered[1,2].


1 *Global EV Outlook 2023, IEA, Paris, p.121ff NZE Net Zero Emissions Scenario APS Announced Pledges Scenario*
2 *Benchmark Minerals Intelligence (2023) IRA supercharges USA's gigafactory capacity pipeline as it overtakes Europe for first time, Company Announcements*
*T&E (2023) Two-thirds of European battery production at risk, Company Announcements*

**FIGURE 1**

Announced battery production sites until 2030




Source: IAEA (PRIS)

# Digital, data, artificial intelligence (AI) – Driving the step change

Producing batteries and their components is costly and highly complex, and as a multitude of new organizations race to market, even the incumbent players have acknowledged they need to modernize and transform their operations. All players in the battery industry are facing a multitude of challenges. Two main ones are:

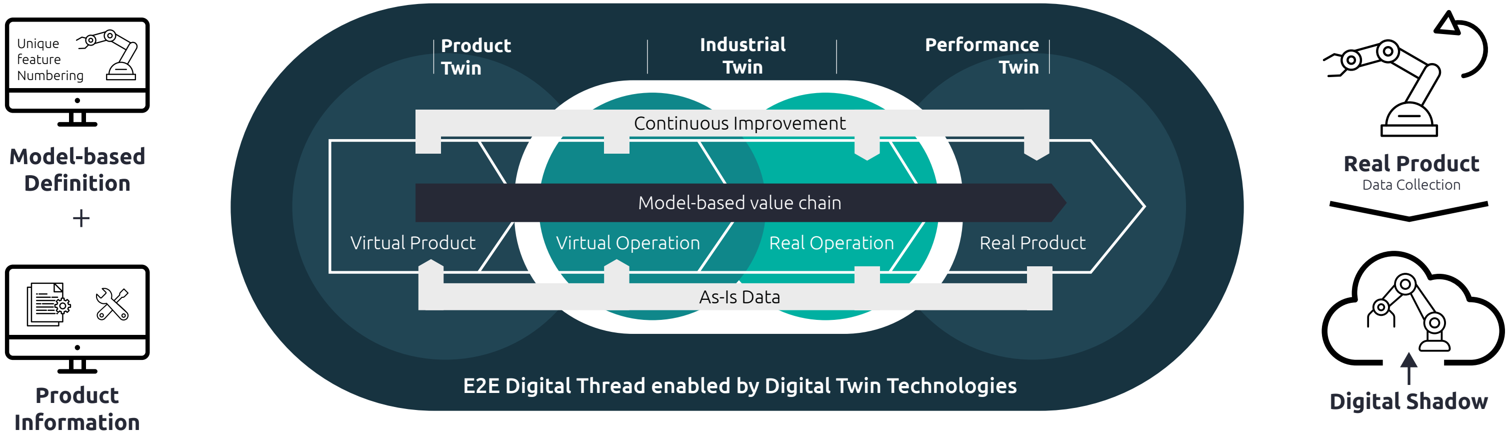
**Challenge #1: Time-to-Market:** It takes about five years from a small-scale pilot factory to the completion of a gigafactory with stable production. Given the current demand for battery and battery components, manufacturing organizations need ways to streamline their processes to get gigafactories up and running faster at scale and quality to remain competitive.

## Companies that do not produce in a short time at scale & at cost will not survive

**Challenge #2: High scrap rate:** It is not enough to quickly start production in a gigafactory. Today, gigafactories suffer from a high scrap rate of up to 30% in the ramp-up phase. Such waste and its associated costs are unsustainable from a business perspective, as a 10% scrap rate reduction can save $200-$300 million per annum for a 30 GWh factory[3]. Furthermore, gigafactory high scrap rates result in increased energy consumption and more waste, not to mention costly delays in production.

**FIGURE 2**

Digital Twin enables continuity between R&D and operations to accelerate the commissioning and ramp up




3 Battery Power (2023), *The Cost Benefits Of Investing In Solutions To Reduce Battery Waste And Scrappage In Gigafactories, Hitachi High Technologies*

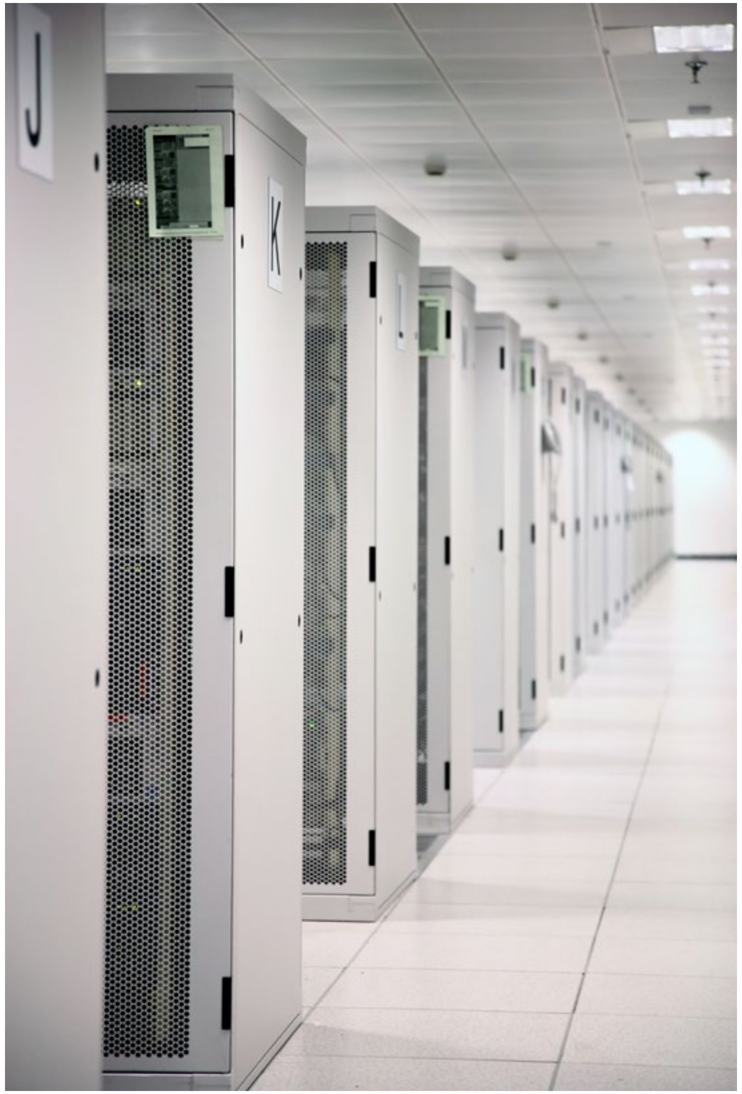
## Enabling a step change through digital and data

So, how can the industry overcome these challenges? How can a step change be made? Certainly not by optimizing the traditional approach, but by adopting a data-driven battery development and production method.

**Taking a simulation-first approach to gigafactory development:** By leveraging digital twins of the cell, pack, and manufacturing process, as well as the gigafactory as a whole, organizations can virtually design and commission optimal production lines, thus minimizing extensive prototyping and avoiding costly changes on the factory floor. The right combination of digital solutions and services is believed to bring the required acceleration in production ramp-up in the battery industry.

**Connecting the digital and physical manifestations of gigafactories:** By integrating data from virtual and physical facilities, organizations can facilitate end-to-end integration of the production process and accelerate physical commissioning. Combining virtual and physical data can identify and help organizations address potential quality or production issues early. Teams on the shop floor can act fast, assisted by data-driven automation and decision aiding, to accelerate manufacturing ramp-up and operations at scale.

**Developing and deploying a data-driven operations strategy:** Data and the use of AI are the backbone of a step change in gigafactory performance. Organizations can leverage data from the Industrial Internet of Things (IIoT) to identify potential quality issues and make changes to meet market needs. It is recommended to start from a data-centric architecture blueprint for the battery industry and associated ontologies, tailoring it to the client's best fit and requirements. An end-to-end solution and deployment of hardware and software solutions and services from the enterprise level to the shop floor is needed. The key is to enable a fully data-driven and closed-loop operation based on a highly scalable, flexible, and interoperable architecture. This helps organizations develop a solid data platform and a standardized data model that permits interoperability from different sources to access and analyze the information they need. Based on proof of concepts with clients and industry, companies can achieve scrap rate reduction significantly faster with data-driven manufacturing solutions and services.



## Upstream supply chain – is the raw material supply sufficient?

Lithium prices are expected to remain high in the mid to long term as capacity shortages are announced. Scenarios considering varying future cell technology show that the need for lithium is growing by a factor of around 40 between 2020 and 2040, leading to potential supply risks[4].

**Challenge #1: Global transformation:** The extraction and transformation of metals carry a high social and environmental cost. Metal supply is becoming increasingly critical, commercial tensions between miners and their industrial customers are growing, and regulations are creating new constraints.

**Challenge #2: Complex Sourcing:** The extension of the battery metals sector is slow. Difficulties and delays are evident in industrializing innovative new plants, whether upstream for metal production and refining or downstream for battery production. Multi-sourcing will be imperative for several years to come, in order to guarantee supply quantities and lead times.

**Challenge #3: New Logistics:** Requirements of gigafactories are modest in individual terms, but micro-batch logistics need to be invented by miners, wholesalers, logisticians, and traders, who are more accustomed to managing bulk quantities of ores and metals.

**Challenge #4: Legislative:** The regulatory requirement for end-to-end traceability of battery quality and corporate social responsibility (CSR) certification of the metal extraction and transformation process demands the implementation of many digital services and complex electronic exchanges between all players in the value chain.

**Challenge #5: Up-front Financing:** The lack of a strategic vision by public authorities in the past meant that mining players were unable to find the support needed to obtain financing.

## Coalitions of interest and digitization can turn things around

Studies show that today, the metals and mining industry qualifies as a data-poor environment and can be described as less digitally mature than comparable industries, such as automotive or chemicals[5]. However, by accelerating digital transformation, metals and mining players can boost throughput, simplify processes, lower costs, improve metal recovery and yield, save energy and reduce supply chain complexity. This can give economically viable access to more battery metals. Many companies are willing to embrace a digital strategy and reap its benefits. However, when it comes to conversion, there is a gap that exists due to specific industry requirements and old-fashioned ways of doing things.

The mining companies are forced to change. As outlined, regulations like the European battery passport require the change to digital and improved traceability. This opens unique opportunities to use the regulatory required data and the necessary infrastructure, enrich it with additional data, and run specific intelligence for real-time and long-term insights and decisions.

Also, systems need to be set up to ingest and use data to be fully connected to the ecosystem and make use of its digitization efforts. Conversely, it is imperative to incorporate third-party market services and platforms into the comprehensive digital strategy to optimize their utilization.

For Europe and North America, it is a chance to take the lead by defining and agreeing on a governance structure, marketing methods, associated services, and technological underpinnings for a unified solution.

### Can circularity fill the gap? Or new chemistries?

Currently, the recycling industry cannot provide significant additional volumes, which means it cannot fill the gap in battery metal supply immediately. This is due to a shortage of recycled batteries, the immaturity of the recycling process due to product complexity, and the availability of recycling facilities.

The continuous innovation in the chemistries for battery cells is trying to lower the dependency on rare metals such as cobalt or lithium. How quickly these new concepts can really change the predicted demand for scarce resources needs to be proven. Still, in other industries, emergencies have accelerated such processes.

4 IEA (2021), The Role of Critical Minerals in Clean Energy Transitions, IEA, Paris
5 Rockwell (2021) The Connected Mine Evolution
WEF (2023) Connected, Safe, Intelligent – Mining in Modern Age
BGR (2020) Assessment of the Effects of Global Digitalization

# Recycling of batteries – starting with gigafactory scrap

The topic of recycling is becoming increasingly important. While in the short term, most gigafactory scrap is used in recycling. Within this decade, the recycling market will grow to an estimated market size of $19-22 billion by 2030[6]. A growing number of batteries are on the market, and they will reach end-of-life. Therefore, significant growth opportunities in the recycling space are emerging.

Within the recycling market, several challenges regarding technology, profitability, logistics, and safety need to be solved:

**Challenge #1: Changing battery designs:** Evolving and diverse battery designs and materials create a need for automated sorting and design for recycling.

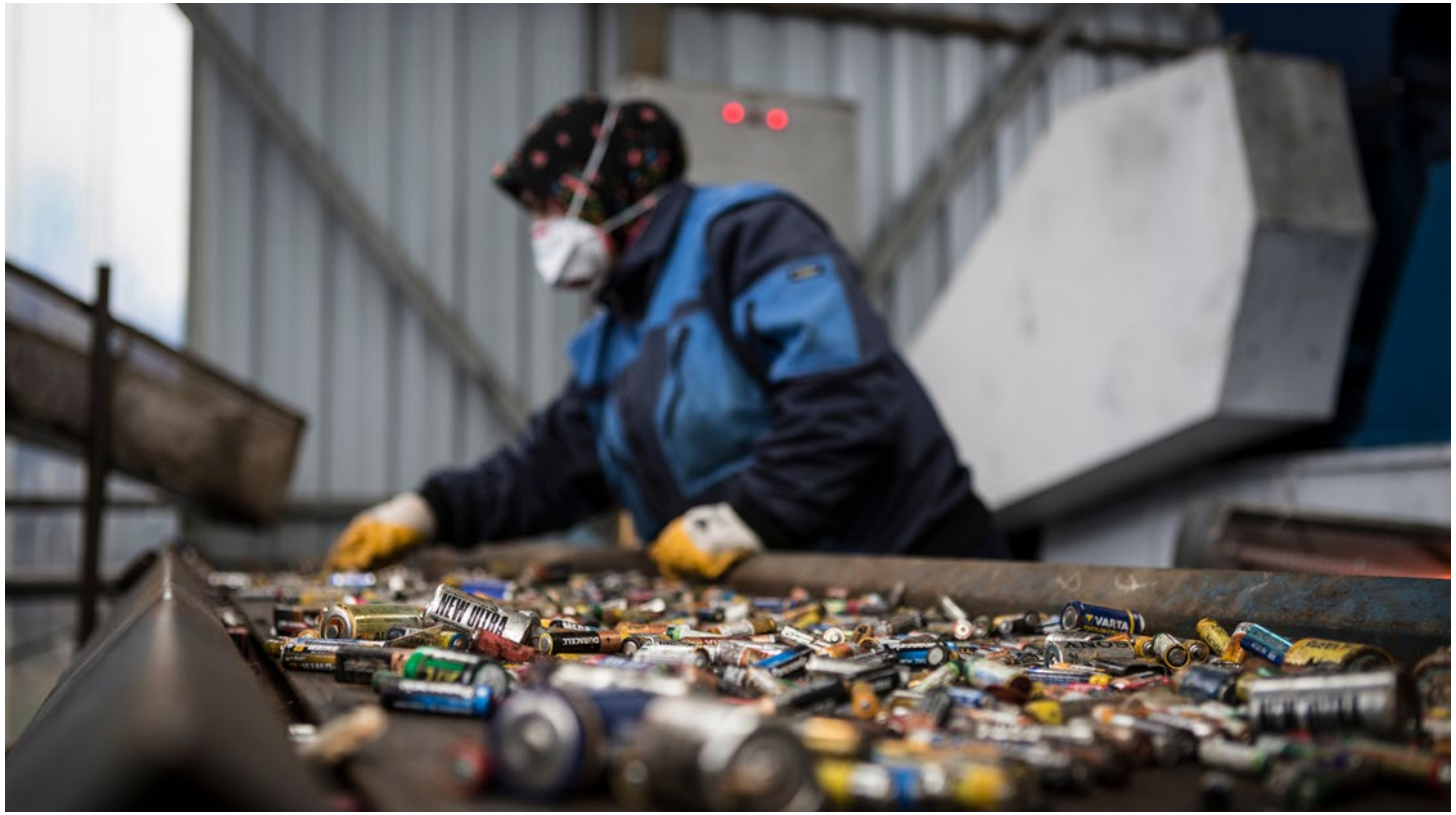
**Challenge #2: Safety hazards and manual effort:** Separation of components is technically challenging with safety hazards and requires manual work.

**Challenge #3: Scalability and ramp up:** Scaling up and industrialization of recycling technologies is necessary to handle gigafactory scrap, but also to be ready for future recycling volumes.

**Challenge #4: Commercial impact:** Maintaining economic viability is challenging as it is cost- and energy-intensive.

**Challenge #5: Traceability in recycling:** Complex supply chains and a lack of standardization has led to challenges. Transparent information about the battery's health and used materials must be available digitally at end-of-life.

**Challenge #6: Collection and transportation:** A lack of efficient collection and transportation systems for used lithium batteries leads to increased costs and challenging business cases.



6 Marketresearch Future (2023), *Lithium-Ion Battery Recycling Market*,
EMR (2023) *Global Battery Recycling Market Outlook*

### The race is open to seize a fast-growing market

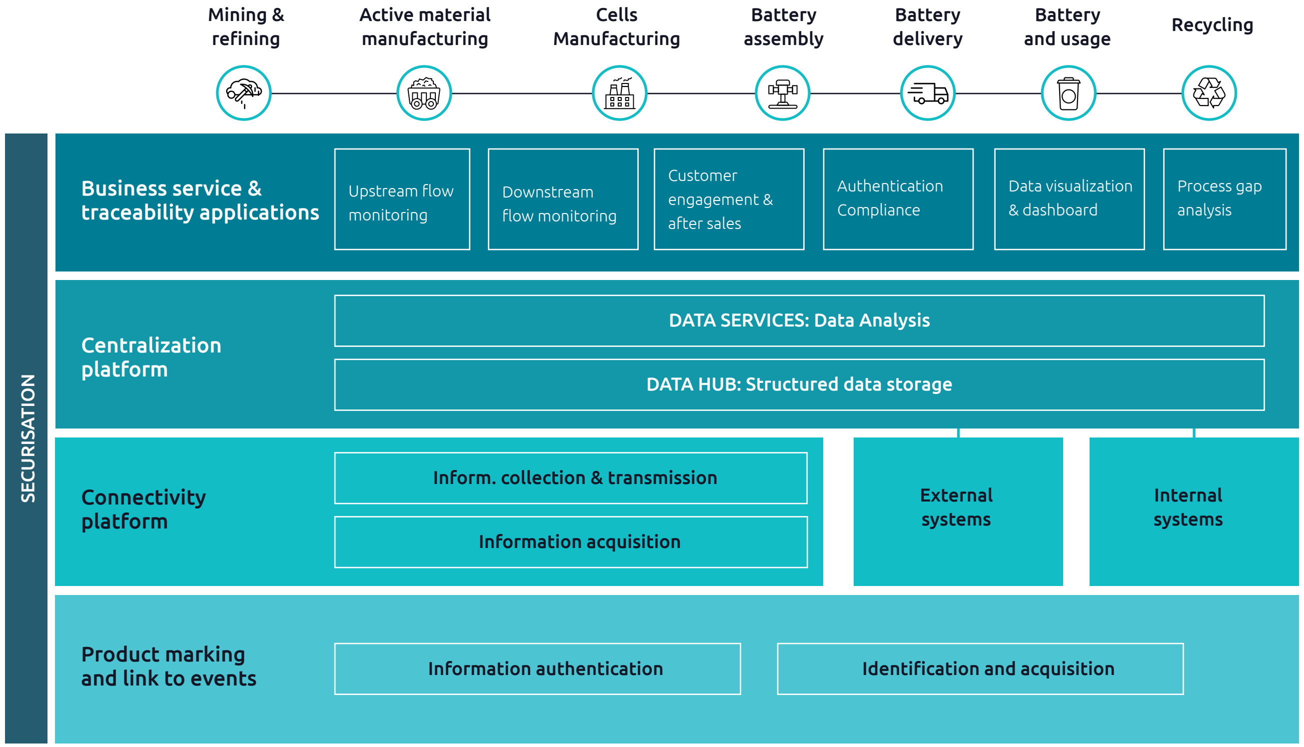
Due to the current lack of batteries to be recycled at scale, it is a different situation than in the battery manufacturing industry, where demand is high. But at some point, the industry must be ready to follow the ramp-up of electric vehicle (EV) battery production. Until then, use the time to develop the technologies and digital enablers to ramp up quickly. The processing of the scrap produced during cell production and battery assembly is therefore where innovations can be developed and tested already.

## How digital tools can enable the circular economy for batteries

To cope with the various challenges of the recycling industry, there is a need to leverage data and implement digital tools. Digital continuity and traceability powered by digitization provide better information about a battery when it comes in for recycling. As a result, disassembly of physical and chemical components can be automated and made safer, faster, and cheaper. The digital twin of batteries assists in algorithm training and facilitates virtual testing for machine-driven innovations in battery design for simplified recycling. This occurs prior to physical implementation, resulting in expedited and cost-effective development and improvements. Such models and processes capture knowledge for faster replicability and efficient scaling-up of recycling capacity. Integrated into the overall (extended) enterprise, information technology/operational technology (IT/OT) architecture, scrap and recycling management becomes automated and efficient, providing additional data from the analysis that can flow back into the manufacturing process and product improvements.

**FIGURE 3**

E2E traceability is enabled by a multi-technological ecosystem



## Who will design, produce, and recycle all these batteries?

In this rapidly expanding industry, which is projected to maintain a compound annual growth rate (CAGR) of over 29% in the next decade, both, well-established companies and newcomers, are vying for a highly skilled workforce.

**Challenge #1: Lack of talent:** There is a surge for specific battery skills in the market, but the market cannot deliver the needed expertise or the quantities required. A wide range of experts are needed to successfully ramp up new battery development and gigafactory production, ranging from electrochemists, system engineers, process engineers, and digitalization specialists, as well as large amounts of qualified blue-collar workers for the production. By 2025, about 800,000 workers must be upskilled, trained, or reskilled to meet the growing workforce demand[7]. Companies must find a way to be very efficient in training the workforce, and to be an employer of choice to retain employees.

### Making it simple is key

**Challenge #2: Limited time to train & gather experience:** Although there is a need for a rapid ramp-up in operations, the time available to train people is limited. This limitation, combined with the shortage of skills, can only be addressed when the amount of training needed is reduced. Therefore, the work needs to be simple, straightforward, and easy to understand while being safe, effective, and attractive to keep talent.

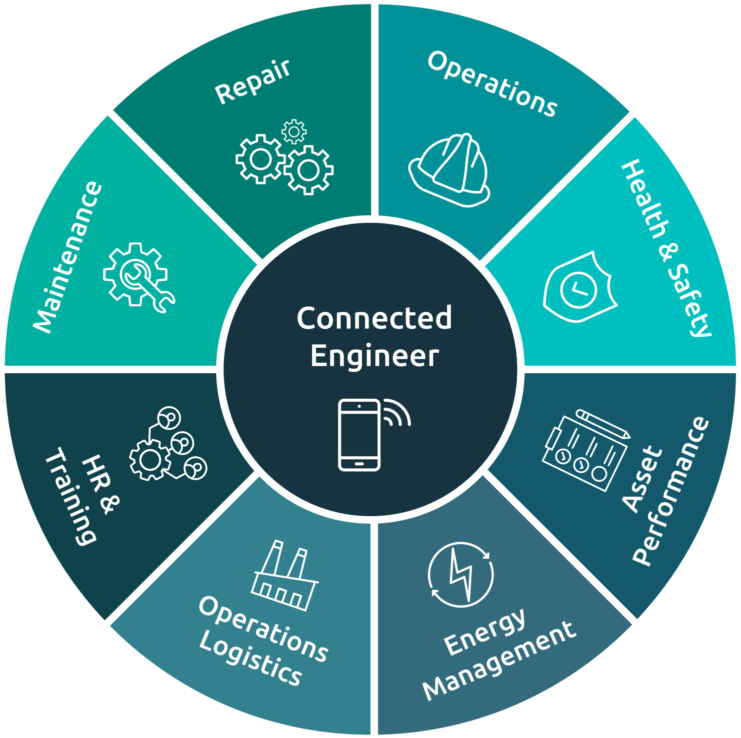
## The new way of working is a digitally enabled operator

To address these challenges, it is necessary to implement innovative and intelligent methods for training, support, and operations. The opportunities that digitization and data bring to the table need to be leveraged to the maximum potential.

To achieve a high plant efficiency quickly, a skilled workforce is essential. Higher automation, more autonomous decisions, and AI-based decision aids will reduce the needed skill level in the workforce, leaving specific knowledge to a smaller group of specialists. It is crucial to capture and formalize specialist knowledge, making it available to the workforce through automation/decision aids and agile training elements. Ontologies, natural language processing, and generative AI, all smartly combined, are a means to realize such knowledge capture and the basis of making it available again.

**FIGURE 4**

Future Operator: Connected or Augmented Worker solution to maximize organizational performance




7 EIT Inno Energy (2022) *European Commission set to grant EIT InnoEnergy 10 million Euros to bridge growing skills gap across battery value chain*

## Levers for talent upskilling

Making training as real as possible, ensuring continuous lessons learned flow into training, and reacting to the latest changes, advancements and insights are key. Hence, it is imperative to integrate the training system into the operational system, ensuring connectivity to a single source of truth. This enables the seamless linkage of operational changes and insights directly into training and expert support, facilitating immediate feedback and improvement. It also provides the opportunity, using tools like augmented reality/virtual reality (AR/VR), to offer training during regular operations for continuous skill enhancement, including real-time corrections and support.

Basic training shall be real, interesting, and to the point. Digital twins and synthetic environments are a means to train a larger staff, regardless of location, which is also essential when replicating gigafactories worldwide. Just as the factories are to be network-managed, so too will the training. Variations across locations and production lines are pinpointed through end-to-end traceability across products, processes, and factories, allowing for the management of their impact on training.

The future of work lies with connected and digitally enabled operators, making things easier and more efficient, as well as safer, more enjoyable, and rewarding for the workforce.

# Conclusion

## Battery players need to holistically embrace digital and data to win the gigafactory race

Data-driven business agility is the core of successful gigafactory design, industrialization, and operation. A holistic enterprise architecture designed for a fully digital and data-driven system provides the framework needed while ensuring digital continuity.

This approach not only yields benefits in product, process, and factory engineering but also offers advantages in terms of time to market and cost. Moreover, adjacent disciplines should seamlessly integrate, utilize a common single source of truth, and harness the generated data to maximize their effectiveness. Supply chains driven by upcoming regulations and training must be fully digitally integrated to improve company performance and address current challenges.

With recycling being an integral part of a factory and an important piece of the value chain, the gigafactory must be entirely digitally integrated, both internally and externally, for effective battery production at cost and scale.

The battery industry is a closed-loop ecosystem with high investment, many challenges, and potential risks, but also great opportunities. Going digital by design across the whole value chain is mandatory to be successful.

**FIGURE 5**

Accelerating in overcoming challenges is crucial for market success

# ELECTRIC VEHICLES: MARKET REVIEW AND RECENT TRENDS

MATTHEW MORRIS, UK

MIKE LEWIS, UK

## Trends in electric vehicle markets

| Trend Category | Major Trends | Additional comments |
|---|---|---|
| Trends in electric light-duty vehicles | Electric car sales continue to increase, led by China | In 2022, China was the frontrunner once again, with **China accounting for around 60%** of all new electric car registrations globally |
| | Over 26 million electric cars were on the road in 2022, up 60% relative to 2021 and more than 5 times the stock in 2018 | The increased sales resulted in **more than 26 million electric cars** on world's roads in 2022, representing a 60% uptake from 2021 |
| | The number of electric car models rises, especially for large cars and SUVs, at the same time as it decreases for conventional cars | The race to electrification is increasing the number of electric car models available on the market. In 2022, the number of available options reached 500, up from below 450 in 2021 and more than doubling relative to 2018-2019 |
| | Emerging markets see encouraging growth | China, Europe and the United States , the three major markets for electric cars , accounted for about **95% of global sales in 2022** |
| | Sales of electric light commercial vehicles continue to increase, catching up with electric car sales | Electric light commercial vehicle (LCV) sales worldwide nearly doubled in 2022 relative to 2021 to more than 310 000 vehicles, even as overall LCV sales declined by more than 10% |
| | Electric two-wheeler sales declined in China while global electric three-wheeler sales continued to rise | Global electric two-wheeler sales totalled **about 9.2 million** in 2022, a drop of nearly 18% from 2021. This drop is almost entirely attributable to the dip in sales of electric mopeds and motorcycles in China, which fell from 10.2 million in 2021 to under 7.7 million in 2022, even as the overall two-wheeler market there continued to grow |
| Trends in electric heavy-duty vehicles | Electric truck and bus sales shares | In 2022, **nearly 66,000 electric buses and 60,000 medium- and heavy-duty trucks** were sold worldwide, representing about 4.5% of all bus sales and 1.2% of truck sales worldwide. |
| | Zero-emission vehicle model availability expanded in 2022 in the medium- and heavy-duty truck segments | The number of models on offer for zero-emission trucks has continued to expand in 2022, with nearly 840 current and announced medium- and heavy-duty vehicle models in the Global Drive to Zero Emission Technology Inventory (ZETI) database |
| | China dominates heavy-duty battery production | European and North American electric bus and truck makers rely heavily on Asian battery makers. Given their dominance in lithium iron phosphate (LFP) battery chemistries, China's CATL produces the vast majority of batteries for trucks |

# EV sales in 2022

| | Cars | Buses | Trucks | Vans | Total |
|---|---|---|---|---|---|
| **Global** | **10,200,000** | **65,400** | **59,500** | **307,900** | **10,632,800** |
| **China** | 5,900,000 | 54,300 | 51,500 | 131,500 | 6,137,300 |
| **Europe** | 2,600,000 | 4,770 | 2,815 | 92,200 | 2,699,785 |
| **North America** | 1,112,400 | NA | NA | NA | 1,112,400 |

Source: IEA

- Electric car sales exceeded 10.6 million in 2022, with a total of 14% of all new cars sold were electric in 2022, up from around 9% in 2021 and less than 5% in 2020
- This resulted in more than 26 million electric cars on world's roads in 2022, representing a 60% uptake from 2021
- Battery electric vehicles (BEV) accounted for over 70% of total annual growth, as in previous years
- Three markets, viz. China, Europe and the United States dominated the global sales.
- China was the frontrunner once again, accounting for around 60% of global electric car sales. More than half of the electric cars on roads worldwide are now in China and the country has already exceeded its 2025 target for new energy vehicle sales
- In Europe, the second largest market, electric car sales increased by over 15% in 2022, which implies that more than one in every five cars sold was electric
- Electric car sales in the United States , the third largest market, increased 55% in 2022, reaching a sales share of 8%

# Cumulative electric vehicles sales (2010-22)

| Year | Buses | Cars | Trucks | Vans | EV - Grand Total |
|---|---|---|---|---|---|
| 2010 | 2000 | 7570 | 24 | 1600 | **11194** |
| 2011 | 1010 | 48000 | 300 | 3700 | **53010** |
| 2012 | 2600 | 118000 | 450 | 11011 | **132061** |
| 2013 | 5700 | 201000 | 910 | 11005 | **218615** |
| 2014 | 16300 | 330000 | 380 | 11020 | **357700** |
| 2015 | 121000 | 550000 | 17000 | 27780 | **715780** |
| 2016 | 106000 | 750000 | 15005 | 23170 | **894175** |
| 2017 | 91530 | 1180000 | 81000 | 86140 | **1438670** |
| 2018 | 98600 | 2050000 | 57600 | 80190 | **2286390** |
| 2019 | 81700 | 2080000 | 38400 | 59280 | **2259380** |
| 2020 | 73700 | 2970000 | 34420 | 86500 | **3164620** |
| 2021 | 56900 | 6500000 | 41000 | 156300 | **6754200** |
| 2022 | 65400 | 10200000 | 59500 | 307900 | **10632800** |
| **EV - Grand Total** | **722,440** | **26,984,570** | **345,989** | **865,596** | **28,918,595** |

# Electric Vehicles-Three Major Markets

## China, Europe and the United States - the three major markets for electric cars , accounted for about 95% of global sales in 2022.

### China

- In 2022, China was the frontrunner once again, with China accounting for **around 60% of all new electric car registrations globally**
- Half of the world's electric cars are in China, with more than 50% of all the electric cars on the world's roads, a total of **13.8 million**
- In 2022, battery electric vehicles (BEV) sales in China increased by 60% relative to 2021 to reach **4.4 million,** and plug-in hybrid electric vehicles (PHEV) sales nearly tripled to **1.5 million**
- In 2022, the share of electric cars in total domestic car sales reached 29% in China, up from 16% in 2021 and under 6% between 2018 and 2020. China has therefore achieved its 2025 national target of a 20% sales share for so-called new energy vehicles (NEVs) well in advance

### Europe

- Europe accounted for **10% of global growth** in new electric car sales
- In Europe, electric car sales increased by more than 15% in 2022 relative to 2021 to reach **2.7 million**
- Despite slower growth in 2022, electric car sales are still increasing in Europe in the context of continued contraction in car markets: total car sales in Europe dipped by 3% in 2022 relative to 2021
- Europe remained the world's second largest market for electric cars after China in 2022, accounting for **25% of all electric car sales and 30% of the global stock**
- European countries continued to rank highly for the sales share of electric cars, led by Norway at 88%, Sweden at 54%, the Netherlands at 35%, Germany at 31%, the United Kingdom at 23% and France at 21% in 2022.
- In volume terms, Germany is the biggest market in Europe with sales of **830,000 in 2022, followed by the United Kingdom with 370,000 and France with 330,000.**
- Sales are expected to continue increasing in Europe, especially following recent policy developments under the **'Fit for 55' package.**

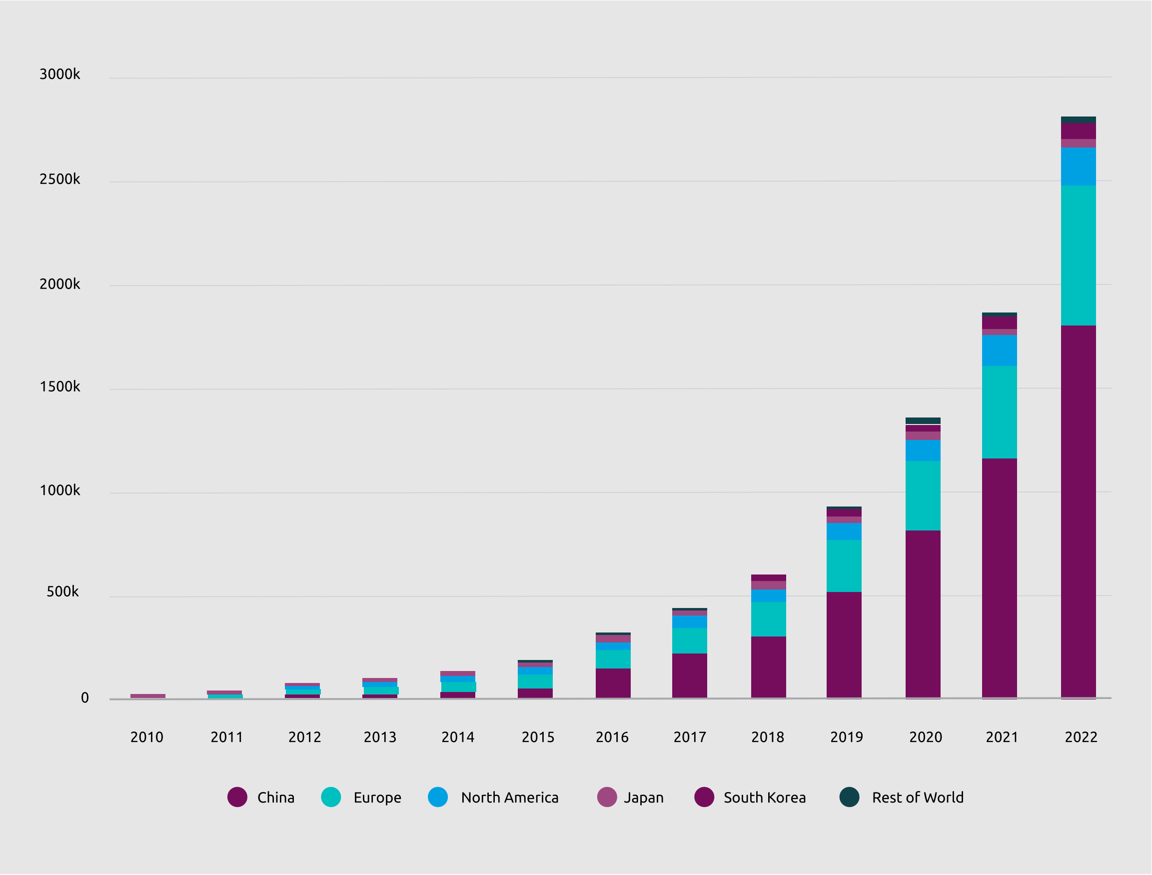
### United States

- In the United States, electric car sales increased **55% in 2022** relative to 2021, led by battery electric vehicles (BEVs)
- **Sales of BEVs increased by 70%,** reaching nearly 800,000 and confirming a second consecutive year of strong growth after the 2019-2020 dip.
- Sales of plug-in hybrid electric vehicles (PHEVs) also grew, however by only 15%
- Overall, the United States accounted for **10% of the global growth in sales**
- The total stock of electric cars reached 3 million, up 40% relative to 2021 and accounting for 10% of the global total.
- The Inflation Reduction Act (IRA) has triggered a rush by global electromobility companies to expand US manufacturing operations
- Between August 2022 and March 2023, major EV and battery makers announced cumulative post-IRA investments of **USD 52 billion in North American EV supply chains,** of which **50% is for battery manufacturing,** and **about 20% each for battery components and EV manufacturing**

# EV charging infrastructure

**FIGURE 1**

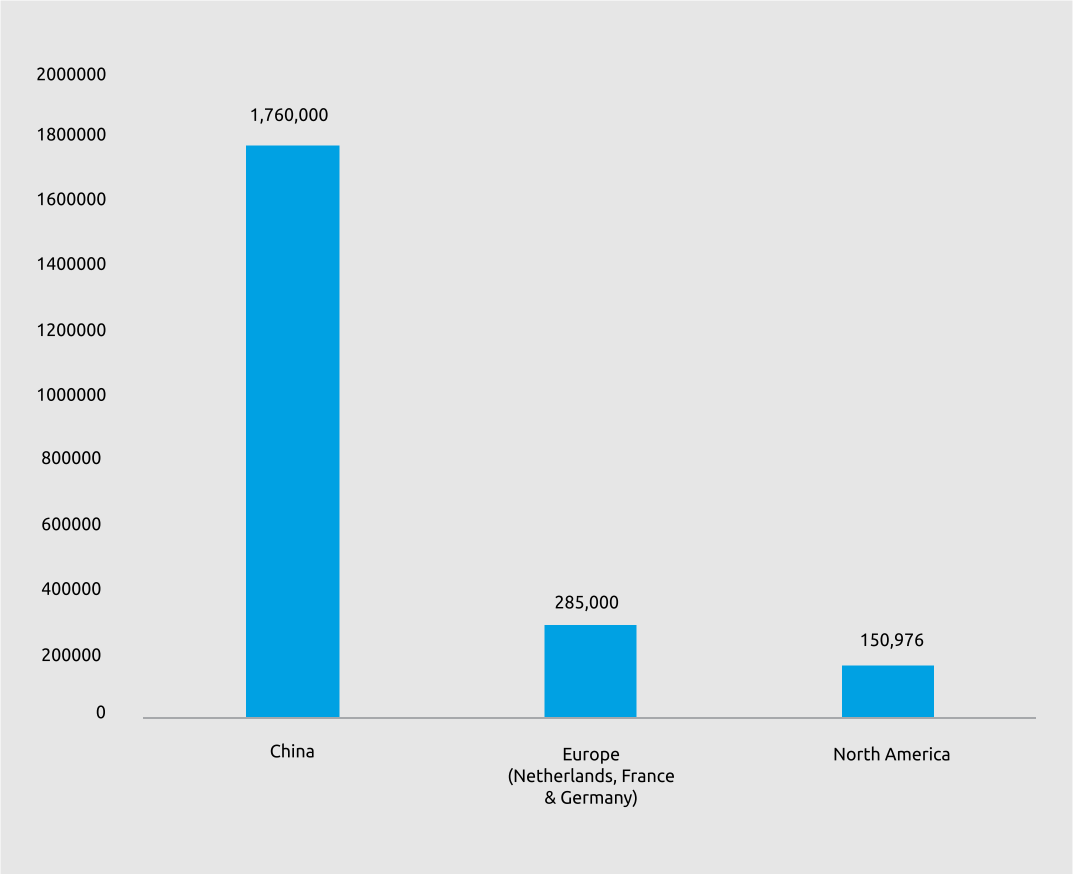
EV charging infrastructure (2010 - 2022)




Source: Bloomberg NEF

**FIGURE 2**

EV charging points (2022)




Source: IEA

At the end of 2022, there **were 2.7 million public charging points worldwide,** more than 900,000 of which were installed in 2022, about a 55% increase on 2021 stock

## Slow chargers:

- Globally, more than 600,000 public slow charging points were installed in 2022, 360,000 of which were in China, bringing the stock of slow chargers in the country to more than 1 million
- At the end of 2022, China was home to more than half of the global stock of public slow chargers
- Europe ranks second, with 460,000 total slow chargers in 2022, a 50% increase from the previous year
  - The Netherlands leads in Europe with 117 000, followed by around 74 000 in France and 64 000 in Germany
- The stock of slow chargers in the United States increased by 9% in 2022, the lowest growth rate among major markets

## Fast chargers:

- The number of fast chargers increased by 330,000 globally in 2022, though again the majority (almost 90%) of the growth came from China; China accounts for total of 760,000 fast chargers
- In Europe, the overall fast charger stock numbered over 70,000 by the end of 2022, an increase of around 55% compared to 2021
- The United States installed 6300 fast chargers in 2022, about three-quarters of which were Tesla Superchargers. The total stock of fast chargers reached 28,000 at the end of 2022.

# Electric Motorcycles and Trucks

FIGURE 3

Electric Motorcycles and Trucks

| | China | ASEAN[4] | North America and Europe | India | Other South Asia | Latin America | Africa |
|---|---|---|---|---|---|---|---|
| 2021 market size,[1] million units | ~15.0 | ~12.0 | 2.1 | 15.1 | 2.3 | ~2.8 | ~1.0 |
| Estimated CAGR 2021-30, % | 0-1 | 4-5 | 5-6 | 6-7 | 5-6 | 5-6 | 12-14 |
| Moped/ Bebek,[2] % | – | 15-20 | – | 3-4 | 0-5 | 15-20 | 0-5 |
| Scooter, % | 80-85 | 70-75 | 25-30 | 28-30 | 25-30 | 0-1 | 0-1 |
| Light motorcycle, % | 0-5 | 5-10 | 10-15 | 60-65 | 65-70 | 70-75 | 90-95 |
| Heavy motorcycle,[3] % | 0-5 | 0-5 | 50-60 | 4-5 | 0-5 | 0-5 | 0-5 |
| Electrification level, % | ~15 | ~2 | ~8 | ~4 | <1 | <1 | <1 |

Source: McKinsey & Company

## Electric Motorcycles:

- It is predicted that electrification could also transform two-wheelers, viz. the mopeds, scooters, motorbikes, and motorcycles that account for about 30% of global mobility
- These vehicles are an essential link in the transportation network, especially in China, South Asia, and Southeast Asia, with about 45 million units sold in fiscal year 2021
- The global two-wheeler market is projected to have a compound annual growth rate of 8.7 percent through 2029 when it will reach a value of about $218 billion
- While China and the developing world concentrate on smaller, typically work- or transportation-focused machines; North America (excluding Mexico) and Europe are more bifurcated, with premium brands selling more than 500 cubic capacity products

## Electric Trucks:

- In 2022, around 60,000 medium- and heavy-duty trucks were sold worldwide, representing about 1.2% of truck sales worldwide
- In 2022, an estimated 52,000 electric medium- and heavy-duty trucks were sold in China, representing 4% of total sales in China and about 85% of global sales
- In addition, many of the trucks being sold in Latin America, North America and Europe are Chinese brands
- Electric trucks sales shares remain low across most major markets. With the exception of China, cumulative electric medium- and heavy-duty truck sales to date number in the hundreds in most countries (just under 2000 electric trucks were sold across the entire European Union in 2022)

# Accelerating to net zero

**Through a combination of government incentives, regulations evolutions, technology improvements, and the potential for cost savings, the past five years have seen a significant increase in the adoption of electric vehicles (EVs) by private citizens and businesses alike.**

**Between 2019-23 global EV growth rose from 2m vehicles to 11m. Similarly, electric vehicle charging facilities grew from 500,000 sites to over 2 million in the same period.**

**The next five years will be critical to supporting the global energy transition and revealing if electricity can be the long-term fuel for road transportation.**

We see 5 technological that must mature within the time period:

**Challenge #1: Expansion of public charging infrastructure**
As the demand for EVs continues to grow, it must be supported by rapid growth of the public charging infrastructure

**Challenge #2: Home charging solutions**
Home charging options must become more diverse and accessible. EV owners will have a range of choices, from standard AC charging stations to faster Level 2 chargers and even more advanced Level 3 DC fast chargers installed at residences.

**Challenge #3: Smart-Grid Integration**
Vehicle-to-Grid/Home/Buildings (V2G/H/X) technology: In support of smart-grid evolution, V2G technology will be critical in smoothing the demand curve and the load-demand balance for the electric system.

**Challenge #4: Wireless charging technology**
Wireless charging technology is already proven to work, and will continue to advance and gain popularity in the coming years.

**Challenge #5: Digital Customer Experiences**
Enhanced user experience through digital solutions: Of all the technological forces within the EV and charging ecosystem, it is the area of delivering digital customer experiences which has made the least relative progress.

## Challenge 1: Public charging infrastructure

As the demand for EVs continues to grow (forecasts suggest over 110m units produced worldwide by 2028 1), it must be supported by rapid growth of the public charging infrastructure. Governments, utility companies, generators, and regulators, as well as private entities, will need to coordinate, cooperate, and invest in building charging stations in centers of population and across the road network. The goal of eliminating range anxiety and establishing a dependable, widespread charging infrastructure aims to enhance the accessibility and convenience of EV charging for both current electric vehicle drivers and prospective first-time buyers.

Public charging infrastructure – which will need to be a network or networks provided by incumbent fuel retailers, dedicated EV charging companies, or small-scale local public interest groups – will need to provide a combination of low-power and high-power fast-charging networks to suit the needs of different driver scenarios.

The prevalence of high-power fast-charging networks will accelerate, enabling EV drivers to charge their vehicles rapidly. However, while they drastically reduce charging times, advanced charging technologies such as 350 kilowatts (kW) place a higher load on the overall power grid.

To enable electric vehicles for long-distance travel to rival the convenience of internal combustion engine vehicles, we must effectively utilize a blend of battery storage and advanced smart grid methods, ensuring drivers have reliable access to the power they require precisely when they need it.  IE 2 have noted in most countries  as the number of EV's on the road increases, the number of publicly available charging points is decreasing.

## Challenge 2: Home charging solutions

Home charging options must become more diverse and accessible. EV owners will have a range of choices from standard AC charging stations to faster Level 2 chargers, and even more advanced Level 3 DC fast chargers installed at residences. Smart charging systems will integrate with renewable energy sources and allow for optimal charging times to reduce costs and maximize efficiency.

## Challenge 3: Smart grid integration

In support of smart grid evolution, V2G technology will be critical in smoothing the demand curve and the load-demand balance for the electric system by allowing EVs to not only consume electricity but also feed it back to the grid or the home when needed. This capability will need to become more widespread, perhaps as part of future home charging solutions. Creating a two-way flow of electricity between vehicles and the power grid also requires modifications to most domestic electrical systems. EV owners may need incentives to participate in demand response programs to support utilities in using the stored energy in EV batteries to balance the grid during peak demand periods.

## Challenge 4: Wireless charging technology

Wireless charging technology is already proven to work and will continue to advance and gain popularity in the coming years. As with all aspects of EV and smart grid, the ability to access the benefits of this innovation is dependent on the speed at which it can be added to national infrastructure.

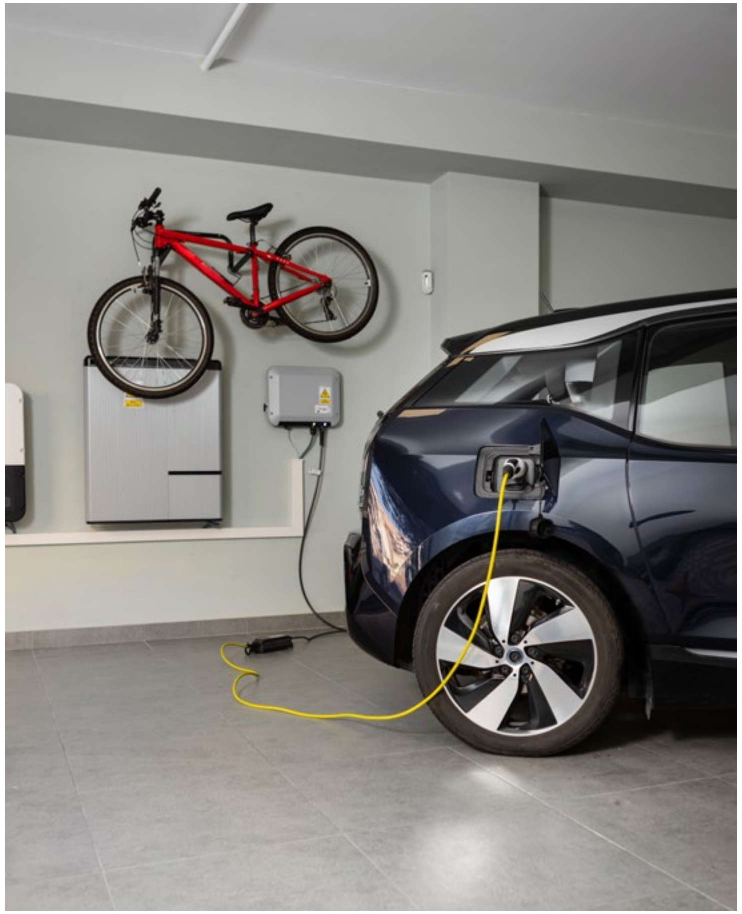
## Challenge 5: Digital customer experiences

Among all the technological facets within the EV and charging ecosystem, the aspect that has shown the least relative advancement is the delivery of digital customer experiences.

If the growth in physical charging networks and EV vehicle adoption can be described as rapid, the evolution of digital experiences to access such services has been sedentary. For years, drivers have had up-to-the-minute information on traffic conditions, the location of the nearest open supermarket, the location of the closest fuel station with the most competitive price, and the estimated time of arrival from within a single mobile app.

The opportunity to design for the needs of EV drivers and shape how EV drivers interact with charging infrastructure elements will become the next competitive edge for suppliers of charging services. Providing aggregated mobile apps and platforms to provide real-time information on the availability of charging stations, charging rates, and even reserve a spot in advance, will be differentiators for those suppliers who can get it right.

Crucially, it will be the digital identity of the EV driver that will incorporate personalized recommendations and loyalty programs, which is the ultimate prize for those suppliers wishing to have a long-term presence in the market.



# Customer needs include:

## Network coverage

Seamless charging network access is one of the primary challenges EV drivers face. Digital solutions should provide a seamless process for finding and accessing charging stations. This includes real-time availability information, intuitive maps, and user-friendly interfaces that allow drivers to easily locate and navigate to the nearest charging station.

## Network roaming

App integration and interoperability must exist between different charging networks and charging station providers. EV drivers should be able to use a single app or platform that integrates with multiple charging networks, eliminating the need for separate accounts and payment systems. This unified experience will simplify the process and reduce friction for EV drivers.

## Network availability

Real-time charging information is crucial for EV drivers. The digital customer experience should offer accurate details on charging station availability, charging speeds, and estimated charging times. Additionally, integrating dynamic pricing information can help users make informed decisions based on cost and optimize their charging experience.

## Integrated payment systems

Simplifying payment processes is crucial for a seamless digital customer experience. Ideally, EV drivers should be able to make payments through a single app or platform, eliminating the need for multiple accounts or payment method, the suppler should take care of all of that. Secure and easy-to-use payment systems, including options for contactless payments and automatic billing, can greatly improve the user experience.

## Personalization and recommendations

Digital platforms can leverage user data to provide personalized recommendations and suggestions to EV drivers. By analyzing driving patterns, charging preferences, and historical data, the system can offer tailored charging solutions, such as recommending nearby charging stations, suggesting optimal charging times, or even predicting charging needs based on upcoming trips.

## Customer support and feedback channels

A robust digital customer experience should include easily accessible customer support channels. EV drivers should have the option to reach out for assistance, report issues, or provide feedback directly through the digital platform. Prompt and responsive customer support is crucial for addressing any concerns or technical difficulties that drivers may encounter.

## Enhanced communication and notifications

Clear and timely communication is essential for a positive digital customer experience. EV drivers should receive notifications about charging station availability, charging progress, completion alerts, and any relevant updates or changes. These notifications can be delivered via mobile apps, SMS, or email, ensuring that drivers are well-informed and can plan their charging accordingly.

## Integration with smart home and smart grid technologies

The digital customer experience can be further improved by integrating EV charging with smart home and smart grid technologies. This includes features like remote monitoring and control of charging sessions, integration with renewable energy sources, and optimizing charging schedules based on electricity prices and grid demand. These capabilities empower EV drivers to make eco-friendly and cost-effective charging decisions.

# ELECTRICITY CONNECTIONS: IS THE IMPACT OF ELECTRIFICATION HOLDING BACK DECARBONISATION?


MICHAEL TAYLOR, UK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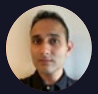

RANBIR SINGH, UK

## The Electrification Problem

**It is widely recognised that a major part of the global decarbonisation effort will be shouldered by the adoption of renewable power generation and the electrification of transportation, industrial and domestic sectors. As investment in low carbon technologies soar, global electricity networks are increasingly unable to keep pace with connection applications.**

Electrification is causing a strain at all levels across electricity networks. In most cases, the transition to a low carbon power system is driven through the installation of renewable generation options. This adds significant transmission network strain as large volumes of usually intermittent generation sources are connected. Furthermore, the decarbonisation of the SME industry and domestic sectors will increase distribution network strain through the mass adoption of Electric Vehicles (EV), embedded generation and electric heat options, such as heat pumps.

Connection speed and network reform are increasingly recognised as a pace setter for the energy transition, such that the success, or failure in achieving decarbonisation targets ultimately hinges on the rate that nations are able to progress electrification.

### What is holding back electricity network connections?

The upgrading of the electricity network is a critical part of enabling electrification and eventually meeting net zero targets. Whilst electrification presents unique challenges at a national level, as a result of national system design, there is commonality across key challenges which present an excellent opportunity for shared learnings. These include:

- **Central regulatory reform:** essential in ensuring market and network rules promote the right behaviours from network operators and provide clear signals to investors
- **Utilising Distributed Energy Resource Management (DERMS):** improve connection planning and network development
- **Connection application management and prioritisation:** ensure connections contribute to network resilience and deliver positive consumer outcomes

In this article, we will explore a series of case studies to discuss how electricity connection speeds can be increased.

# Case Study – Connection Processes Reform: US, UK and Australia

## Network Reform to Unlock Connection Speed

**On August 16th 2022 the US announced the Inflationary Reduction Act (IRA), offering nearly $400bn in tax credits for clean energy, climate mitigation & agricultural projects[1].**

The Department of Energy (DOE) report that the US will need to expand its transmission systems by 60% to meet 2030 targets, whilst also needing to triple the current capacity to achieve the 2050 target of a decarbonised economy[2]. In response, the DOE has committed up to $20 Billion of federal investment to improve electricity networks, through a series of programs, including[3]:

- **Grid Resilience Utility and Industry Grants ($2.5bn):** fund network technology solutions improve grid resilience
- **Smart Grid Grants ($3bn):** increase flexibility and efficiency of power systems, targeted at domestic entities (state/local governing institutions)
- **Grid Innovation Program ($5bn):** provide financial assistance to governing institutions and grid owners for innovative solutions that improve grid resilience and reliability
- **Transmission Facilitation Program ($2.5bn):** innovation fund to support transmission system developments through application of capacity contracts (purchasing up to 50% of maximum capacity) to de-risk inflight, or pipeline projects

Given the IRA and 'Building a Better Grid' are still relatively recent initiatives, its unclear whether the federal investment has been sufficient to manage the high volumes of electricity projects being connected to the grid. Furthermore, it is unclear whether the decision to manage stimulus through schemes, which can often include lengthy application and vetting processes, will be able to keep pace with the simplicity of the IRA tax credit model.

1 https://impact.economist.com/sustainability/circular-economies/go-green-or-bust-could-a-green-industrial-revolution-spark-an-American
2 https://www.energy.gov/gdo/building-better-grid-initiative
3 https://www.energy.gov/articles/biden-harris-administration-announces-13-billion-modernize-and-expand-americas-power-grid

## Ofgem launch connections review

**In May 2023, UK Energy Regulator (Ofgem) launched its review into an electricity connections reform[4].**

The review was instigated under the backdrop of news headlines quoting transmission connection times in excess of 15 years[5]. Failure to address these prolonged connection wait times introduces significant risk to the UK's net zero targets for both the power system in 2035 and the whole economy by 2050.

### The failings of first-come-first-served

The UK operates on a 'first come first served' basis for electricity connection applications at the transmission level and through much of its distribution networks. At the transmission level in particular, the formation and scale of the connection queue and the overall size indicates severe market distortion, with demand outstripping connection capacity. Furthermore, there is a distinct lack of queue prioritisation, resulting in potentially higher priority projects being delayed at the expense of lower priority activities.

4 https://www.ofgem.gov.uk/publications/open-letter-future-reform-electricity-connections-process
5 https://www.current-news.co.uk/industry-calls-on-beis-to-solve-network-constraints-with-delays-of-up-to-15-years/

The queue length is compounded by the application process, which allows for investors to speculate on prospective projects, to ensure their place in the line, regardless of project maturity.

In addition, there has historically been little scrutiny on project maturity for connection applications, which can result in the approval of projects that have outstanding, critical dependencies, such as planning permission. This results in 'zombie' projects populating the queue, holding back high priority projects. This ultimately reduces the accuracy of generation capacity projections, and further complicates network planning.

## Connections Reform Initiative

**The Clean Energy Council (CEC) mobilise the industry to ramp up generation connection to grid times through the Connections Reform Initiative (CRI)[6]**

The CRI has brought together a diverse set of Australian energy market stakeholders to address concerns around delays and the increased complexity in the connections process.

The first phase of the CRI activity focused on introducing collaborative, cross-industry ways of working, simplifying regulatory change processes and introducing a more flexible approach to minimum standards to better reflect network capability. Solution outputs within these target areas were consolidated into a collective delivery roadmap, outlining when review recommendations would be implemented[7].

The CRI's roadmap recently went through its second iteration, where the emphasis shifted from ideation/planning to implementation. However, there were some notable shifts in short term strategic direction, as demonstrated by the reallocation of the connection 'batching' workstream into the Streamlined Connections Process (SCP)[7].

6 https://www.cleanenergycouncil.org.au/advocacy-initiatives/energy-transformation/connections-reform-initiative
7 Connections Reform Initiative (CRI) – Connections Reform Roadmap: Version 2 (May 2023)

The decision to reform the connection 'batching' workstream into the SCP was due to 'batching' recommendations being unable to progress because of cross review dependencies. The SCP focus shifted into undertaking a end-to-end system review and identifying near term initiatives to trial through regulatory sandboxing[7].

Whilst the success rates of the CRI are currently unknown, the roadmap approach is allowing for long term planning, whilst retaining the agility to respond to near-term review developments.

## Unblocking electricity connection processes through central reform

Central reform is a critical aspect of increasing the pace of electricity connection processes. Whilst the approaches adopted by the US, UK and Australia differ, they all beg the question 'are we building the systems of tomorrow, with the frameworks of yesterday' and how can central reform promote electrification?

## Adopting whole system approach to energy system reform

Energy systems are fundamentally linked and it is therefore critical that reviews considered the wider flow of energy, money, data and agreements through the entire system. Failure to consider the wider landscape when undertaking regulatory reform initiatives increases the likelihood that transitional 'debt' is incurred, resulting in unnecessary future rework.

## Ramping up pace of regulatory change and simplification

Energy system requirements are evolving at a pace that central regulation systems are struggling to adapt. Increasing the pace of change will be critical in adapting to a framework that supports efficient implementation of innovative projects and achieving the necessary future targets.

## Effective planning for near, medium and long term success

Successful energy system evolution will require robust mechanisms for identifying where connections are required to provide clear signals for investment. Leveraging development roadmaps can be an effective tool, providing they are regularly reviewed to respond to near-term events.

# Case Study – Utilising DERMs and ADMS to Improve Network Management

## Adopting and integrating emerging DERMSandADMSTechnologycanhelp DSOs realise efficiencies in network and connection management

Electrification is fundamentally changing the distribution network landscape, as increased penetration and volume of distributed assets increases the need for flexible and responsive system management. This is pushing the traditional Distribution Network Operator (DNO) to transform into a Distribution System Operator (DSO), but what technologies can help enable this transformation?

### Distributed Energy Resources Management Systems (DERMS)

DERMS are control systems that allow for management and optimisation of Distributed Energy Resources (DERs) within electricity networks, such that DSOs can dispatch and control DERs in near-real time[8].

DERMS common 'use-cases' include Volt/Volt Ampere Reactive (Volt/VAR) optimization (VVO), power quality management, and the coordination of DER dispatch (when possible) to support operational needs. DERMS platforms can also offer clients a variety of benefits which are defined by the following use-cases[9]:

**Asset Management and System Planning**

- Precision Demand Response and DER Management
- Telemetry and Control
- Dynamic Network Topology
- Alarms, dashboard, single line diagram, audit logs, user manual
- Control strategy management features
- Optimal DER Plan Creation
- DER Fleet Management
- Volt VAR Control
- Network/Resource Constraint Management Utilizing DERs
- Energy Arbitrage and Usage Optimization

**Analysis and Forecasting**

- Energy Arbitrage and Usage Optimization
- Precision Demand Response and DER Management
- Telemetry and Control
- Dynamic Network Topology
- DER and Load Forecasts
- DER Situational Awareness
- DER Analysis to inform planning Internet of Things (IoT) aggregation functionalities
- Alarms, dashboard, single line diagram, audit logs, user manual
- Control strategy management features

8 DERMS Requirements and Considerations: A Utility Perspective (Arizona Public Service)
9 DERMS Solutions – BESC Research Services (March 2021)

## Advanced Distribution Management Systems (ADMS)

ADMS Platforms are designed to effectively monitor, control and optimise distribution of electricity across a network. The primary function of ADMS is to improve efficiency and reliability of distribution networks through real-time monitoring; fault detection and restoration; outage management; and grid optimisation. However, ADMS are not typically designed to support many millions of SCADA points, or act as a holistic customer enablement platform[10].

## Integrating DERMS and ADMS technologies

The integration of DERMS and ADMS offer a number of advantages in transitioning traditional distribution networks towards flexible, resilient future systems. One example is in the management of Virtual Power Plants (VPPs), which aggregates and coordinates a fleet of DERs to act like a single power plant. DERMS and ADMS can play a role in VPP, where:

- DERMS plays a critical role in monitoring, controlling and optimising the individual DERs, ensuring they responding to real-time signals, working effectively and contributing the required capacity to the VPP
- ADMS ensures the VPP integrates with the wider network infrastructure and can coordinate its activities with other network assets and network operations to promote network resilience and reliability

Overall, integrating DERMS and ADMS should drive a reduction in electricity cost through increasing asset output, maintenance and life-span. They should also increase the uptake of DER which tend to be low-carbon sources of electricity, such as wind and solar, reducing the carbon intensity of electricity used to power our homes and businesses[10].

## UK energy networks ramp up application of DERMS

In the UK, implementation of DERMS currently only exists in small pockets of the network, however DERMS adoption is ramping up as all major UK DNOs are setting up frameworks to enable DERMS.

Furthermore, the UK is designing its electricity markets to reward flexible Distributed Energy. As such, starting in 2023, any capital grid upgrade that costs more than £1 million ($1.34 million) will need to prove that a flexibility based alternative solution, such as a VPP, is not a reasonable alternative option to meeting the system need.

This is a departure from the traditional "cost of service" structure for UK utilities, which typically determine their grid upgrade needs based on future load growth forecasts and earn guaranteed rates of return on the resulting capital investments.

10 The Interconnected Roles of DERMS and ADMS – A deep dive into complementary management systems

# Case Study - Application Request Management

## Our approach leverages deep Australian electricity distribution connections process knowledge and solution templates

BETTER CONNECT MVP

### Context and Challenges

Essential Energy is a NSW Government owned corporation with responsibility for building, operating and maintaining Australia's largest electricity network, spanning 95 per cent of New South Wales and parts of southern Queensland

Essential Energy receive around 60,000 applications a year for low voltage connections. Effectively managing and actioning such a large volume of connection applications comes with series of challenges, which were as follows[11]:

FIGURE 1

**Manual**

Connections process facilitated in largely manual environment using workflow management tool, and access Database platform to record and store information

**Visibility**

Minimal or no visibility of the project lifecycle for the customers and convoluted internal processes resulting in delays for processing of design stage

**Data**

Transfer of the critical project data between Essential Energy teams and the systems needing to be handled manually, creating rework

11 Ausgrid Capgemini End to End Connections (Dec 2021)

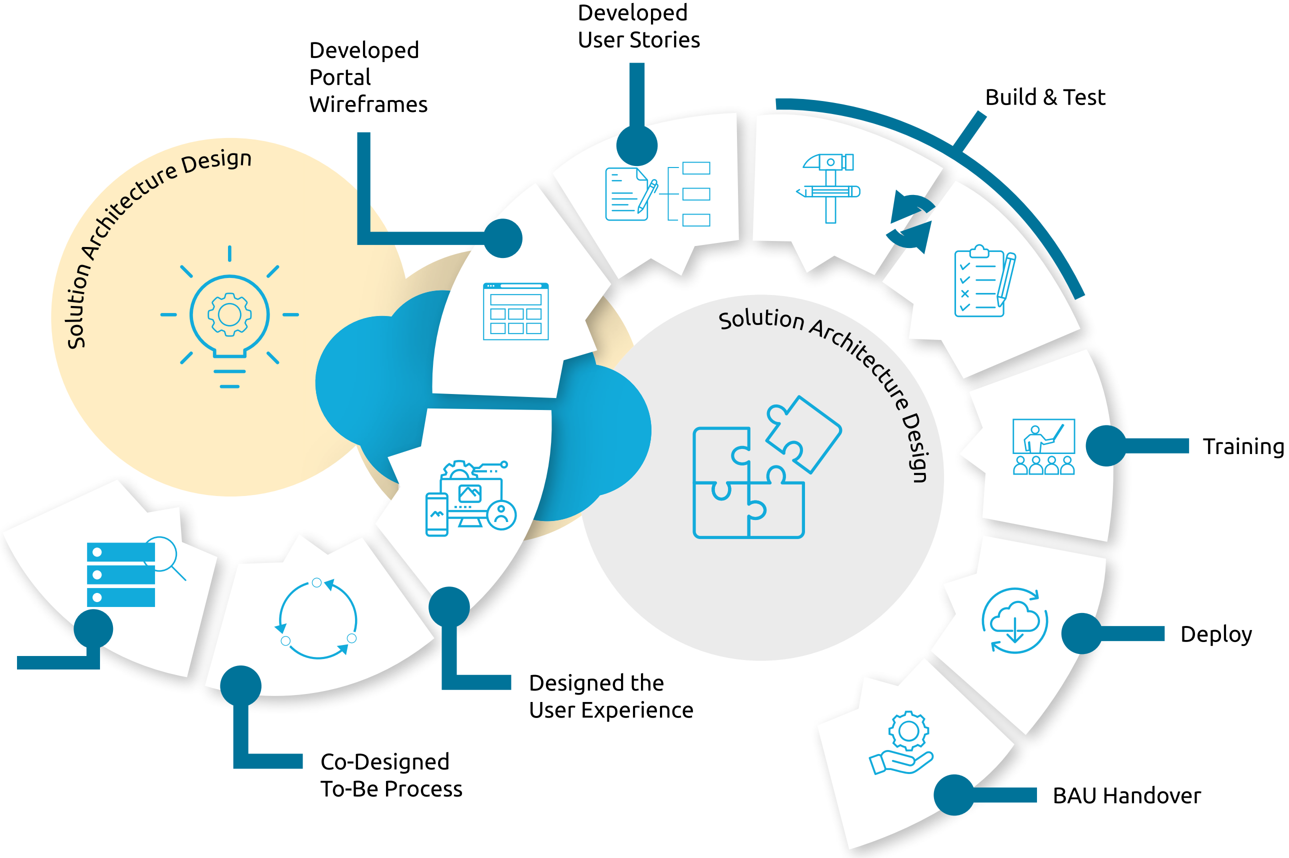
## Solutions and Benefits

Capgemini delivered a solution to enable automation of Design sub process for the customer connections process. This was achieved by:

- Using Salesforce Service Cloud for internal console and Community Cloud for the front end portal to submit and track work request
- Defining requirements by utilising an accelerated, collaborative 'discovery' phase that focused on process design, user journeys, and internal/external personas
- Implementing agile approach to change management, design, build and test salesforce functionality
- Interactive train the trainer sessions, empowering SME's within the organisations to provide end user training and supporting delivery of end user sessions

This has ultimately led to faster, easier, more efficient lodgement of work requests. Automated workflows allow segmentation, and allocation of work, reducing manual administration and elimination of 90% data entry requirements for design and certification processes

FIGURE 2



# Case Study - Connections Management

## Capgemini Engineering Support Enedis in Accelerating it's Grid Connection Activities


### Approach and Solutions

- Clear scope of service based on four work packages (Coordination, Study Monitoring and Control, Service Providers Monitoring and Control, Acceptance of Work/ Commissioning)
- Performance based on KPIs built together by Enedis and Capgemini
- Teams of 6-7 project managers organised around a senior technical expert on each regional branch with the support of national experts and the project office
- Completion and update of Enedis information system

**Coordination**
- Manage the realisation of each reception work study
- Coordinate all stakeholders
- Update systems in real time

**Studies**
- Carry out the study work
- Control/manage the study
- Complete the work

**Construction**
- Get the actual work done
- Monitor the execution of work
- Create and check document
- Complete the work

**Reception**
- Manage access and MES
- Carry out the acceptance of work
- Complete the work

## Context and Challenges

Enedis is the main French DSO and as such they are in charge of developing, operating and modernising 95% of the French electricity distribution network.

Enedis was facing new challenges due to the increasing levels of renewable generation on the distribution network, the development of self consumption, and the emergence of new electricity uses such as electric vehicles.

In this context, Capgemini has provided engineering services to facilitate the grid connection of customers of Enedis. More than 40 project managers within Capgemini's teams have coordinated grid connections projects (from first studies to commissioning) since 2015 within regional branches (Paris region, Marseille and Montpellier regions, Alsace, Toulouse and Pau regions)

## Key Technologies

- High voltage / Low voltage substations
- EV charging stations
- Renewables (Solar PV and Wind Power Plan)
- Electricity riser in collective buildings
- Individual connections <36KVA or >36KVA
- Authorisations H0/B0, AIPR

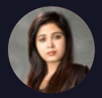
## Results and Added Value

Capgemini is one of the two main national partners of Enedis and strongest ally regarding grid connection project management

- Activity has been growing since 2015
- Capitalisation and deployment ongoing in new regions
- Implementation of a tailormade training program for new consultants
- Expense control through performance-based payments with reduced tracking effort
- Respect of customer objectives; billing budget and schedule compliance

# LCOE
# LEVELIZED COST OF ENERGY


DEBARGHYA MUKHERJEE, INDIA


NUPUR SINHA, INDIA

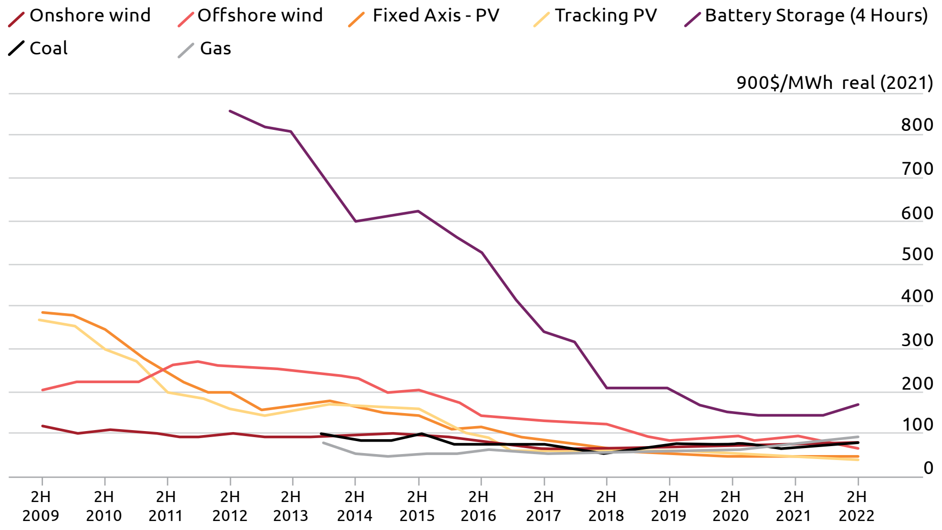
## Global LCOE benchmarks, H2 2022

**Global supply chain pressures have started to ease and key commodity prices are cooling off** after a turbulent 18 months. **Inflationary effects are still catching up with renewables projects financed in 2H 2022** and some key commodities remain stubbornly high. In addition, new macroeconomic challenges have emerged. **Inflation is at multi-decade highs and central bank interest rate rises are hitting capital-intensive renewables and storage projects hard.**

**Higher fuel and carbon prices, elevated material prices and higher debt costs have pushed up LCOEs for coal, gas and standalone battery storage projects.** Central bank rate hikes in 2H 2022 have increased debt cost by 20%, compared to 1H. Rising debt costs affect renewables more than fossil fuel plants due to the higher upfront investment needs. A strong dollar has weakened the purchasing power of developers who rely on equipment imports and increased capex.

FIGURE 1

Global LCOE benchmarks (H2 2022)




Sources:BloombergNEF

# Global average LCOEs for onshore wind and solar PV are expected to remain 10-15% above 2020 levels in 2024

Electricity generation costs from new utility-scale onshore wind and solar PV plants are expected to decline by 2024, but not rapidly enough to fall below pre Covid-19 values in most markets outside China. Although commodity and freight prices have dropped from last year's peaks, they remain elevated. At the same time, developers' financing costs have increased due to rising interest rates.

In addition, macroeconomic risks in the global economy – associated with rising inflation, higher interest rates and the energy crisis caused by Russia's invasion of Ukraine – lead to a higher cost of capital, including for renewable energy projects. In real terms (i.e., excluding the impact of inflation), the weighted average cost of capital (WACC) is expected to increase in most large solar PV and wind markets, excluding China. The higher cost of capital could offset most of the cost decreases resulting from lower commodity prices and further technology innovation in the next two years. Consequently, the average LCOE for utility-scale PV and wind could be 10-15% higher in 2024 than it was in 2020.

**FIGURE 2**

Wind onshore LCOE index based on average annual input costs, 2018-2024

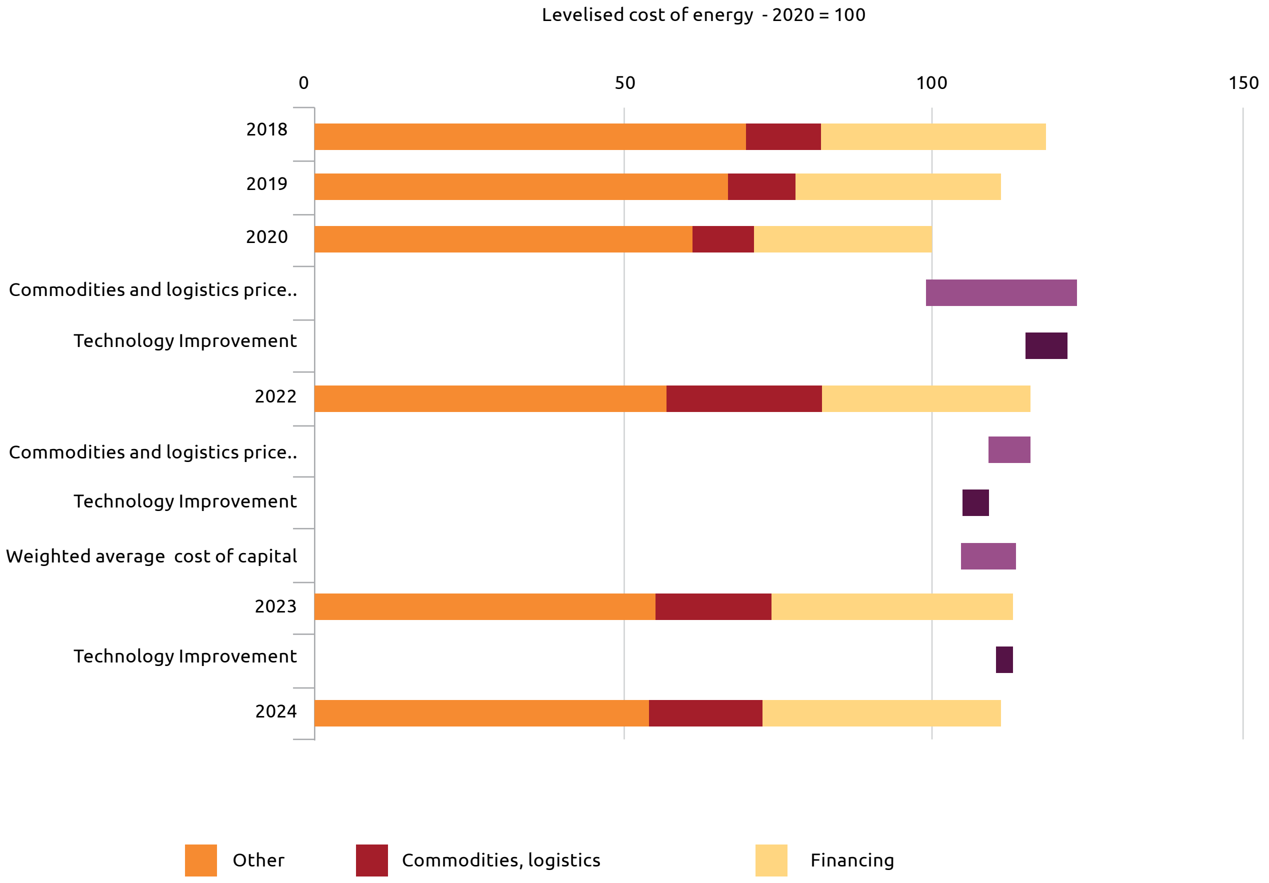
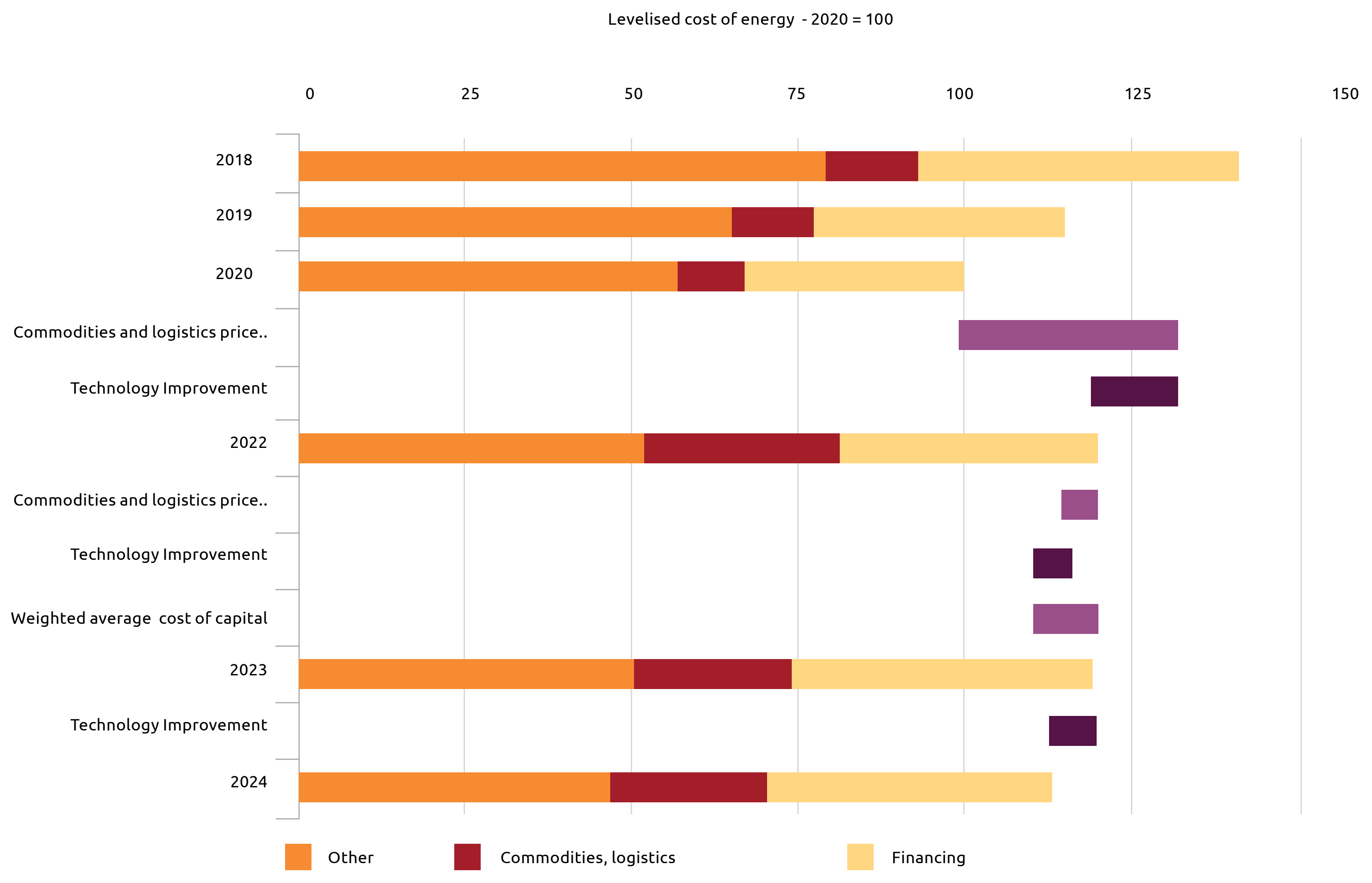


**FIGURE 3**

Solar PV utility scale LCOE index based on average annual input costs, 2018-2024



## U.S. and European LCOE 2022

Solar and wind are still the most affordable sources of electricity, but their LCOE has increased for the first time in 2023 in U.S. In a base comparison, without considering subsidies, fuel prices, or carbon pricing, utility-scale solar and wind have the lowest LCOE of all sources.

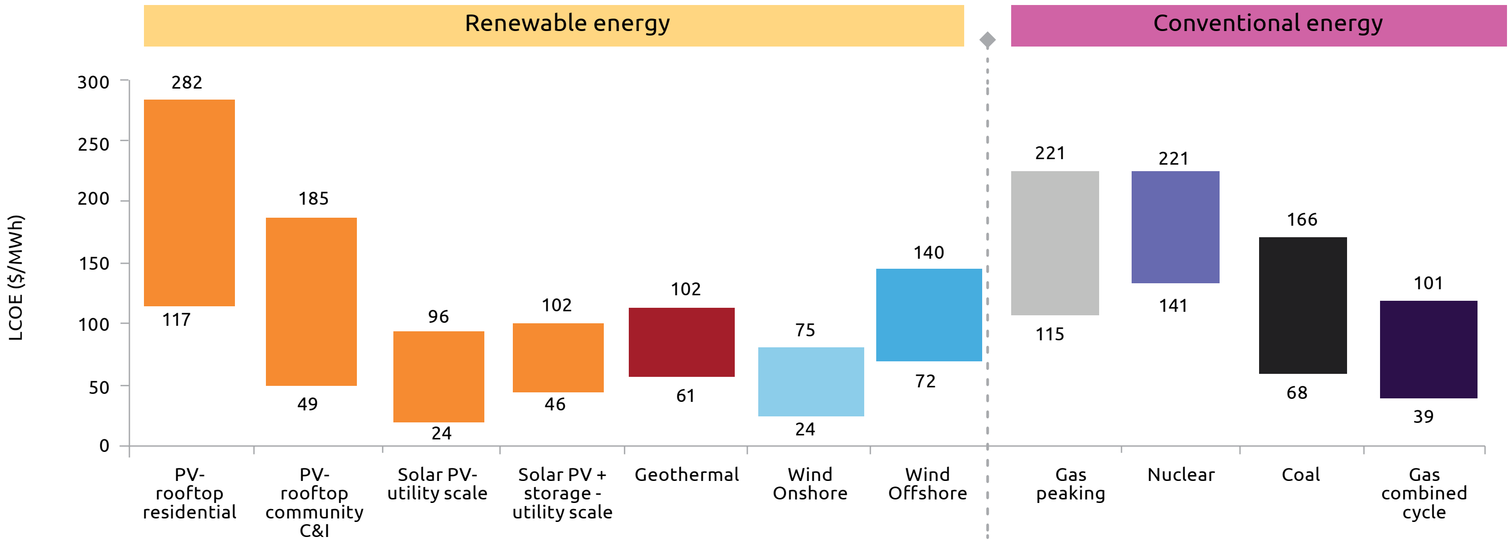
Utility-scale solar PV comes in anywhere from $24/MWh to $96/MWh, while onshore wind registers the lowest possible LCOE over the shortest range, from $24/MWh to $75/MWh. Offshore wind's LCOE ranges between $72/MWh and $140/MWh.

Wind and solar will attract the lion's share of energy investment in Europe and continue to benefit from growing scale. Europe's pivot away from its dependence on Russian supply caused the price of gas to skyrocket. However, until low-carbon technologies catch up, gas will continue to be a critical bridging fuel. LCOE figures for renewables and energy storage in 2022 rose by an average of 19% due to supply chain bottlenecks and commodity price inflation.

Onshore renewables remain the most cost-effective energy technology in Europe; the average LCOE for onshore wind across Europe expected to drop by more than half to €23/MWh by 2050 compared to 2022, making it the most cost-competitive technology. Comparatively, offshore wind remains expensive, although costs are set to decrease the most in this sector by 2050: LCOE should reduce by 68%.

**FIGURE 4**

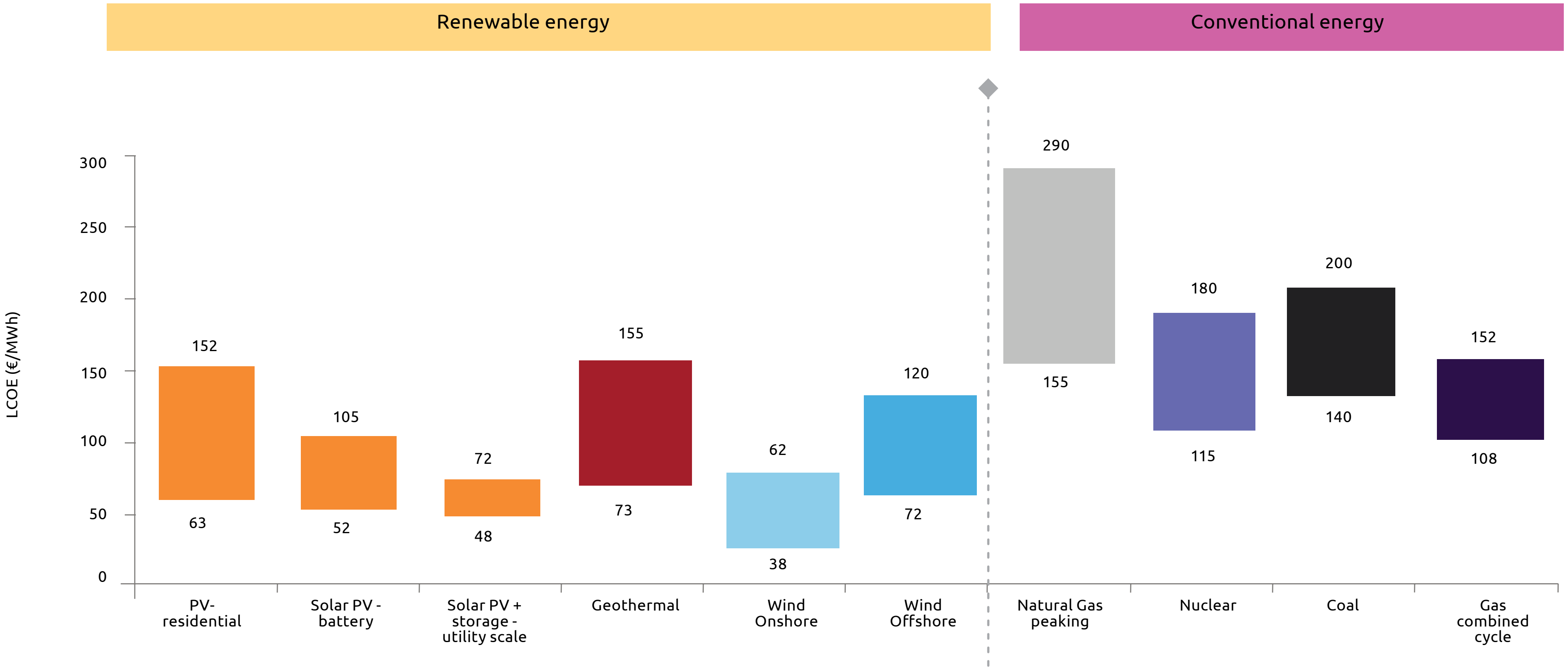
U.S. LCOE - Unsubsidized Analysis ($/MWh)




Source: 2023 Lazard's Levelized Cost of Energy Analysis, Wood Mackenzie, Fraunhofer

**FIGURE 5**

Average European LCOE (€/MWh)



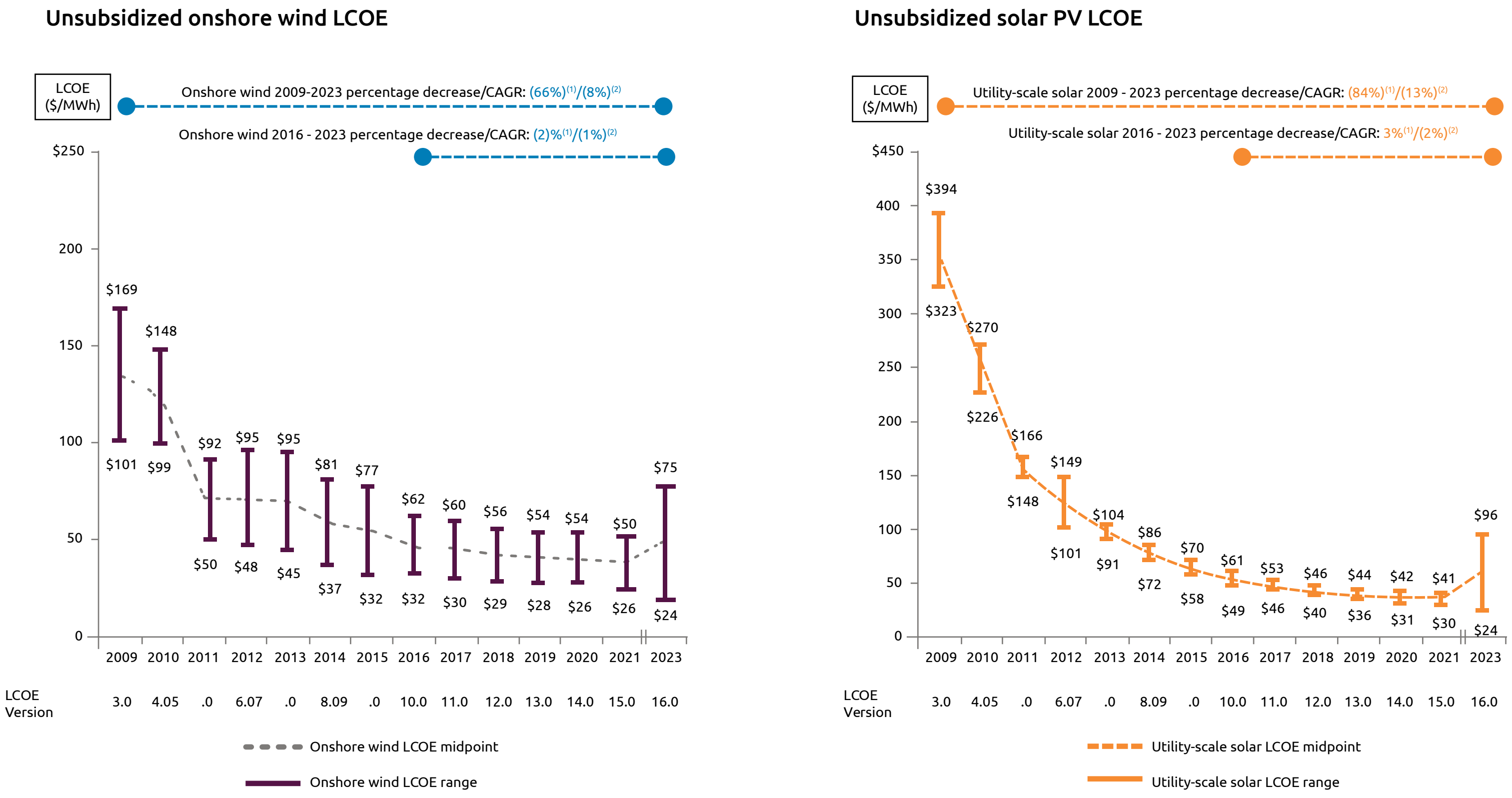

Source: 2023 Lazard's Levelized Cost of Energy Analysis, Wood Mackenzie, Fraunhofer

# For U.S., Utility-scale solar and onshore wind LCOE increased for the first time in 2023

Even in the face of inflation and supply chain challenges, the LCOE of best-in-class onshore wind and utility-scale solar has declined at the low-end of cost range, the reasons for which could catalyze ongoing consolidation across the sector.

Although the average LCOE has increased for the first time in the history of studies; Inflation, supply chain challenges, and the global energy crisis all had a role to play.

**FIGURE 6**



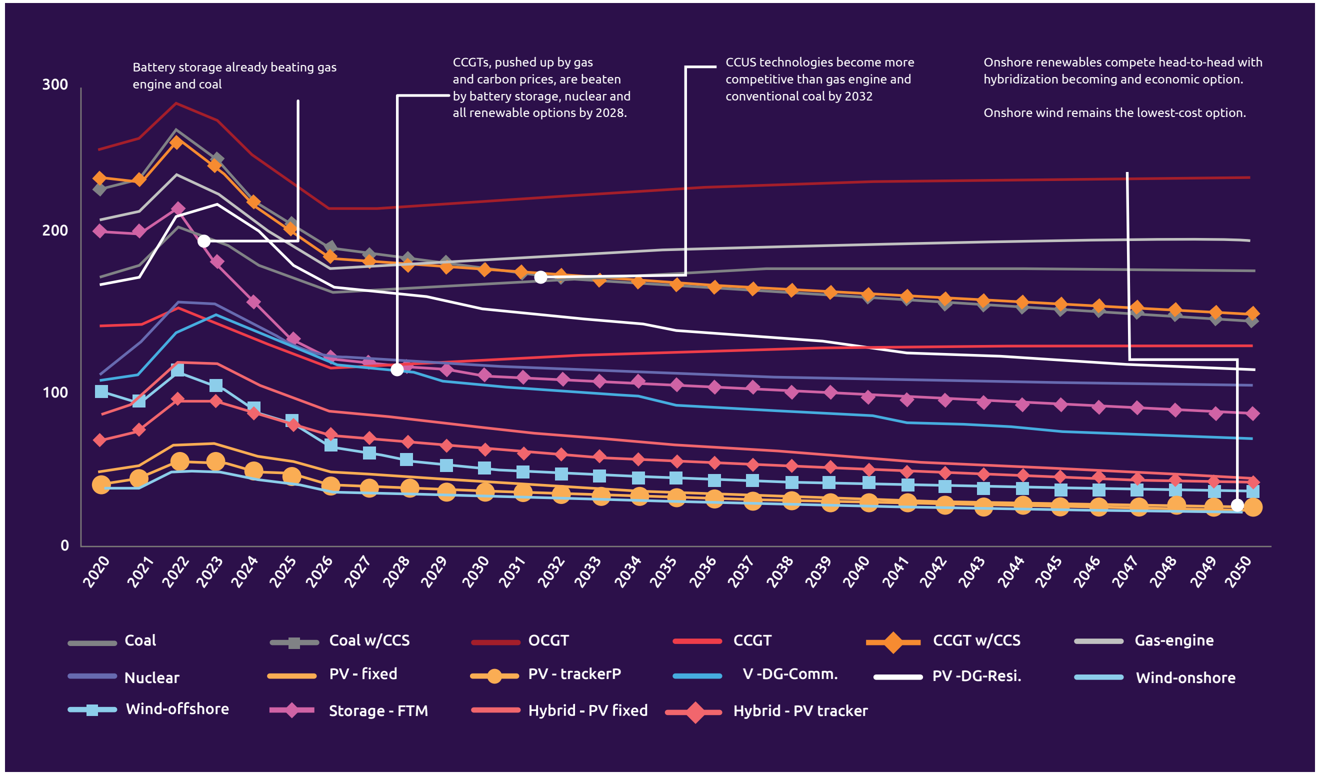

Source: 2023 Lazard's Levelized Cost of Energy Analysis

# For Europe, gas is expensive but remains system critical until low carbon options can displace it

Key markets in the European power generation and storage sector will attract 1.64 EUR trillion from 2023 to 2050 with 78% of investments going towards wind and solar. Commodity price inflation and supply chain bottlenecks have pushed up the power sector investment requirements by $140 billion between 2023 and 2050

**FIGURE 7**

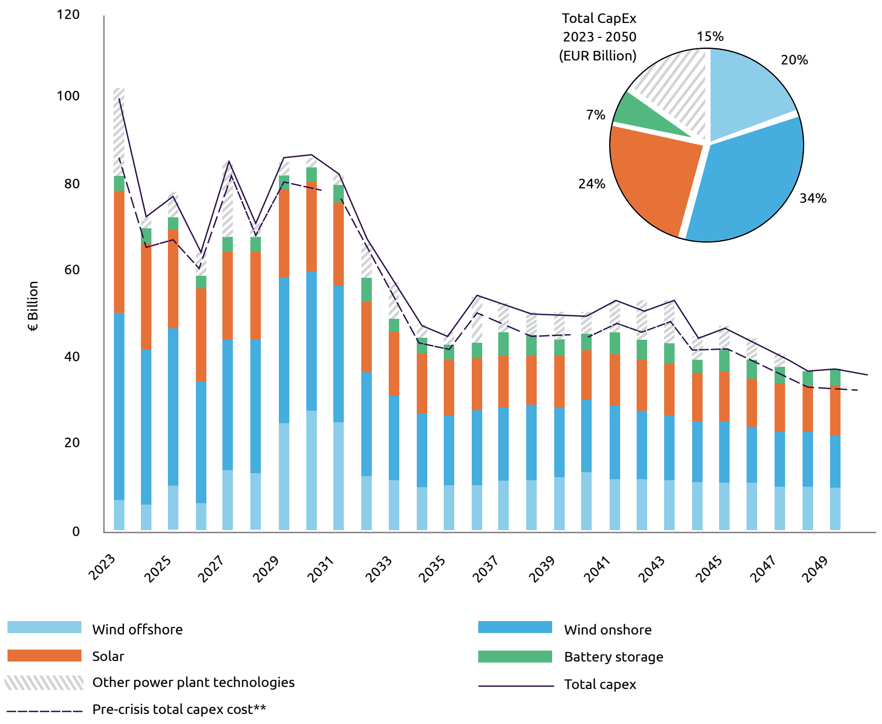
Technology average LCOEs ( € / real 2022 )




Source: Wood Mackenzie

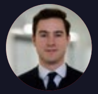
**FIGURE 8**

Power plants Total CapEx by Technology



# NETWORKS AT THE CENTER OF THE ENERGY TRANSITION

## WILL ENERGY NETWORKS ENABLE OR HINDER THE TRANSITION TO NET ZERO?



TOM CARR, UK

JOHN BRIGNELL, UK

**As the world races toward a net zero future, energy networks have emerged as the pivotal engines in the pursuit of decarbonization. Historically anchored in thermal power generation, these infrastructures now find themselves at the crossroads of the global energy transition. Their role is unmistakably crucial, wielding the power to either catalyze or obstruct our collective endeavors against climate change. Yet, it's essential to underline a foundational challenge: Electricity, which currently represents approximately 20% of all energy consumed worldwide, must account for over 50% in a net zero scenario, additionality encompassing heating, cooling and mobility. An almost tripling of global grid capacity will be needed to achieve this, in less than three decades. This is not merely an investment conundrum.**

The significance of energy networks as pace-setters for achieving net zero emissions cannot be overstated. These networks play a vital role in integrating renewable and distributed energy sources into our existing energy infrastructure, making them pivotal in the transition to a sustainable future.

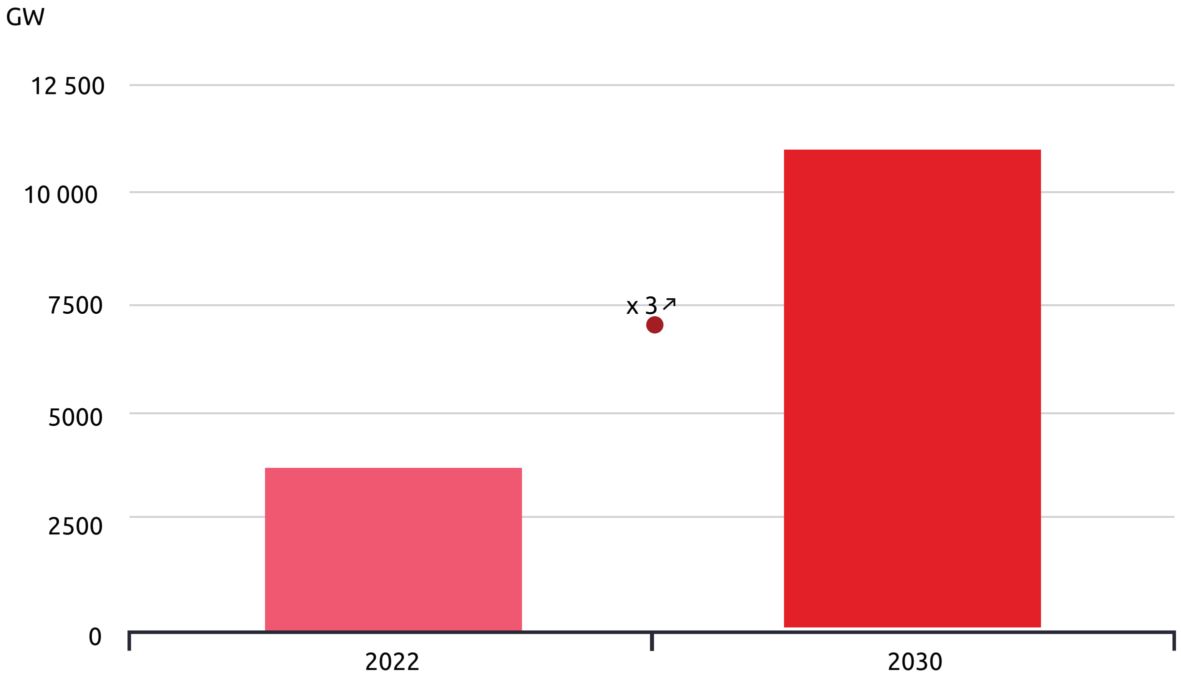
Energy networks face a myriad of challenges on the path to decarbonization. From the need to integrate distributed and decentralized renewable energy sources to the complexities of bidirectional power flows and the daunting task of expanding transmission grids, the road ahead is arduous. Furthermore, questions of cost implications, regulatory frameworks, and public engagement loom large, demanding bold solutions and decisive action.

However, energy networks also possess immense potential to lead the charge toward net zero. By embracing innovative technologies, adopting a digital-first approach, and fostering collaboration across stakeholders, they can become the driving force behind decarbonization. With the power to connect renewable energy assets, optimize grid operations, and empower consumers, energy networks have the capacity to transform our energy landscape and accelerate progress toward a sustainable future.

In this article, we will delve into the challenges faced by energy networks and explore the potential solutions that can empower them to become true catalysts for decarbonization success. From visionary regulation to anticipatory investments, from leveraging flexibility to embracing open data and digitalization, each step forward will bring us closer to achieving our net zero ambitions.

**FIGURE 1**

Global renewables power capacity in the Net Zero Scenario, 2022 and 2030




Note: Tripling global installed renewables capacity to 11,000 gigawatts by 2030 provides the largest emissions reductions to 2030 in the NZE Scenario.

Source: IEA
https://www.iea.org/reposts/net-zero-roadmap-a-global-pathway-to-keep-the-15-0c-goal-inreach/executive-summary

### Challenge #1: Adapting to the era of renewables

Energy networks were originally designed to support thermal power generation, relying on centralized fossil fuel power plants. However, integrating distributed and decentralized renewable sources poses significant challenges. Retrofitting existing infrastructure to accommodate the intermittent nature of renewables and managing the complexities of diverse energy sources requires innovative solutions and flexibility in network design and operation. This challenge is increased by the changing nature of demand. With electrification, demand will increase significantly – in the United Kingdom, demand is predicted to double by 2050[1] but it will also change in nature. Peaks and troughs will shift as electric vehicles (EVs) and electric heating demands become significant facets of our future energy systems. Demand will also become more flexible and price sensitive, with demand shifting to take advantage of cheap electricity when the sun shines and wind blows.

### A clear decarbonization roadmap

Governments can play a crucial role by providing clear decarbonization goals, as well as a roadmap. Setting ambitious targets for renewable energy deployment and carbon reduction creates a strong incentive for energy networks to adapt their infrastructure and operations to accommodate renewable sources. By establishing a clear direction, governments can encourage investments in research, development, and implementation of technologies and practices that enable the integration of renewables into the existing network, fostering a smoother transition toward a clean energy future.

### Challenge #2: Keeping pace with rapid deployment

The rapid deployment of renewable energy assets presents connection constraints for energy networks. Connecting wind farms, solar installations, and other renewable sources to the grid requires careful planning, engineering, and coordination. The challenge lies in ensuring timely connections to meet the increasing demand for clean energy while maintaining grid stability and reliability.

### Anticipatory investment

Energy networks can adopt an anticipatory investment approach. This involves proactive planning and investment in grid infrastructure to keep pace with the rapid deployment of renewable energy projects. According to International Energy Agency estimates, $1-3 dollars needs to be spent on grids for every $1 spent on renewables. By identifying potential areas for renewable energy development and strategically upgrading the grid infrastructure in advance, energy networks can reduce connection delays, enable faster integration of renewable assets, and ensure a smooth transition toward a more sustainable energy system.

## Case study: Great Britain's Accelerated Strategic Transmission Investment (ASTI) to meet 50 GW of offshore wind goal

In April 2022, the U.K. government set an ambitious aim of connecting up to 50 gigawatts (GW) of offshore wind generation by 2030[2]. This was an unprecedented and highly-challenged ambition.

This policy was translated into practicality by the transmission system operator, National Grid Electricity System Operator (ESO), which was tasked with determining how to reinforce the existing electricity network to make it possible. Using a holistic network approach[3] they identified 26 projects needed in the next eight years, requiring £20 billion in investment. However, these came with a significant risk to delivery if the continued incremental approach to network build was not scrapped to shift to a coordinated anticipatory approach.

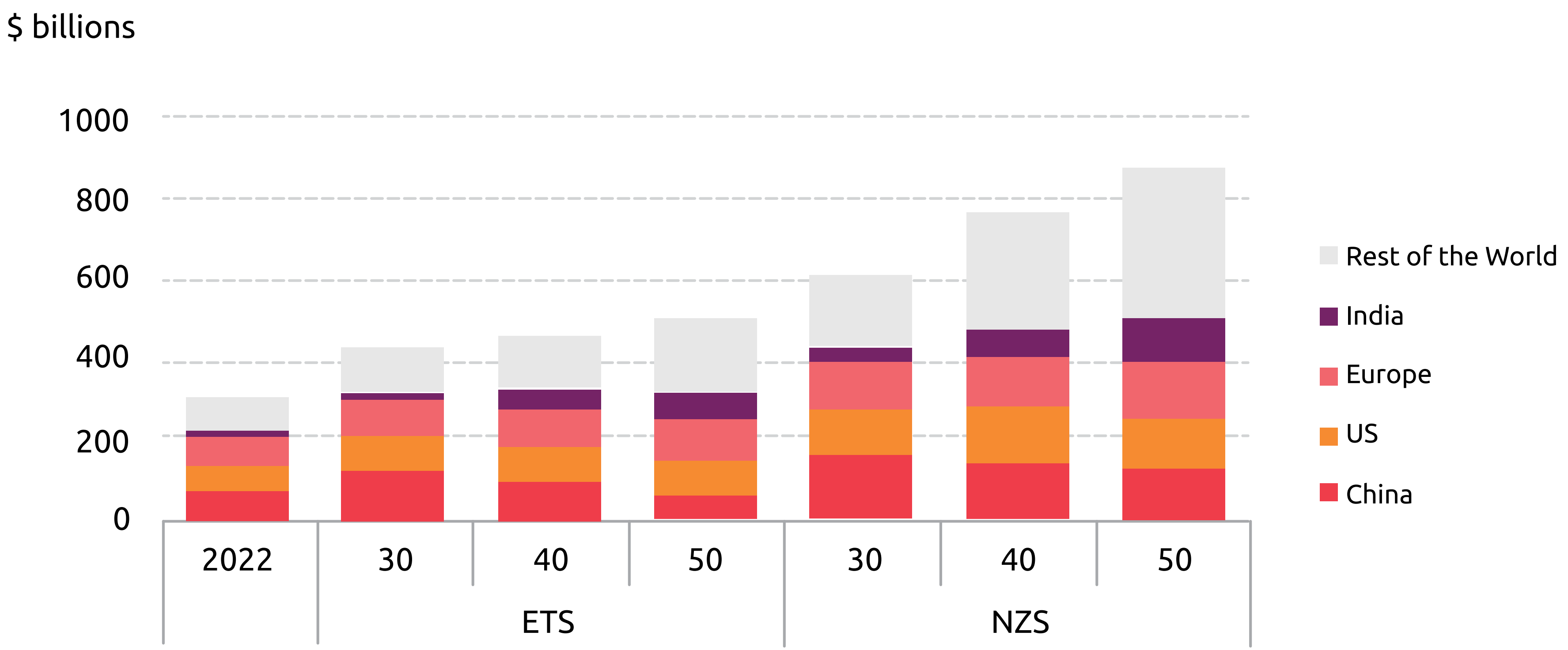
In December 2022, Ofgem, the national energy markets regulator, responded to this by overhauling the planning system for strategic investments into the transmission network[4]. They gave the green light to all 26 projects to be delivered by the regional transmission operators without competition. This could potentially shave years from their delivery dates, securing an additional £2.1 billion in consumer benefits and unlocking significant decarbonization to be delivered through meeting

1 Delivering a reliable decarbonised power system, UK Climate Change Committee

2 British energy security strategy - GOV.UK (www.gov.uk)
3 ESO Holistic Network Design
4 Ofgem ASTI Framework Decision

**FIGURE 2**

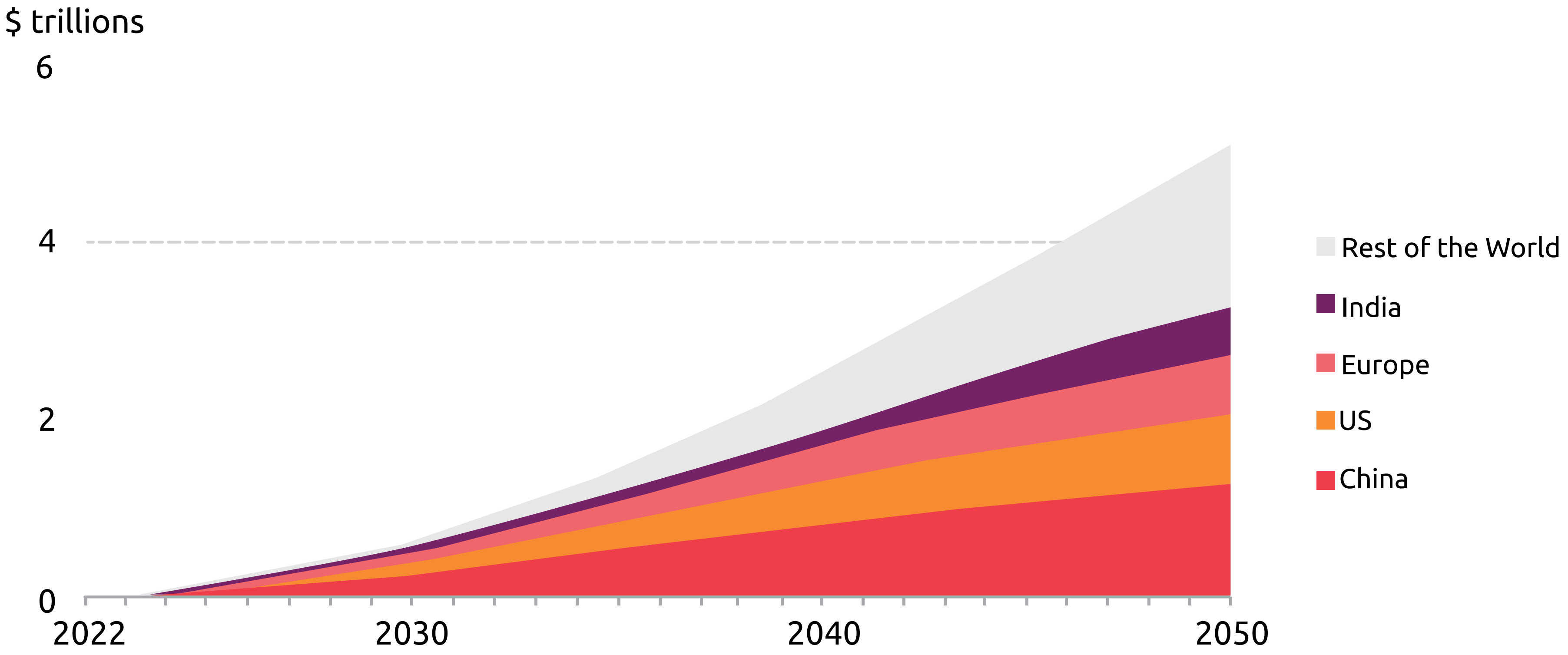
Global annual grid capex by region




Source: BloombergNEF. Note: Values for 2030, 2040 and 2050 are averages over the preceding dacade.

**FIGURE 3**

Cumulative capex on power grid digitalization by region




Source: BloombergNEF. Note: Excludes smart meters.

### Challenge #3: Embracing the two-way energy flow

Energy networks have traditionally operated with unidirectional power flows, from centralized power plants to end consumers. However, with the rise of distributed generation, such as rooftop solar panels, energy networks must adapt to handle bidirectional energy flows. This transition requires technological upgrades, advanced metering systems, and enhanced grid management strategies to effectively manage the dynamic exchange of power between the grid and distributed energy resources.

## Case Study: Denmark's flexibility market

Denmark's flexibility market serves as a successful example of enabling bidirectional power flows. Denmark has achieved a high level of integration of wind power into its electricity system, with wind energy accounting for approximately 50% of its electricity consumption. This accomplishment is supported by the country's flexible market rules, which allow consumers, prosumers, and aggregators to actively participate in the energy market and provide flexibility services. The Danish Energy Agency highlights that this approach has enabled efficient bidirectional power flows, better integration of renewable energy, and increased grid stability.

### Market rules to enable flexibility

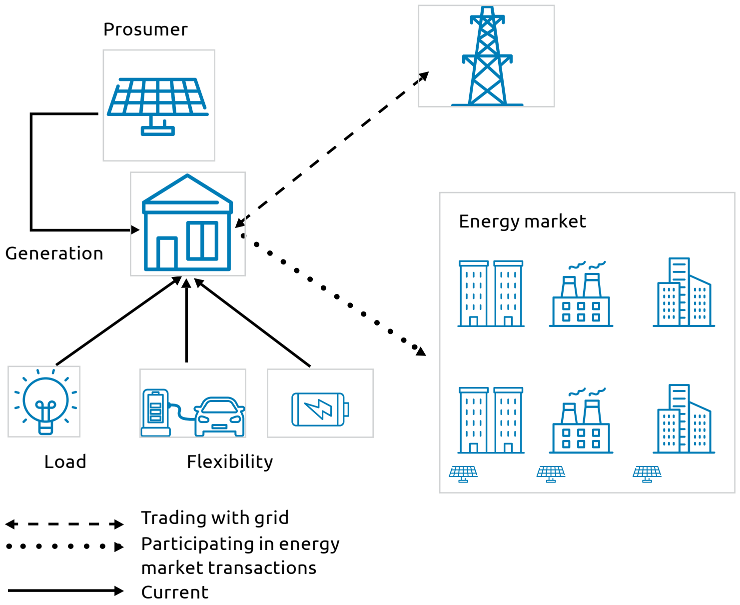
Energy networks can establish market rules that enable the expansion of flexibility providers and aggregators. These rules can facilitate the integration of distributed energy resources into the grid by allowing them to participate in energy markets, providing flexibility services to the system. These new rules should allow for flexibility providers to participate not only in wholesale markets but also in balancing and congestion markets. By incentivizing the participation of diverse actors and encouraging the development of innovative business models, energy networks can unlock the potential of bidirectional energy flows, optimize grid operations, and effectively manage the integration of distributed energy resources, thus accelerating the transition to a more flexible and sustainable energy system. Close collaboration between the transmission and distribution operators will be crucial to enabling this shift in the market and optimizing system flexibility to empower consumers and lower costs.

### Challenge #4: Scaling up for a renewable future

To accommodate the growing share of renewable energy and ensure its efficient transmission, significant expansion of transmission grids is necessary. Offshore wind farms and remote solar installations, often rich in renewable resources, may be located far from population centers, requiring extensive transmission infrastructure development. This expansion requires substantial investment, environmental considerations, and careful planning to ensure grid reliability and optimization of renewable energy resources. Expanded grids will additionally need to be built to be resilient to climate events (floods, wildfires, hurricanes etc.), in particular grid assets connecting offshore and coastal wind sources. Our networks will need to operate safely and efficiently through decades of hostile climate events before reducing temparutes reduce their severity.

## Case study: The North Sea Wind Power Hub

The North Sea Wind Power Hub[5] is an initiative that aims to enhance cross-border interconnections for offshore wind energy transmission in the North Sea region. By connecting countries such as Germany, the Netherlands, and Denmark, this project seeks to unlock the vast potential of offshore wind energy. The North Sea Wind Power Hub aims to connect 180 GW of offshore wind capacity by 2045, which will facilitate the efficient transmission of renewable energy across borders and contribute to the decarbonization goals of the participating countries.




5 https://northseawindpowerhub.eu/

### Challenge #5: Managing cost implications and finance

The transition to a low-carbon energy system involves significant costs, including infrastructure upgrades, technology deployment, and system optimization. Determining who bears these costs and when they are incurred presents a challenge. Additionally, the availability of financing options and the fair distribution of costs among different stakeholders can be complex. The current regulated asset base (RAB) incentive model for grid operators needs to be adopted to stimulate investment in system innovation.

### Open data to facilitate collaboration

Open data refers to the availability and accessibility of information related to the energy system, costs, and financing models. By promoting transparency and collaboration among stakeholders, open data enables a more inclusive and participatory approach to decision-making and cost allocation.

Open data facilitates collaboration among governments, energy networks, industry players, and financial institutions. It allows for better understanding and assessment of the costs associated with the energy transition and enables the identification of cost-saving opportunities; it also encourages the development of cost-effective solutions. By sharing information and lessons learned, stakeholders can collectively work toward optimizing the deployment of renewable energy technologies and reducing overall costs.

## Case study: World Bank Open Energy Data Portal

World Bank is one of the largest financial institutions globally, investing billions annually in projects that will reduce poverty and increase prosperity. World Bank recognizes the importance of access to energy as critical in these pursuits, and invested more than $5 billion in energy programs in the last five years (FY18-22).

The bank has also recognized the value of the data they have access to as a result of their significant involvement in the delivery of global energy projects and have set up the EnergyData.info[6] website as a dedicated open data platform for the energy sector. The platform is freely accessible to support stakeholders globally in designing and delivering projects with open data analytics applications ranging from sizing an optima solar/storage system, to designing electrification pathways, and estimating off-grid energy services markets.

### Challenge #6: Meeting the demands of decarbonization

The evolving energy landscape requires a workforce and adequate capacity to deliver, operate, and maintain the growing renewable energy infrastructure. However, there is often a shortage of skilled personnel with the necessary expertise in clean energy technologies and practices. Adopting digitally enabled approaches and system operation methods can be highly beneficial to meeting these demands.

### Digitally-enabled construction approaches and system operation modernization

Across the globe, network operators, are not only extending and reinforcing their grids, many have embarked on their digital journey. More and more, regulators are changing the regulatory regimes to allow grid investment in digitalization next to hardware investments.

The digitization journey covers many parts of the grid operators activities. Digitally-enabled construction approaches should be deployed to leverage technologies such as Building Information Modelling (BIM), drones, and remote monitoring systems. These tools streamline construction processes, improve efficiency, and enhance safety measures. They also enable accurate project planning, optimize resource allocation, and reduce costs.

Modernizing system operation methods through digitalization and automation can enhance grid management and maintenance practices. Advanced monitoring systems, smart meters, smart substations, and data analytics enable real-time, automated monitoring and control of energy networks. This improves system reliability, enables predictive maintenance, and facilitates rapid response to disruptions. By leveraging digital technologies to deliver an integrated "Smart Grid", energy networks can optimize their operation, minimize downtime, and improve overall performance.

6 https://energydata.info/

## Case study: Amazon's 2025 upskilling pledge

In response to the rapidly evolving landscape of work due to automation and artificial intelligence (AI), Amazon launched the ambitious initiative "Upskilling 2025" in 2019[7]. Committing $700 million, the tech giant aims to retrain 100,000 of its U.S. employees by 2025, assisting them in transitioning to more technically advanced roles or even new professions outside of the company.

To achieve this, Amazon has introduced diverse training programs, such as the Amazon Technical Academy, which transforms non-technical staff into software engineers, and the Machine Learning University, designed for those already in technical roles. Beyond preparing its workforce for future internal roles, Amazon's effort emphasizes equipping employees with skills valuable beyond its ecosystem.

This proactive approach is seen as a strategic move to not only prepare for the future of automation but also to offset potential negative optics arising from job displacements due to technology. Similar ambitious approaches are needed in the energy sector to embrace the digital revolution and support people in building new skills and transitioning to new careers.

7 https://www.aboutamazon.com/news/workplace/upskilling-2025

# Conclusion

## Energy networks at the center of the transition to net zero

Energy networks play a pivotal role in the success of the transition to net zero. They serve as the backbone for integrating renewable and distributed energy sources into our existing infrastructure. However, achieving net zero is a collaborative effort that involves various external forces. Regulatory frameworks, technological advancements, and supportive policies are equally crucial in enabling the transformation of energy networks. By aligning these external forces with the capabilities of energy networks and implementing solutions like clear decarbonization goals, anticipatory investments, and collaborative partnerships, we can empower energy networks to drive the transition to a sustainable future. It requires a collective commitment from governments, regulators, industry stakeholders, and society as a whole to unlock the full potential of energy networks and pave the way toward a cleaner, greener, and more sustainable world.

## Call to action

**Governments:**

- Set clear decarbonization goals and provide a roadmap for the transition to net zero
- Establish supportive regulatory frameworks to incentivize clean energy investments and ensure equitable cost distribution

**Energy networks:**

- Adapt infrastructure for renewable and distributed energy integration
- Invest in anticipatory measures and grid upgrades to address connection constraints
- Promote flexibility and bidirectional power flows through market rules
- Embrace digital technologies for optimized system operation
- Collaborate with educational institutions to develop skilled workforces

**Industry and technology providers:**

- Innovate and develop cost-effective clean energy technologies and solutions
- Collaborate with energy networks to deploy compatible technologies
- Ensure seamless integration with existing infrastructure

***To achieve net zero, we must empower energy networks through clear goals, strategic investments, and collaborative partnerships, driving the integration of renewable sources and fostering a sustainable energy future.***

# 04

# MONEY FLOWS

# HOW THE MONEY FLOWS

**TORBEN SCHUSTER**
Vice President, Trading and Energy Transition

**Upfront last years market supply and price disruption governments, industry bodies, market facilitators and market participants heavily discussed if the market design is still working and in line with the key objectives of energy policies (cp. figure 1).**

**The interaction and effects between state interventions and market mechanisms were never so clearly to observe as before. Fact is, the energy goes where the money is.**

Especially the goal of sustainability and the transition from traditional, fossil-fuel-based energy to a green and $CO_2$-neutral energy world is one of the biggest changes and tasks since industrialization. Steering this change in the right direction already requires forward thinking regulation, investment and alignment across borders.

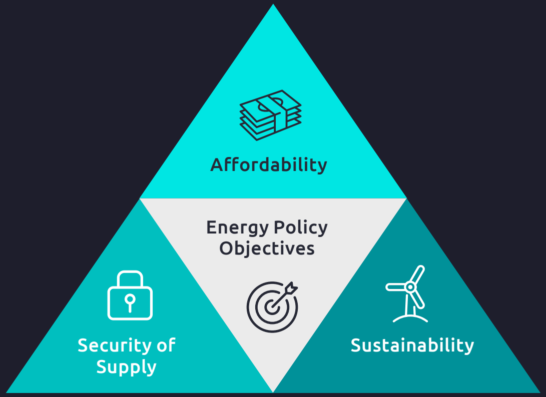
The last year' sky-rocketed gas prices proved, especially in Europe, that structurally weak energy markets were not able to stand the stress test. With a significant portion of electricity being generated from volatile renewable assets and a flexible back-up being produced in thermal power plants burning imported gas, significant price volatility is predestined.

The key question of this chapter therefore is how money is flowing in and across the energy value chain and if even more state intervention is required or not. Therefore, this chapter investigates:

- How wholesale and consumer prices developed in 2022 and to what extent state intervention played a role (article 1)
- Which global interventions took place to answer energy market turmoil (article 2)
- Which discussions are ongoing to adjust the energy market design to make it more robust for further stress tests (article 3)
- How energy market players performed and developed across the globe (articles 4-6)

**FIGURE 1**

Energy Policy Objectives - the trillema continued



# Conclusion

## The key facts presented in this chapter lead to the following conclusions:

**#1: Intervention sometimes is part of the problem:** Looking at the gas price development and regulation, storages needed to be filled with certain percentage rates contributed to the price rally in 2022.

**#2: Market design discussions are influenced by market turmoil:** The drafts of the new energy market design and related discussions were very much driven by discussions about pricing mechanisms on the energy market. There seems to be no fundamental change, but the time required to discuss this is missing on very concrete proposals and international alignment of recommendations.

**#3: Money intervention arrived and helped on consumer side:** Looking at the world's energy price composition, there is already quite some state intervention with existing fees, tariffs, and also subsidies. This definitely increased in 2022, when states helped to stabilize end consumer prices and consumption. The discussions if funding of this intervention could be carried by increased company profits took too long and the market (driven by reduced energy consumption) was faster than further regulations, which mostly did not enter into force or remained ineffective.

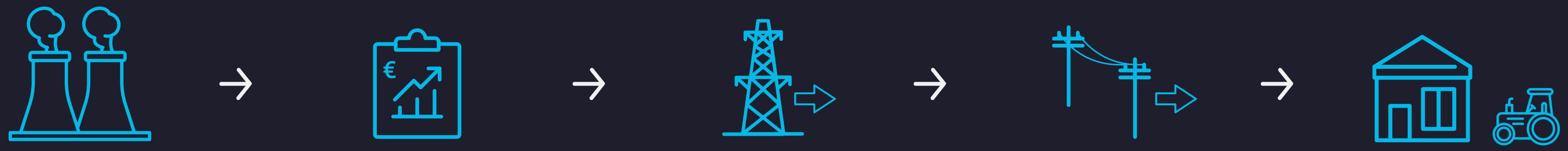
**#4: Security of supply is the clear winner:** In 2022, the balance of the above-mentioned energy triangle was clearly shifted towards affordability and also security of upstream supply. There was a huge push for new supply resources (e.g. LNG), both financially, but also wrt. decreasing bureaucracy in infrastructure measures. Also coal-fired power plants experienced some revival as replacement of gas.

**#5: Don't forget about the grid:** Everyone agrees, that energy transition happens in the grid. Nevertheless, grid expansion and stability of the grid, especially upfront further growth of renewables and increasing volatility was only addressed to limited extent. All discussions encourage flexibility needs, but how to get there and which technologies are supported, especially financially remained vague.

**#6: Industry money is following clear signals:** Looking at geographies, which were not hit by the energy crisis to the same extent, e.g., Australia, reveals, that new energy market participants and partnerships arise along the value chain, but especially on these parts, where clear regulatory signals (e.g., XX% share of renewables by 20XX or $CO_2$ neutral country by 20XX). Also, investments in renewable energy and related technologies are constantly on the rise.

**FIGURE 2**

Energy utilities are **moving from traditional, fossil-fuel-based, one-directional, simple business models** with the energy consumer at the end of the value chain



Central fossil-fuel energy production → Large volume, manual energy trading → Unidirectional energy transmission → Unidirectional energy distribution → Energy consumers with fossil-fuel cars

... **to new composed business models** based on decarbonized, bi-directional, blurring value chains with the prosumer / flexumers* at both ends and profitability outside traditional central energy productions.

Next-gen, intelligent energy production incl. prosumers → Intelligent storage and flexibilities (flexumers*) → Volatile, mixed volume automated energy trading → Bidirectional intelligent energy transmission → Bidirectional intelligent energy distribution → Prosumer / flexumer* with smart meter and e-cars



*Flexumer = Energy Consumer + Energy Producer + Energy Flexibilities

## It is possible to develop an electricity market entirely based on renewable and $CO_2$-neutral energy.

However, this requires a more radical approach to infrastructure refurbishment and development providing substantial incentives to commercialization of currently nascent and new technologies (e.g., batteries of any kind as alternative source of flexibility).

By this, not only (or sometimes exactly not) a simple subsidization of asset development is meant, but also an innovative market regime, allowing new players to find their niche on the market.

Last year showed that the demand for flexibility is inherently there and therefore can be easily monetized. However, market rules with respect to very short-term trading and balancing are not yet mature enough to reduce the associated commercialization risks.

So, 2022 proved that global energy markets are not mature enough to survive without any state intervention, especially on the end consumer/ affordability and supply side. But it is also clear that the market is resistant enough to recover in a short time and the focus of the international state community should not be too short-term at all.

There is rather some evidence, that an aligned, to some degree adoptable and global energy strategy is  critical, so global energy market development has a clear direction for market players to contribute and invest in.

# 04

1. WORLDWIDE ENERGY PRICE COMPOSITION DEVELOPMENT: INTERVENTION AND REFORM IS CRUCIAL
2. HOW DID EUROPEAN GOVERNMENTS REACT TO THE BIGGEST ENERGY CRISIS OF THE CENTURY?
3. RELECTRICITY MARKET DESIGN: HOW MUCH INTERVENTION IS NEEDED?
4. EUROPEAN PLAYERS - PRIORITIES, INVESTMENTS AND FINANCIAL RESULTS
5. NORTH AMERICAN PLAYERS - PRIORITIES, INVESTMENT AND FINANCIAL RESULTS
6. AUSTRALIAN PLAYERS - PRIORITIES, INVESTMENT AND FINANCIAL RESULTS

# WORLDWIDE ENERGY PRICE COMPOSITION DEVELOPMENT: INTERVENTION AND REFORM IS CRUCIAL

DEBARGHYA MUKHERJEE, INDIA

TORBEN SCHUSTER, GERMANY

## State intervention and market redesign to achieve a sustainable energy future

**To assess the development of energy prices worldwide, following components were examined: What role do the wholesale markets play, what are the price regulation practices, and state intervention and market designs. Long-term redesigns of Europe's power market are considered critical to avoiding future price volatility, balancing the needs of consumers and producers, and bolstering investment in new generation capacity.**

Starting in 2020, the world has encountered four distinct energy crises:

- The Covid-19 pandemic, which led to a sharp decline in demand for energy resources.
- The subsequent recovery plans, which unexpectedly increased energy demand, potentially jeopardizing supply security.
- Russia's invasion of Ukraine, posing a threat to the security of fossil fuel supplies in Europe.
- The rise in inflation and interest rates, resulting in higher costs for new energy assets such as renewables and nuclear plants. This increase is primarily due to the significant impact of capital expenditure on the levelized cost of electricity (LCOE), which can account for up to 80%

Wholesale electricity and natural gas prices nearly quadrupled from previous records in Q3 2022 (compared to 2021), creating concerns for skyrocketing energy costs for consumers and businesses. These scenarios prompted discussion on state intervention and market designs to safeguard energy affordability. To alleviate the impact of high electricity prices on consumers, several countries have implemented measures such as setting controls on wholesale and retail prices, imposing revenue caps on infra-marginal technologies such as renewables, nuclear, and coal plants, reducing energy taxes and VAT, and providing direct subsidies.

Energy price volatility highlights the structural challenges Europe faces as it seeks to transition its energy system away from carbon-emitting fossil fuels. Following the outbreak of the Russia-Ukraine conflict, European consumers have faced power rates significantly higher than the average production costs. These record high power costs led to high inflation, which became the region's biggest economic problem since 2022.

Fossil fuel consumption subsidies rose globally above $1 trillion for the first time in 2022. According to the International Energy Agency (IEA), in 2022, oil subsidies increased by around 85%, while natural gas and electricity consumption subsidies more than doubled. High fossil fuel prices were the main reason for upward pressure on global electricity prices, accounting for 90% of the rise in the average costs of electricity generation worldwide (natural gas alone was more than 50%).

The most significant surge in Europe's wholesale electricity prices occurred in 2022, with average prices exceeding twice those of 2021. The exceptionally mild winter in 2022/23 helped temper wholesale electricity prices, but prices remain high compared to recent years. Elevated future prices for winter 2023/24 reflect the uncertainties regarding gas supply in Europe over the coming year.

In the European Union, a wide range of responses to the energy crisis have been observed. To reduce reliance on fossil fuels and to increase resilience to price shocks, the European Commission published its REPowerEU plan in May 2022 to accelerate clean energy deployment. At the same time, discussions about electricity market design gained momentum due to soaring wholesale prices. The commission also launched a consultation on market design reform.

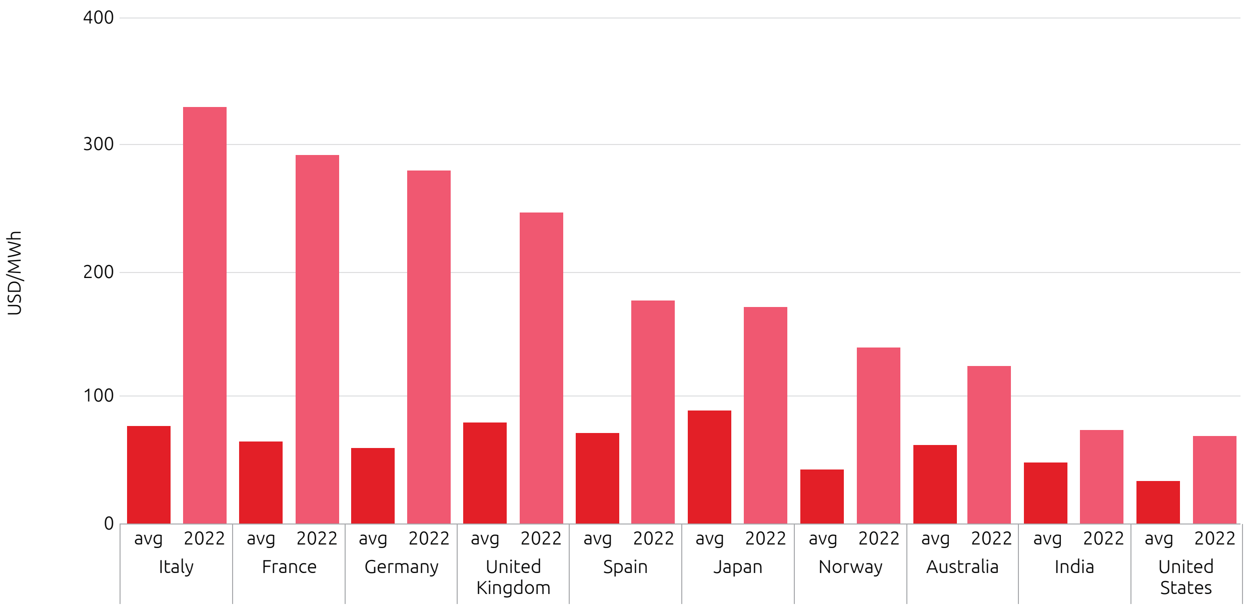
Market interventions can help mitigate the impacts of the energy crisis, but the potential creation of uncertainty in the investment landscape needs to be minimized to ensure that responses to the crisis do not come at the expense of much-needed investment. Electricity markets were impacted differently across the world – Europe being hit the hardest as seen in Figures 1 and 2.

Energy price increases were softened by substantial government intervention. Nearly all EU governments are pursuing either direct payments to households or temporary reductions in bills via lower taxes and other levies. Additionally, the European Union recently adopted a temporary windfall tax on the surplus profits of fossil-fuel companies and on excess revenues made from surging electricity costs.

Several initiatives were particularly noteworthy like the Iberian exception, solidarity contributions, and the German industry support scheme of a EUR 200 billion energy relief plan (called Economic Defense Shield). However, the targeted direct financial support and retail price measures differ significantly.

**FIGURE 1**

Annual wholsesale prices in selected countries, 2002 and 2017-2021 average

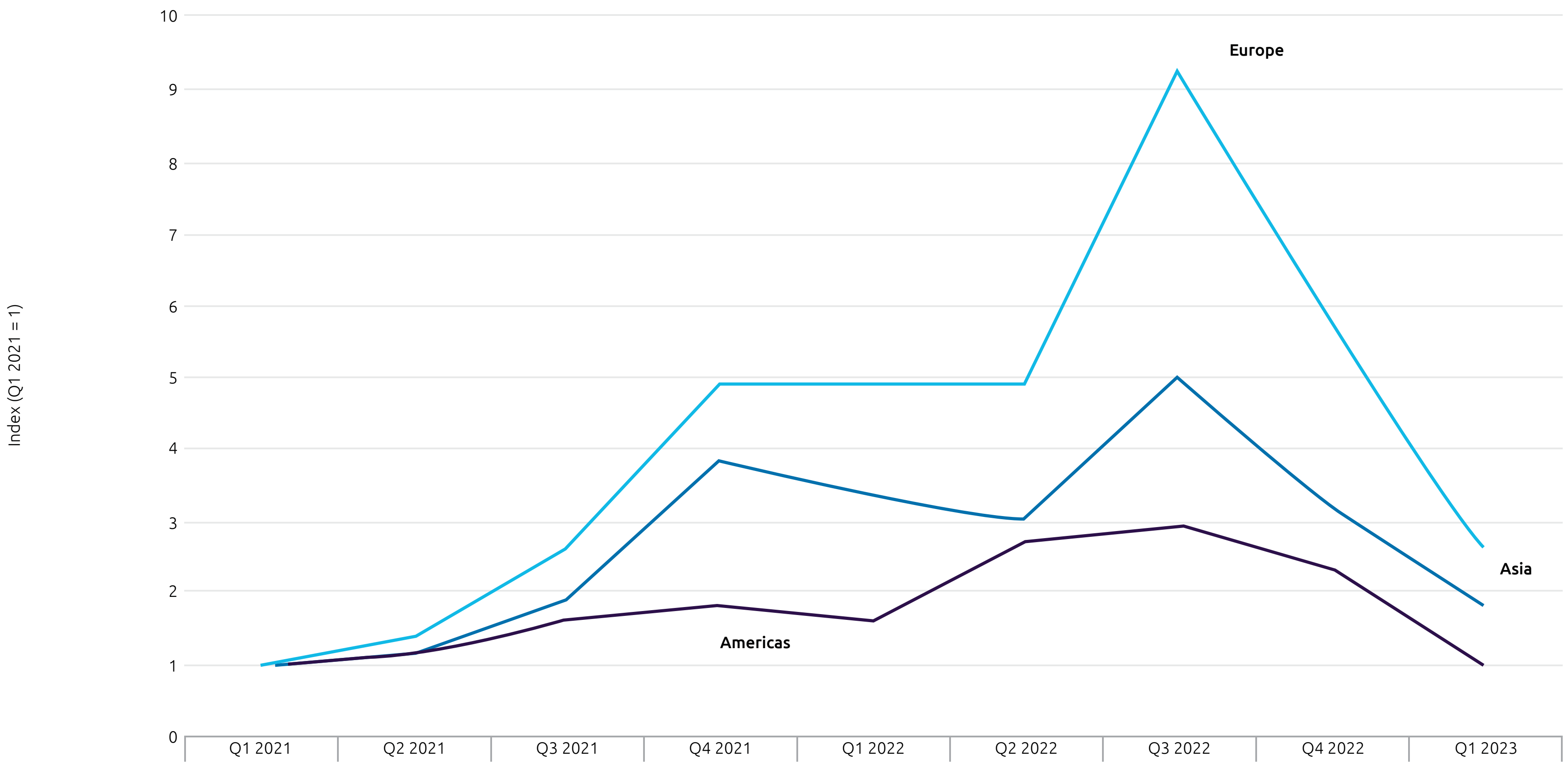



Source: IEA

Note: Avg refers to an average of the years from 2017 to 2021. The annual averages are calculated from the daily wholesale electricity prices

FIGURE 2

Natural gas wholesale price indexes in major markets by quarter, Q1 2021- Q1 2023




Source: IEA

# Electricity prices remain elevated in many regions, led by the high cost of energy commodities

Energy markets have tightened since the Covid-19 pandemic, and the situation intensified considerably following the Russia–Ukraine conflict in late February 2022. This contributed to a global energy crisis. Global energy prices surged because of various factors, including the ongoing geopolitical conflict, a rapid global post-pandemic economic recovery, continued high reliance on fossil fuels, and the severe mismatch between energy demand and supply. This resulted in substantially higher wholesale electricity prices in many regions of the world in 2022, as compared to the year prior.

The Russia-Ukraine conflict mainly endangered gas and fossil fuels supply in Europe, boosting gas prices and liquefied natural gas (LNG) market. In H2 2022, wholesale electricity prices (day-ahead spot pricing) in many European countries exceeded the second-half average prices between 2019 and 2021, with France experiencing a fourfold increase. In H2 2022, the average wholesale price reached almost €330/MWh in Germany and surpassed €320/MWh in France; this was exacerbated by nuclear unavailability. By contrast, in Spain, average prices were much lower for the same time at about €130/MWh due to the Iberian price cap. The demand weighted average price for Germany, France, Spain, and the United Kingdom in H2 2022 was almost four times as high as the H2 2019-2021 average.

The elevated futures prices in Europe for winter 2023/24 reflect the continued uncertainties associated with gas supply for Europe, as presented in Figure 3. Futures with delivery in Q4 2023 are €227/MWh in France and €184/MWh in Germany, while those for Q1 2024 are €258/MWh in France and €186/MWh in Germany.

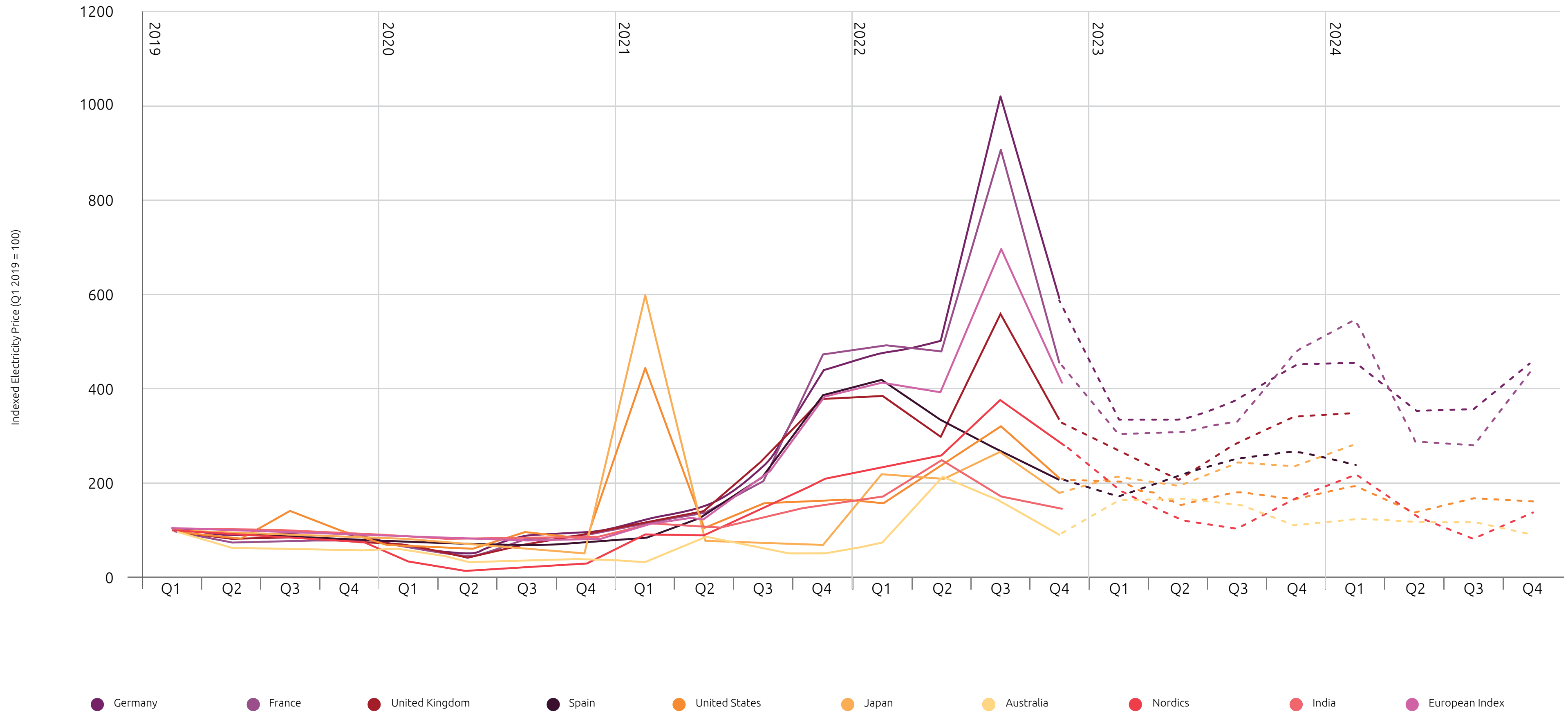
In the United States, the average wholesale price in H2 2022 stood at about $91/MWh, more than twice the 2019-2021 second-half average and 65% higher than the price in H2 2021. This increase was driven by exceptionally high gas prices.

In 2022, Australian wholesale prices averaged AUD $170/MWh, more than double the H2 2021 levels. This was due to surging electricity demand and gas prices.

In India, despite increased coal stocks, higher electricity consumption resulted in a 10% price rise in H2 2022 over the H2 2021 level. The average wholesale price in H2 2022 was INR 5000/MWh (€55/MWh). The strong growth of solar photovoltaic (PV) helped to meet peak loads driven by higher refrigeration and space cooling.

**FIGURE 3**

Indexed quarterly average wholesale Electricity prices for selected regions, 2019-2024 (EUR/MWh)




Source: IEA, EIA, Eurostat

# Supply chain pressure, higher fuel costs and extreme temperature drove the increase of U.S. energy prices

In 2022, the retail price for electricity in the United States stood at an average of 12.5 cents per kilowatt-hour. Average electricity prices for the residential sector were 15.1 cents per kilowatt-hour; the commercial sector was 12.5 cents per kilowatt-hour; and the industrial sector was 8.5 cents per kilowatt-hour.

According to EIA, average price of electricity to U.S. residential customers will increase by 4% in 2023 to 15.7 cents/kWh. Electricity prices rose about 11% in 2022 to 15.1 cents/kWh due to increases in the cost of producing electricity. Reductions in the wholesale price of electricity, largely due to lower natural gas prices in 2023, should help lower residential prices in the future.

In nominal terms, the average monthly electricity bill for residential customers in the United States increased 13% from 2021 to 2022, rising from $121 a month to $137 a month. After adjusting for inflation—which reached 8% in 2022, a 40-year high—electricity bills increased by 5%. A colder winter and a hotter summer contributed to the 2% increase in average monthly electricity consumption per residential customer in 2022. Customers used more space heating during the winter and more air conditioning during the summer.

The cost of fossil fuels (natural gas, coal, and petroleum) delivered to U.S. power plants increased 34%, from $3.82 per million British thermal units (MMBtu) in 2021 to $5.13/MMBtu in 2022. The higher fuel costs were passed along to residential customers and contributed to higher retail electricity prices.

Natural gas prices and consumption increased due to hot weather and rise in air conditioning demand. In 2023, natural gas prices for the electric power sector have averaged about $2.65/MMBtu from June through August 2023, making natural gas a more competitive source of electricity generation compared with coal. In addition, several new natural gas-fired power plants entered service in 2022 and 2023, which increased the electric generation capacity available from natural gas. In 2024, the Henry Hub natural gas spot price could rise by almost 30% over 2023 to an average of about $3.40/MMBtu.

**FIGURE 4**

U.S. Monthly nominal residential electricity price

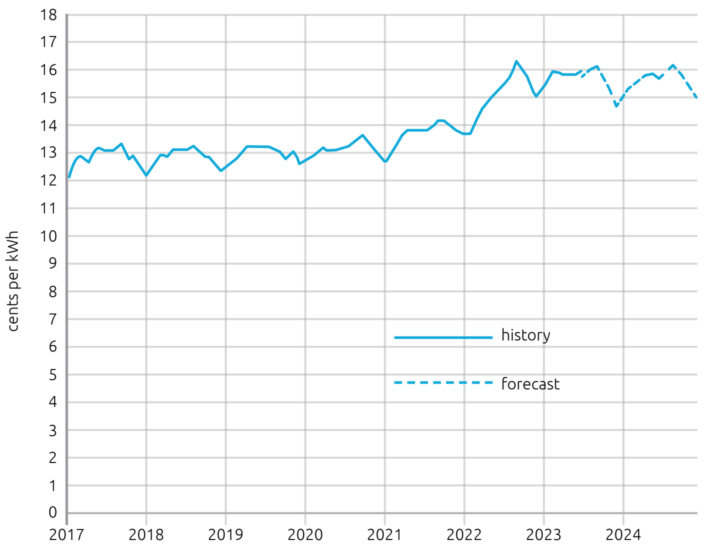
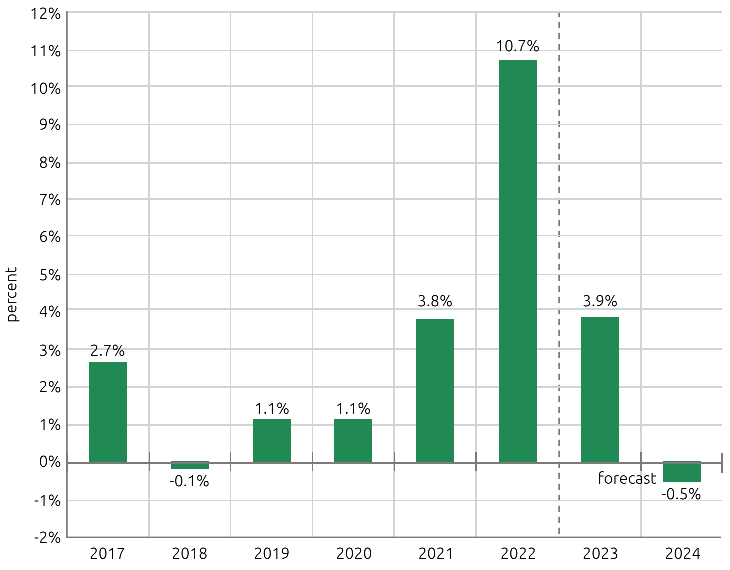



**FIGURE 5**

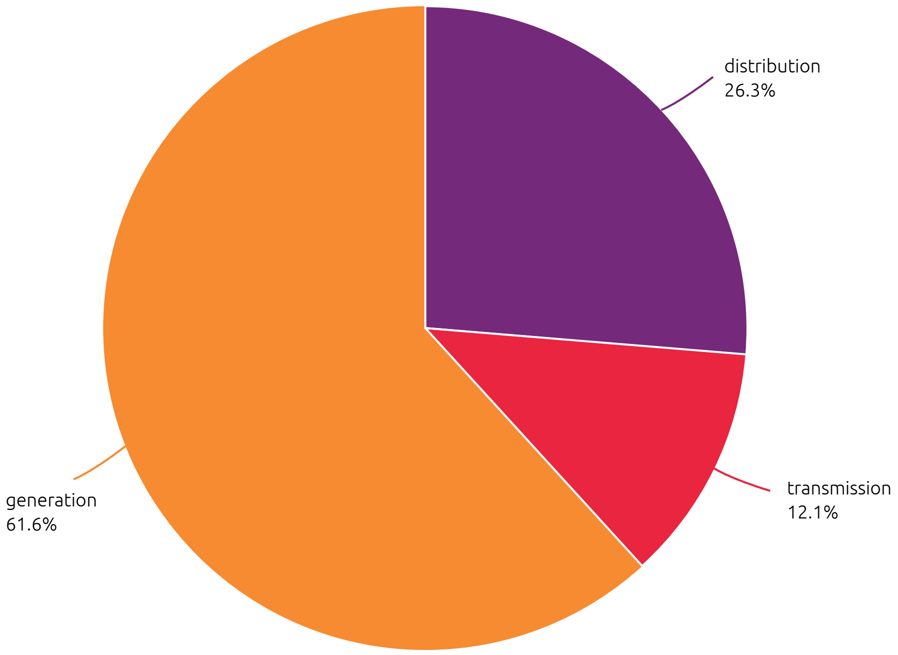
Annual growth in nominal residential electricity prices




Data Source: U.S. Energy Information Administration, Short-term Energy Outlook, June 2023

**FIGURE 6**

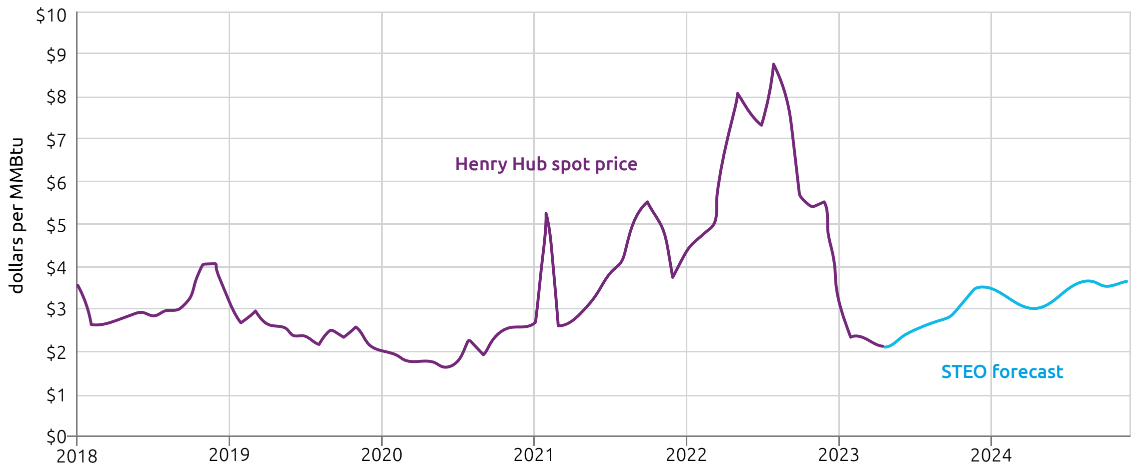
Major components of U.S. average electricity price (2022)




Source: IEA

**FIGURE 7**

Henry Hub natural gas spot price




Data source: U.S. Energy Information Administration, Short-Term Energy Outlook, June 2023 and Refinitiv, an LSEG Business

# Development of European Electricity and Gas prices in H1 2022

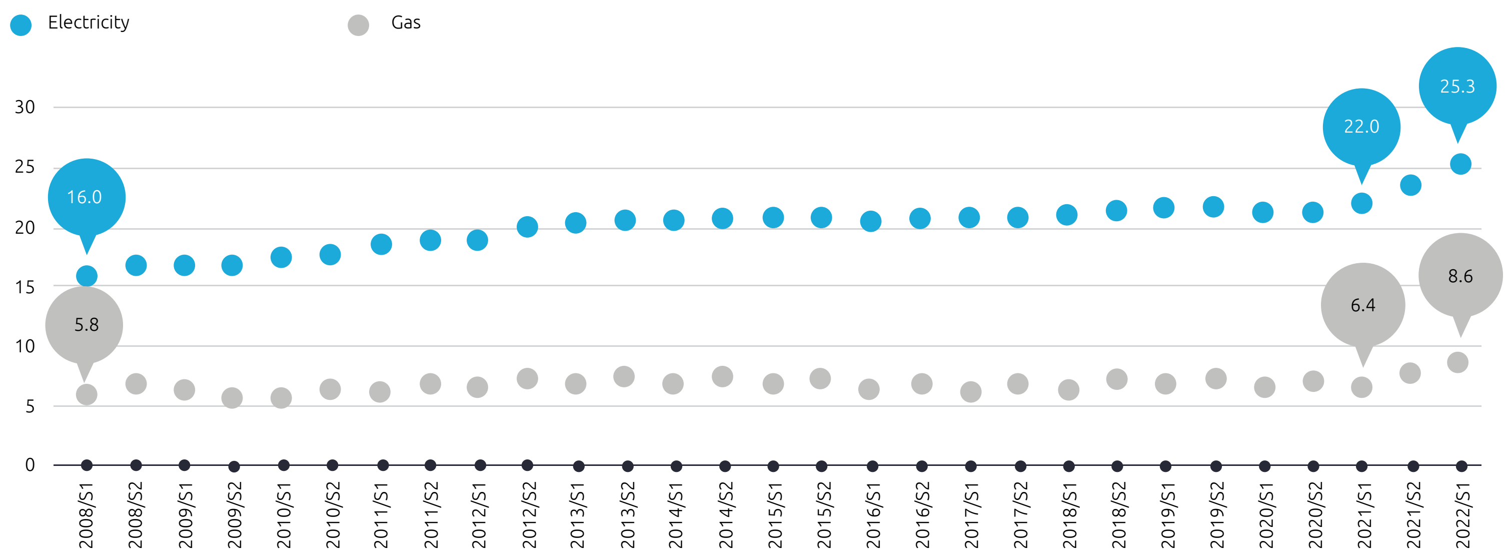
The price of energy in Europe depends on a range of different supply and demand conditions, including the geopolitical situation, the national energy mix, import diversification, network costs, environmental protection costs, severe weather conditions, and levels of excise and taxation.

In the first half of 2022, average household electricity prices increased sharply compared to the same period in 2021, from €0.22 per kWh to €0.25 per kWh. Average gas prices also increased compared to the same period in 2021, from €0.06 per kWh to €0.8 per kWh in the first half of 2022.

In the first half of 2022, the weight of taxes and levies in the final electricity and gas bills charged to households decreased significantly when compared to the previous year. This was due to governmental allowances and subsidies implemented to mitigate the high-energy costs. Compared with the first half of 2021, the share of taxes in an electricity bill dropped sharply from 39% to 24% (-15.5%) and in gas bills from 36% to 27% (-8.6%).

FIGURE 8

Evolution of household electricity and gas prices in the EU
(in € per 100 kWh, all taxes and levies included)




Household electricity prices rose in 22 European Union member states in the first half of 2022, as compared to the first half of 2021. The largest increase (expressed in national currencies) was registered in Czech Republic (+62%), Latvia (+59%), and Denmark (+57%). Decreases in household electricity prices in the Netherlands, Slovenia, and Poland were connected to government subsidies and allowances; in Hungary, prices are regulated.

Gas prices surged the most in Estonia (+154%), Lithuania (+110%), and Bulgaria (+108%), mainly driven by the cost of energy. Average household gas prices (€ per 100 kWh) in the first half of 2022 were the lowest in Hungary (€2.9), Croatia (€4.1), and Latvia (€4.6). They were highest in Sweden (€22.2), Denmark (€16.0), and the Netherlands (€12.9).

# Development of European household and non-household electricity prices in H2 2022

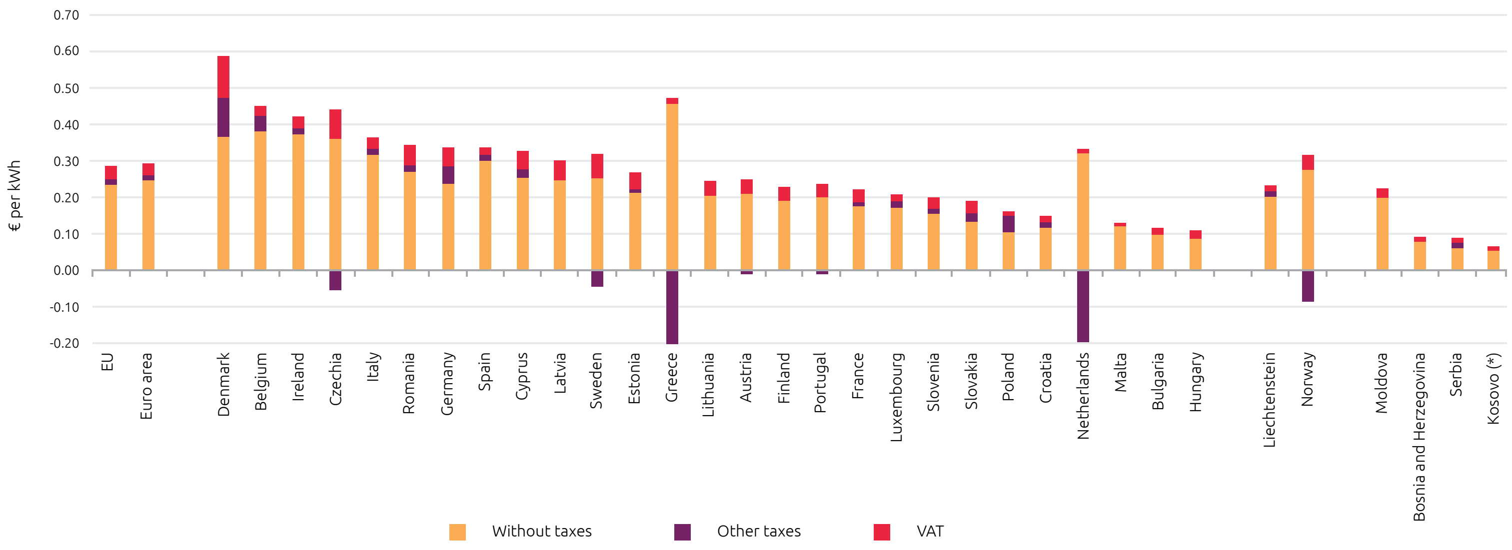
For household consumers in Europe, electricity prices in the second half of 2022 were highest in Denmark (€0.58 per kWh), Belgium (€0.44 per kWh), Ireland (€0.41 per kWh), and Czech Republic (€0.38 per kWh). Energy and supply costs mainly drove the increase. The lowest electricity prices were registered in Hungary (€0.10 per kWh) and Bulgaria (€0.11 per kWh). The average price in the second half of 2022 for electricity by household consumers was €0.28 per kWh.

Various countries opted for measures like reducing taxes and fees, temporary tax waivers to consumers, price caps, providing lump sum support, or allocating vouchers to final consumers; some countries applied regulated prices. The share of taxes in the second half of 2022 was the least in the Netherlands, where the values were, in fact, negative (-136.8%). The Netherlands gave allowances with the most impact to household consumers.

In the Netherlands, electricity prices for household consumers without government intervention, taxes and levies would have been €0.21 and €0.32 per kWh in H1 and H2 of 2022. Also, for Greece, electricity prices for household consumers without government intervention, taxes, and levies would have been €0.30 and €0.45 per kWh in H1 and H2 of 2022. The relative share of taxes was highest in Denmark, making up 38% of the total price. The average share of taxes and levies at the regional level was 15.5%. VAT represented 13% of the total price.

**FIGURE 9**

Electricity prices for household consumers, second half 2022




(1) This designation is without prejudice to position on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo Declaration of Independence.
Source: Eurostat (online data codes: nrg_pc_204)

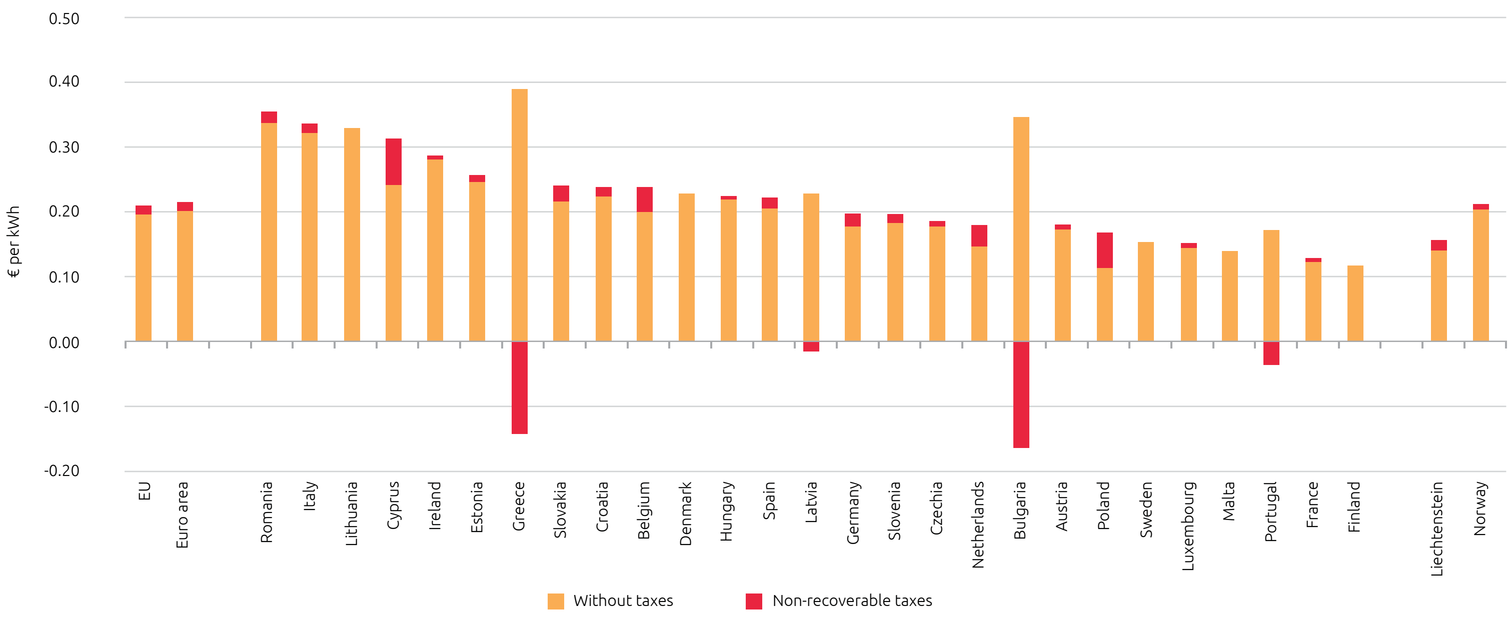
Electricity prices in the second half of 2022 for non-household consumers were highest in Romania (€0.35 per kWh) and Italy (€0.33 per kWh). The lowest prices were observed in Finland (€0.11 per kWh) and France (€0.12 per kWh). The average price in the second half of 2022 was €0.21 per kWh.

**Proportion of non-recoverable taxes and levies on the overall electricity price for non-household consumers**

In the second half of 2022, the share of taxes was highest in Poland and Cyprus, where non-recoverable taxes and levies made up 34.1% and 22.7% of the total price, respectively. The share of taxes for the European Union stood at 5.6%, a substantial decrease compared to the first half of 2022 (12.6%).

**FIGURE 10**

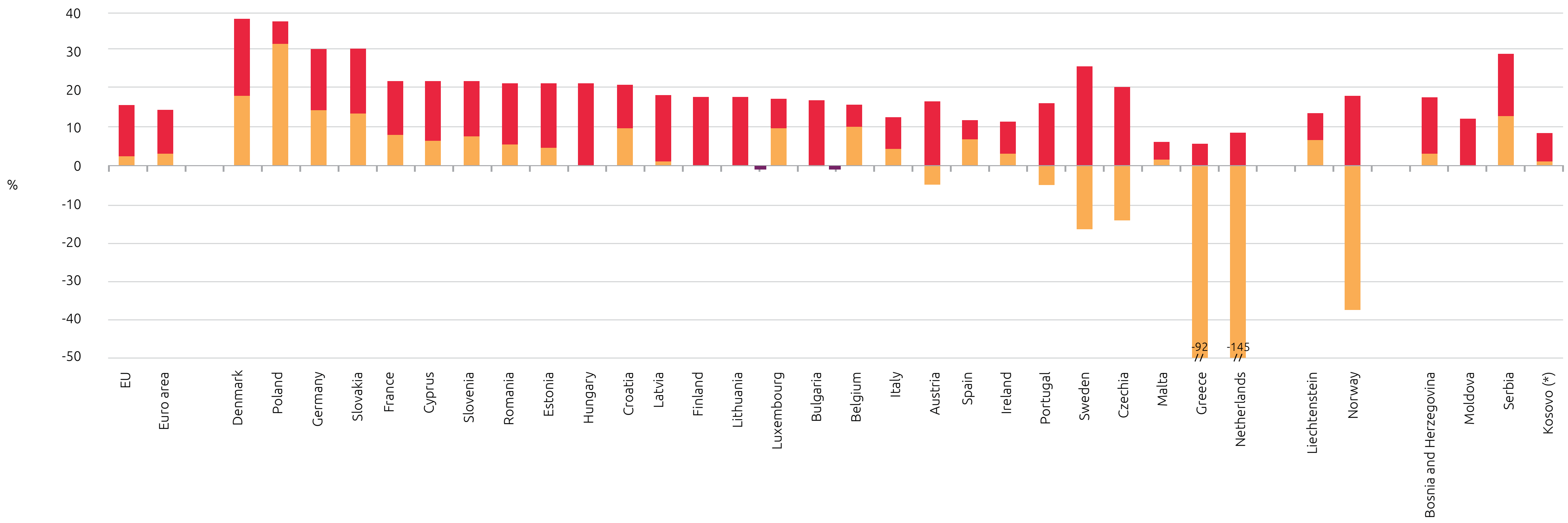
Electricity prices for non-household consumers, second half 2022




(1) This designation is without prejudice to position on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo Declaration of Independence.
Source: Euarostat (online data codes: nrg_pc_205)

**FIGURE 11**

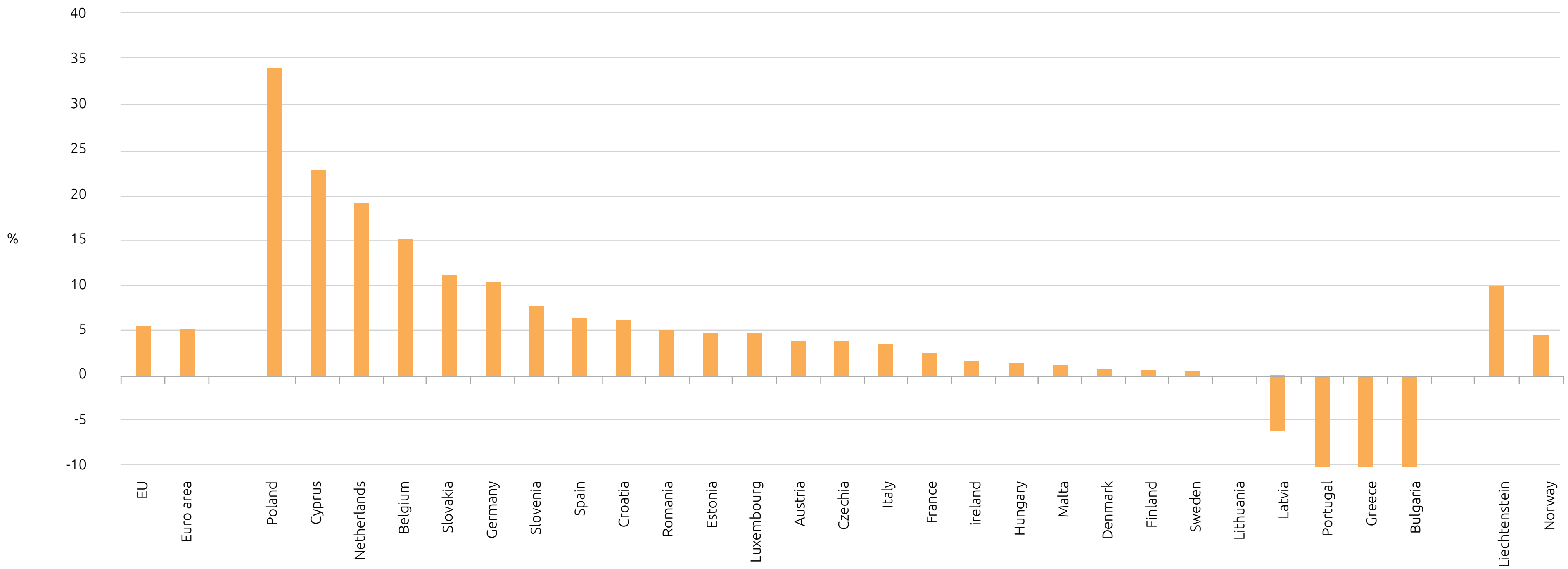
Share of taxes and levies paid by household consumers for electricity, second half 2022




(1) This designation is without prejudice to position on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo Declaration of Independence.
Source: Euarostat (online data codes: nrg_pc_204)

**FIGURE 12**

Share of taxes and levies paid by non-household consumers for electricity, second half 2022




(1) This designation is without prejudice to position on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo Declaration of Independence.
Source: Euarostat (online data codes: nrg_pc_205)

# Development of European household and non-household gas prices in H2 2022

For household consumers, natural gas prices in the second half of 2022 were the highest in Sweden, Denmark, and the Netherlands and lowest in Hungary, Croatia, and Slovakia. The price of natural gas for households in Sweden (€0.2751 per kWh) was more than seven times the price charged in Hungary (€0.0349 per kWh) and 157% higher than the regional average price. The average price for natural gas consumption by household consumers in the EU in the second half of 2022 was €0.1137 per kWh.

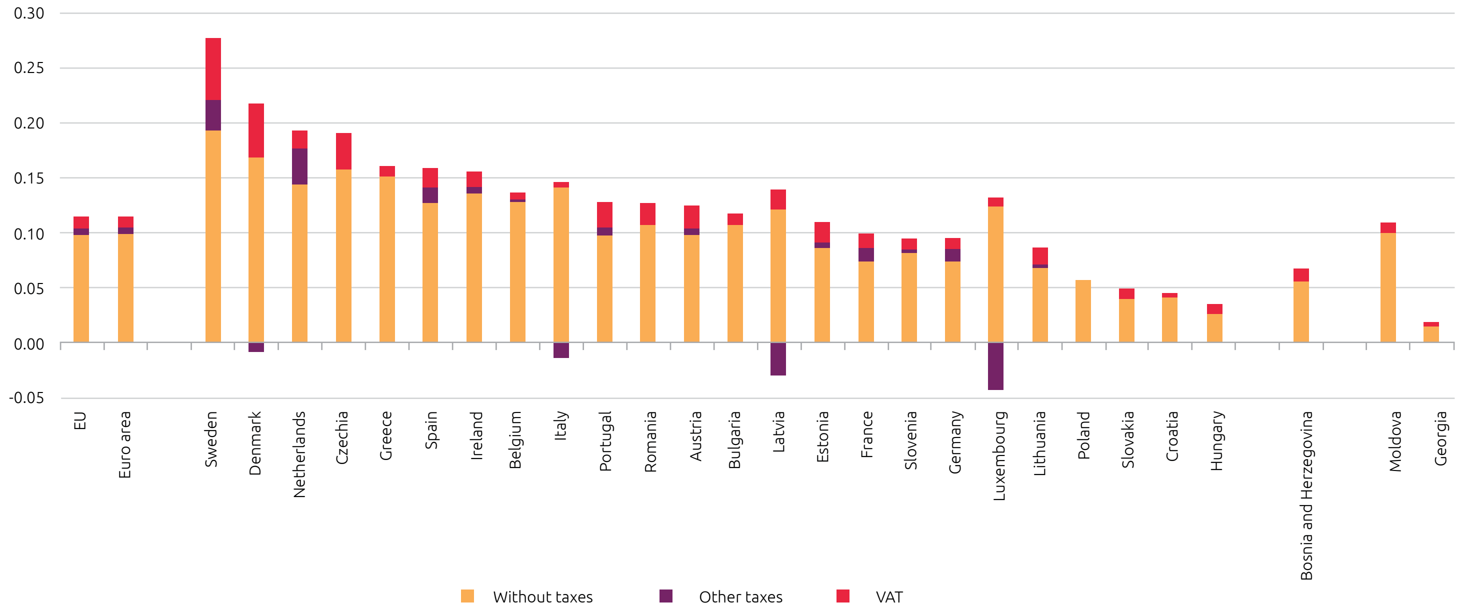
Gas prices for non-household consumers in the second half of 2022 were highest in Finland (€0.1815 per kWh), at more than twice the regional average, followed by Sweden (€0.1662 per kWh). Finland and Sweden have very little natural gas consumption. The lowest prices were recorded in Germany (€0.0613 per kWh). The average price for natural gas consumption by non-household consumers was €0.0812 per kWh.

Taxes and levies paid by household customers for natural gas in H2 2022 were the lowest in Luxembourg. The highest taxes were observed in Sweden, where taxes and levies corresponded to 30.06% of the final price. In the Netherlands, this percentage was 25.71%. The VAT represented 9.67% of the total price. The share of VAT in the total price ranged from 0% in Poland to 23.85% in Denmark.

For non-household consumers, the share of these non-recoverable taxes in the second half of 2022 was 16.6% in Sweden, 15.2% in Germany, and 12.2% in the Netherlands. Greece (-13.7%), Romania (0.5%), and Bulgaria (0.9%) found themselves at the other end of the spectrum, registering the lowest shares of taxes.

**FIGURE 12**

Natural gas prices for household consumers, second half 2022




Source: IEA, EIA, Eurostat

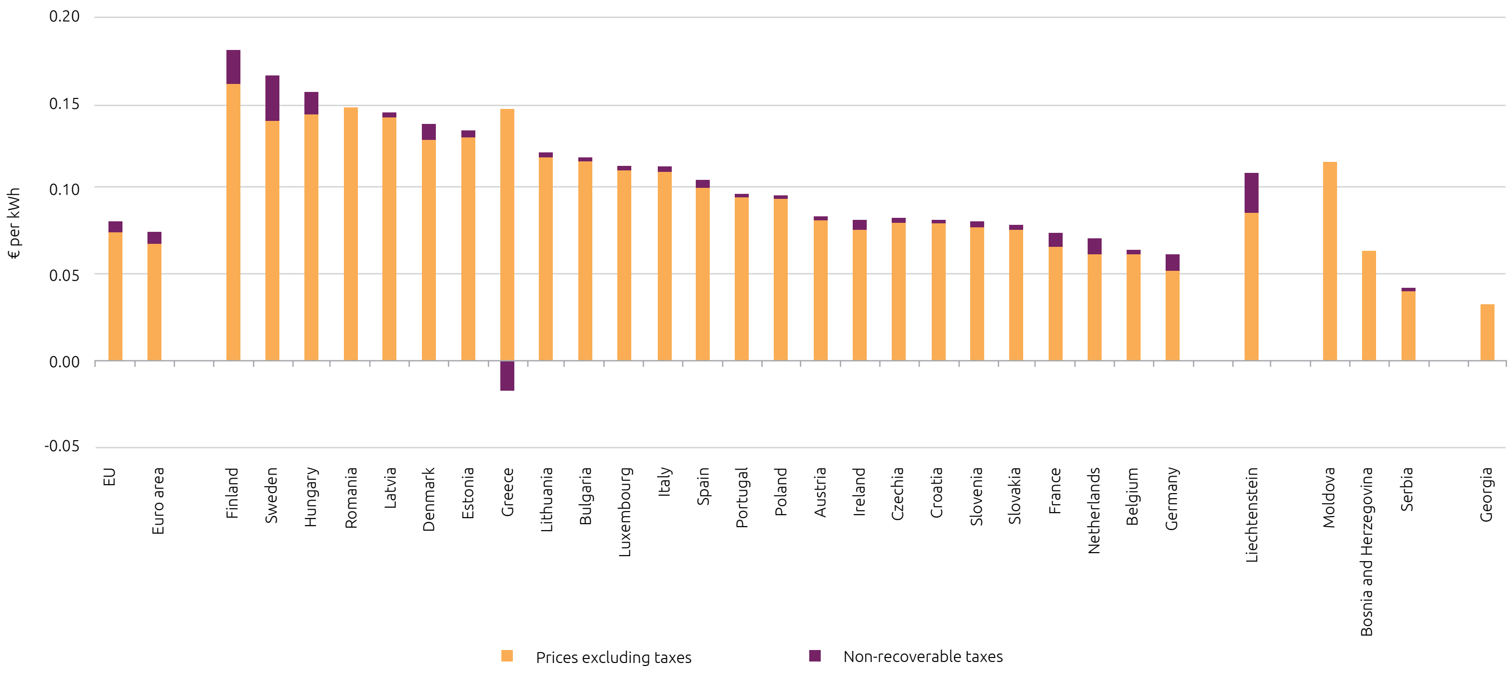
In addition to immediate and temporary measures aimed at lowering prices for energy consumers, European policymakers and regulators are considering several longer-term options to fundamentally reform how the European Union energy market operates and balance the three dimensions of security, affordability, and sustainability. Long-term redesigns of Europe's power market are considered critical to avoiding future price volatility, balancing the needs of consumers and producers, and bolstering investment in new generation capacity.

Since the start of 2023 alone, governments have announced a further $300 billion in short-term consumer affordability measures as households continue to face extremely high energy bills. However, nearly 75% of the support mobilized since the start of the global energy crisis was made available to all consumers, despite calls that the measures would be better targeted to low-income households.

***Most of the affordability measures and support were concentrated in Europe and other advanced economies. Affordability will continue to be a challenge for emerging and developing economies.***

**FIGURE 13**

Natural gas prices for non-household consumers, second half 2022




Source: IEA, EIA, Eurostat

Reduced taxes on petrol and diesel in countries across all continents pushed fossil fuel consumption subsidies to an all-time high in 2022. While these measures were mostly temporary in advanced economies, a range of emerging and developing economies continued to provide long-standing subsidies for transport fuels and electricity. Many governments are committed to phasing out fossil fuel subsidies, while financial pressures have pushed some governments to promptly reduce support.

The considerable volume of support measures is not only intensifying financial pressures on governments but also on utilities, most of which cannot pass their higher costs through to consumers. In the medium term, some utilities might raise tariffs to recoup losses that occurred during the energy crisis. However, some energy companies, particularly oil and gas producers, have made substantial windfall profits in 2022. Consequently, some governments have implemented ad-hoc levies on these gains to finance their affordability measures.

However, market reform or design doesn't ensure affordable electricity prices for end users and doesn't promote specifically low carbon energy (renewable and nuclear) energy sources. Thus, it's critical to speed up the clean energy transition by increasing investment in additional low carbon power generation and supply. **Renewable energy such as Wind, PV Solar, as well as new nuclear reactors also need significant upfront capital expenditure to build the assets. Hence to attract necessary investment into low carbon technologies, market design and reform must ensure price certainty and predictability for investors.**

**FIGURE 14**

Share of taxes and levies paid by household consumers for natural gas, second half 2022


Source: IEA, EIA, Eurostat

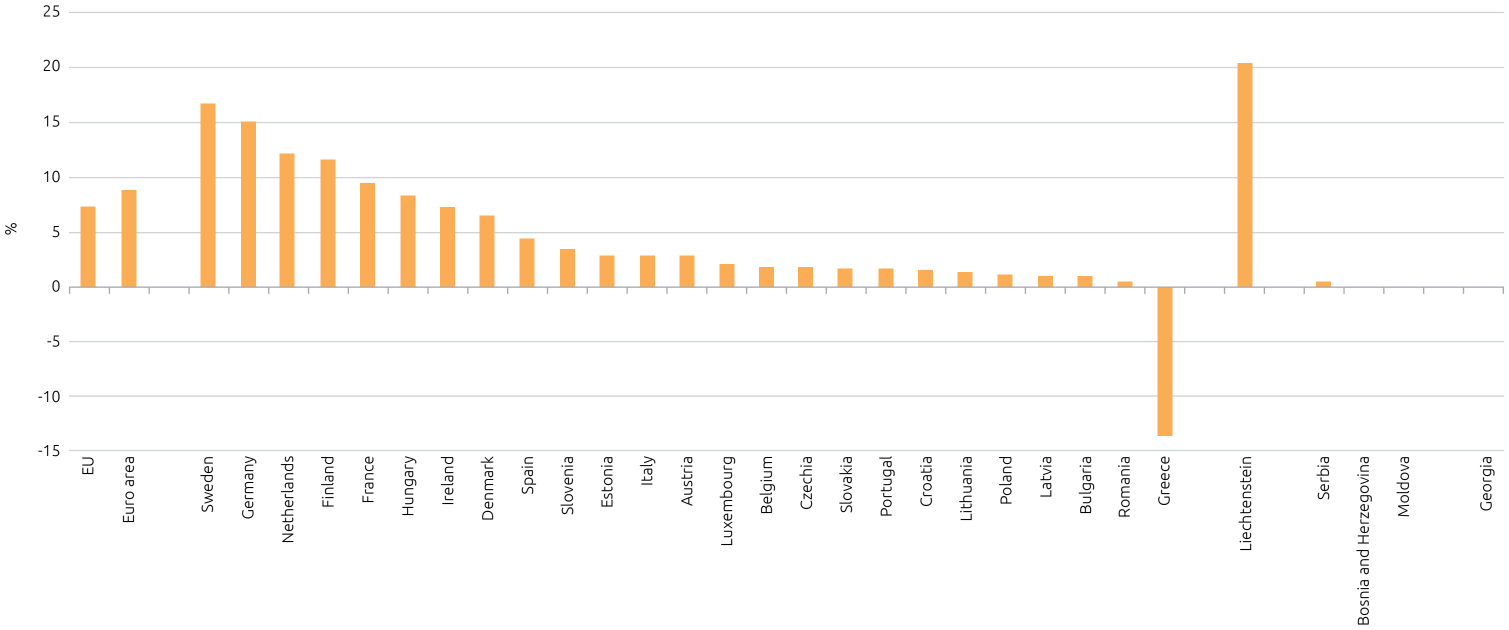
If renewables depend on short-term market price signals, investment will be costly and risky. Furthermore, if the revenues from renewables are subject to market price volatility, investors will be uncertain about their cash flows, leading to higher capital costs. High market volatility is unfavorable for attracting investments in generations with low marginal costs and high upfront capital costs. Hence, there is a strong need to redesign the current electricity market specifically for the European Union. Nuclear reactors of any type – including small modular reactors (SMRs) and European pressurized water reactors (EPRs) represent a huge investment for multiple decades (almost 100 years from the decision to the decommissioning/dismantling). These investments must be secured.

The reform of the region's electricity market design is aimed at maintaining the advantages of a single integrated European electricity market, while also gradually reducing the cost of energy production and usage with renewable sources. Additionally, some countries that are supportive of nuclear power may see the introduction of new nuclear. This is also expected to improve the access to markets to more stable longer-term contracts through Power Purchase Agreements (PPAs), which can drive investments in renewables, as well as secure long-term prices for large consumers. The CfD (two-way Contracts for Difference), where member states guarantee a stable price to producers and consumers, will foster support for new low-carbon energy investment.

***PPA and CfD instruments will be key to enhancing the stability and predictability of energy costs across the European Union and, therefore, essential in boosting its competitiveness.***

**FIGURE 15**

Share of taxes and levies paid by non-household consumers for natural gas, second half 2022




Source: IEA, EIA, Eurostat

# HOW DID EUROPEAN GOVERNMENTS REACT TO THE BIGGEST ENERGY CRISIS OF THE CENTURY?


IRENE GUERRA GIL, GERMANY


DAVID GOTTHEIT, GERMANY


CLAIRE LÖWENKAMP, FRANCE

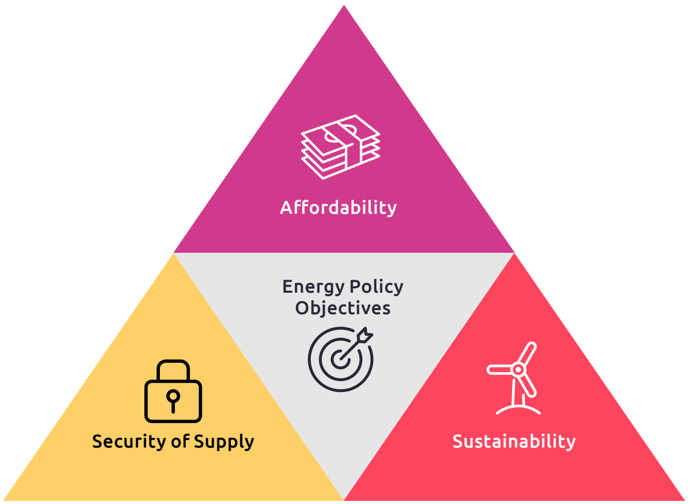
## Facing Russia's invasion

**Putin's war on Ukraine revealed Europe's strong dependence on Russian fossil fuels by causing turmoil in energy markets. To regain control over the energy market and price hikes, the European Union (EU) and more individual countries decided to intervene with important measures. These measures intended to diminish the effect of the energy crisis by pursuing three main goals: ensuring the security of electricity and gas supply, making sure people had the ability to pay their electricity and gas bills, and pushing Europe's green transition by accelerating the expansion of renewable energy.**

Energy prices experienced an all-time high in 2022 mainly because of Russia's invasion of Ukraine, but it was not the only reason. Prices were already increasing in Europe and the war was only the third step of four successive crises. Indeed, during COVID period the demand collapsed, and the recovery plans made the demand boom and endanger the security of supply and value chain disruptions. After Russia's invasion, the inflation and interest rates increased the price of any asset, having an impact on energy and electricity prices. On top of that, in 2022, the reduction of hydropower due to droughts and French nuclear power outages, added to the high energy prices. In fact, the wholesale price of electricity in the EU countries is based on the Merit Order, which links supply and demand. When the demand is very high, the power plants with the highest cost of production are the ones determining the market price. This establishes a relationship between the wholesale electricity price and the price of natural gas, which is mostly imported into the EU. Consequently, the reduction of Russian gas supplies in Europe strongly affected the price of natural gas, the price of electricity overall and made the market very volatile, as gas-fired powerplants provide flexibility when adjusting supply and demand. Most importantly, the uncertainty of not achieving enough gas supplies for the approaching winter of 2022 threatened Europe.

**FIGURE 1**

The measures taken by the EU and individual countries during the energy crisis followed the three main goals of energy policy:
**Energy policy triangle**



As a response, the European Commission and other countries like the United Kingdom (UK) acted immediately, adopting several emergency regulations to address the high prices, secure gas supplies, and support citizens and businesses strongly affected by the energy crisis. In this article, the regulations taken by the EU, its member states, and other countries are illustrated, explained, and compared to provide a general picture of the exceptional state interventions taken since March 2022.

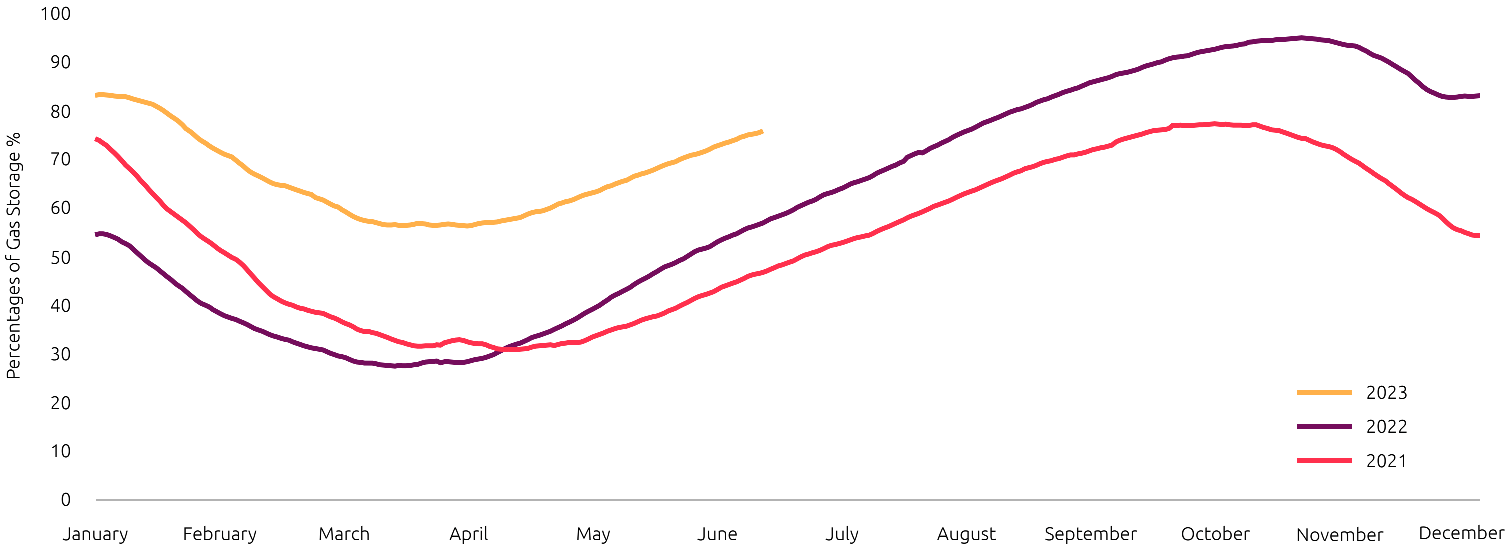
Both generally and in times of crisis, energy policy pursues three main goals - security of supply, affordability, and sustainability. Even though the three goals can be hard to reconcile, all of them must be addressed and balanced. The measures taken as a response to the energy crisis that erupted in 2022 can be organized along this energy policy triangle.

## Security of Supply:

Following the escalation of the war, the biggest fear of governments was the short- and long-term security of supply, with the possibility of gas shortages happening in the following winter. Russia, as the main fossil fuel provider in Europe up until 2022, threatened to cut supplies (and later indeed did so). To address this threat and become less dependent on single suppliers, the EU made it a priority to diversify its gas supplies, supporting the efforts of individual countries to generate new sources and intensify existing ones, and coordinating joint purchases. Increased supplies from established gas producers like the **US, Norway, and the UK compensated for a large share of Russian imports.** To a large extent, new supplies came in the form of liquefied natural gas (LNG): LNG imports in the EU rose by 60% in 2022 compared to 2021. The necessary infrastructure was yet to be built in many cases, like in Germany, where the government worked together with the private sector and managed to charter and connect the first Floating Storage and Regasification Unit (FSRU) in a record time of just under 10 months. Another goal was to increase gas storage levels as much as possible to ensure Europe had enough supply to get through the winter. On June 27, 2022, the Commission introduced the **Gas Storage Regulation,** requiring all EU countries to fill gas storage facilities to 80% by November 1, 2022, and 90% in the years to follow.

**FIGURE 2**

Gas storage levels in Europe




Source: Aggregated Gas Storage Inventory EU

## Europe filled up gas storage tanks to 95% of their full capacity by November 2022, increasing significantly the storage compared to 2021

In the UK, the government decided to increase domestic gas production and increase LNG deliveries in Q4 2022 as well as reopen gas storage facilities to face the winter.

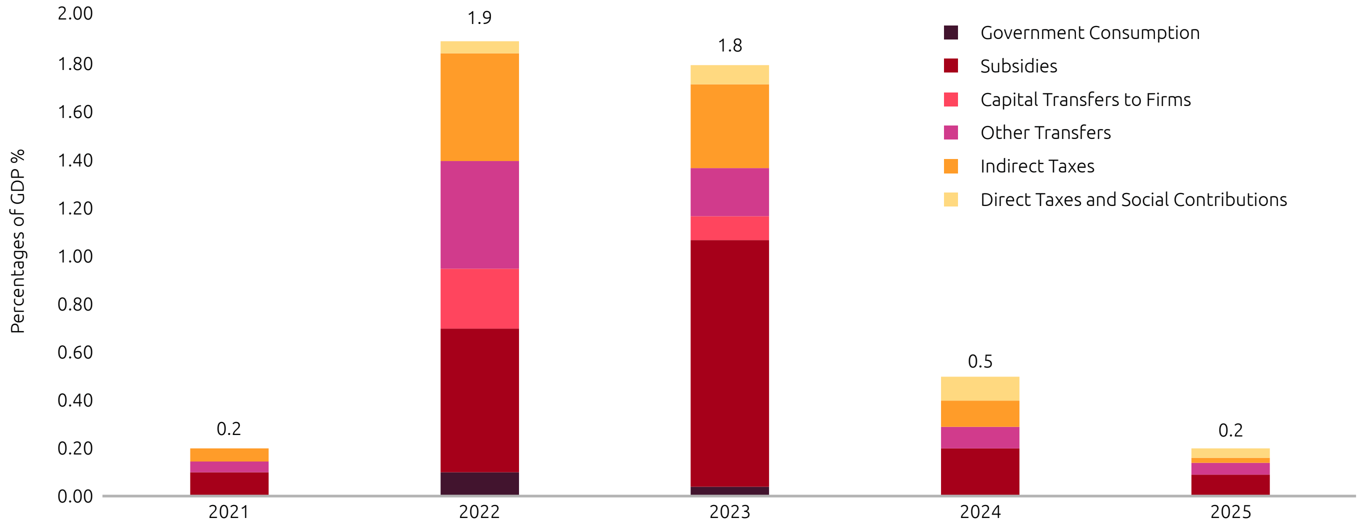
Ensuring the security of supply in Europe included not only great efforts on diversified supply and increased storage but also on savings and demand reduction. Many countries introduced a mix of sobriety measures, including reduced heating of public buildings and facilities, reduced lighting of monuments, and tax incentives to lower consumption, complemented by public campaigns. Besides these governmental stipulations, high prices in the market, as well as ethical reasons had an impact on consumption. On July 20, 2022, the European Commission published a communication called **"Save gas for a safe winter"**, which included demand reduction measures aimed at all citizens and small businesses with the target of reducing gas demand by 15%. After that, on August 5, 2022, the **Regulation on Coordinated Demand Reduction Measures** for gas was published, valid until March 30, 2023, when it was prolonged to ensure a demand reduction of 15% for another 12 months. Targets were exceeded: this winter gas consumption in the EU dropped by almost 20% with the largest savings registered in Finland (–57.3%), Lithuania (–47.9%), and Sweden (–40.2%).

The last steps taken in the battle against a shortage of supply were announced on December 2022, when the EU Commission launched a new mechanism called **AggregateEU.** This regulation was aimed at companies and allowed demand aggregation and joint gas purchases through a new trading platform. The results were seen immediately when the regulation went live on May 2023, where up to 63 European companies submitted requests for a total of 11.625 billion cubic meters (bcm) of gas demand. All international gas suppliers except Russia were allowed to submit tender bids.

While it is hard to attribute gas savings to the different causes over time, analyses show that both industrial and small consumers significantly reduced consumption already before obligations came into force, pointing to market-induced effects. The International Energy Agency (IEA) **estimates** that in the buildings sector, behavioral changes were responsible for gas savings of as much as 7bcm, second just to weather effects (18bcm).

**FIGURE 3**

Size of fiscal support and composition by instrument with a projection horizon of three years




Source: European Central Bank

## Affordability:

The most dramatic consequences of the stratospheric electricity prices were suffered by small companies and low-income households, which found themselves struggling to pay their energy bills at the end of the month. To take away some of the price pressure, the EU and individual countries drastically intervened in the market. The EU increased the percentage of GDP used for fiscal policies in 2022 by 1.7% compared to 2021, where the biggest percentage corresponds to an increase in subsidies and a reduction in indirect taxes to alleviate the pressure caused by the energy crisis and high inflation. These fiscal policies are also significant in 2023 but should start decreasing from 2024 onwards, reaching the original value of only 0.2% of the European GDP in 2025.

Even before the escalation of the war in Ukraine, France introduced an "energy price freeze" in 2021, along with one-off payments for low-income households, to face rising energy prices and overall inflation. This group of measures called the "tariff shield" resulted in a reduction of inflation effects. Without these measures, the inflation between the second quarter of 2021 and 2022 would have nearly doubled. When the war escalated in February 2022, many countries followed the same pattern and started freezing energy prices.

With winter within sight, the EU Commission decided to adopt a new emergency intervention to address the high energy prices on October 6, 2022. A temporary **revenue cap on electricity producers was installed (180€/MWh),** which mainly affected low-cost energy producers like renewables, lignite, and nuclear, as they were the ones profiting the most from high electricity prices.

In addition, excess profits from oil, gas, coal, and refinery companies were taxed by the individual EU countries and redirected to energy consumers as a solidarity measure. To ensure small businesses had resources and recommendations on how to tackle the crisis, the IEA teamed up with the EU Commission and published a recommendation newsletter called "Coping with the crisis" on October 21, 2022. The report included EU support measures which were made available for small businesses and step-by-step explanations on how to become more energy efficient and wise, making them more resilient and secure against the crisis.

In addition, on December 19, 2022, the EU Commission proposed a new regulation to ensure affordability: the Market Correction Mechanism. The regulation comprised a mechanism to control the gas market, ensuring the Title Transfer Facility (TTF) was below a certain cap price and comparing it to the reference base price for LNG imports. This ensured volatile gas prices were controlled and the measure was extended on March 31, 2023, to trading applications other than the TTF.

With respect to additional measures taken by individual countries, the UK launched several packages to help deal with high prices. In fact, the International Monetary Fund said last year that British households have been the worst hit in Western Europe because of the high dependence on gas. To face this the Government introduced the Energy Bills Support Scheme (EBSS), the Energy Price Guarantee  (EPG) for domestic households and business customers, and a general Price Cap calculated by Ofgem. The EBSS, was first implemented by the Government and included a £400 discount on every household's energy bill for winter 2022 to 2023. In addition, the government's EPG subsidy which limited the unit electricity and gas price was implemented in October 2022 and has been prolonged until March 2024. Until June 2023, this measure limited the average household bill to £2500 a year, which was below the £3280 set by the Price Cap, but as of July 1, 2023, the Price Cap fell for the first time under the EPG limiting electricity prices to £2074. According to the UK government, without the implemented domestic schemes and price guarantees, the typical household dual energy bill would have more than tripled between October 2021 and January 2023.

**FIGURE 4**

European Union Regulation timeline


Source: European Commission

## Sustainability:

The longer-term response to Russia's invasion of Ukraine was to accelerate the transformation of Europe's energy system by increasing the share of renewables in the electricity mix as much as possible, to break the reliance on Russian fossil fuels while also pursuing the climate and energy targets. The Commission proposed the increase of EU's 2030 target for renewable energy (RE) from 40% to 45% and launched the **REPowerPlan.** The **REPowerEU Communication** was presented on the 8th of March 2022 and contained a comprehensive set of actions intended to save energy resources, expand RE generation, and diversify Europe's energy supplies. With this strategy, the total RE generation capacities would be pushed to 1236 GW by 2030 from 570 GW in 2022, increasing substantially the target in the Fit-for-55 strategy (1067 GW). To meet the higher targets imposed by this new plan, the Commission needed to complement it with measures to accelerate RE deployment. A new temporary regulation was proposed to reduce the time taken for the permit granting in solar energy, repowering of RE plants, and heat pumps installations called the **Emergency Regulation to Accelerate Renewable Energy Permitting** on December 19, 2022.

Besides enhancing sustainability, boosting RE expansion had the aim to increase energy sovereignty, by ramping up electricity sources within Europe. With an increasing RE share and the gradual electrification of other sectors, the EU hopes to depend less on foreign suppliers to cover their future energy needs.

**In 2022 wind and solar energy generated a fifth of the EU electricity demand (22%) for the first time, reaching an important milestone**

Regarding the heating and cooling systems in the EU, where Russian gas and fossil fuels have always played an important role, the EU had already taken measures before the conflict with a modification of the Energy Efficiency Directive (EED) in July 2021. This established greater energy efficiency targets for the EU as well as decarbonizing heating and cooling systems with electrification, heat pumps, and new energies by 2050. In March 2023, the European Parliament also published a new 11.7% energy efficiency target for 2030. The high electrification demand expected when fossil fuels stop being the main source for heating and cooling in Europe only stresses the importance of accelerating renewable energy sources and deployment for a long-term energy transition.

Individual countries, too, decided to boost renewables expansion as a solution to the energy crisis by setting higher targets and simplifying bureaucratic processes. However, some of them (e.g., Germany) resorted to stronger use of coal as well. While the aim to strengthen the security of supply may have been fulfilled, it was a major setback from a climate perspective to bring back GHG-heavy coal plants out of retirement. Similarly, research activity for alternative gas sources like hydrogen increased across the globe.

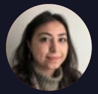
***High energy prices and gas scarcity were beaten thanks to a combination of government regulations and behavioral changes from market consumers***

The EU and its member states addressed all three pillars of the energy policy triangle. The most immediate market interventions happened regarding the security of supply and affordability, where governments decided to diversify gas supplies and implement affordable prices. In some cases, effects were quickly visible, e.g., regarding increased LNG imports and the build-up of the necessary infrastructure. In other cases, like gas savings, the impact of market behavioral changes appears to have been at least as strong as by policy, as the objectives were not only reached but surpassed significantly. On affordability, early price caps and one-off payments helped to reduce the price pressure on consumers, but many other measures, like the EU-wide price cap, were introduced when the worst was already over.

The energy crisis of 2022 and the actions taken by governments revealed once again that the three aspects of the energy policy triangle can pose a "trilemma" and have a complex relationship. For instance, the price hikes that hardly hit many consumers had a positive impact on security of supply by incentivizing saving gas. Similarly, the (limited) revival of coal power helped increase security of supply but was a drawback for sustainability. Beyond the trilemma, governments were and are aiming at regaining energy sovereignty, to which the accelerated RE deployment and diversified supplies are hoped to contribute.

In summary, governments took extraordinary measures in the face of extraordinary problems in the energy market. The repercussions of the energy crisis, which may not have been entirely foreseeable, provided some lessons to be learned for politics, regulators, and businesses.

# ELECTRICITY MARKET DESIGN: HOW MUCH INTERVENTION IS NEEDED?


ANY AKOPYAN, GERMANY


DAVID GOTTHEIT, GERMANY

## The EU's proposal to prepare its market for the energy transition

**The turmoil on global energy markets caused by the Russian invasion of Ukraine has accelerated the existing debate on market design reform in Europe. But the shortcomings of the current market design have been highlighted by experts for years, as energy systems undergo fundamental changes across the value chain. The electricity market reform needs to account for the ongoing paradigm shift to successfully facilitate the energy transition. The European Commission's draft reform tries to reconcile security of supply, affordability for customers, and the energy transition towards renewables.**

Rather than a mere fuel or technology switch, the energy transition represents a real paradigm shift. With the advent of renewable energy sources (RES) like solar and wind as the dominant energy sources, many fundamental features of the energy market system are changing. Power generation is increasingly decentralized and intermittent, as opposed to the centralized and programmable load from conventional sources, posing major challenges for the power grid. Consumers are evolving to prosumers by (partly) covering their own demand. At the same time, electrification of transportation and, in part, heat will increase the power demand in the mid- and long-term.

Markets need to adapt to these fundamental changes in order to distribute energy reliably, sustainably, and at affordable prices in the future. To align these three goals, the market design must facilitate development and evolution across the energy supply chain, from generation to distribution and consumption.

Because of the enormous challenges, the European Commission proposed to reform the market in March 2023. This article will use the proposal to illustrate how regulators deal with the transformative challenges, and touch upon what this could mean for players in the European electricity market.

### Electricity market design in the European Union

Market design shapes the structure and ruleset under which market participants operate to achieve desired outcomes, such as efficiency, competitiveness, sustainability, or reliability. In the EU it is codified through the Electricity Directive (2019/944/EU), Electricity Regulation (2019/943/EU), and others.

To enable the energy transition, the rules and incentive structures for all parts of the value chain need to adapt to the intermittency and decentralization of RES. Current regulation and infrastructures can cause far-reaching imbalances in the power market, for the system as well as consumers. For instance, spot markets and especially intraday trading can become a source of flexibility by moving generation, trading, and consumption closer together to help balance supply and demand even when projected RES generation is higher or lower than expected.

Right now, spot markets based on the merit order (see Chapter 2) are generally efficient, but susceptible to price volatility (e.g., due to intermittent RES, or fuel crises like in 2022 caused by Russia's invasion of Ukraine). If consumer prices are closely linked to spot market prices, electricity bills can become an existential threat to many people and businesses. In the recent energy crisis, governments had to intervene in the market to protect consumers (see Chapter 2).

In general, investments in new large-scale, low-carbon infrastructure must be incentivized. Regarding generation, gas-fired power plants that can use hydrogen will be needed in the future as a predictable power source. Smart metering would also facilitate improvements for demand-side management (DSM), where consumers can react to current prices and shift parts of their consumption, thereby easing the pressure on the grid. Finally, more storage capacity is needed to take in surplus power and give it back when generation is low.

## The Commission's proposal

As the 2022 energy price crisis highlighted the shortcomings in the current electricity market design, the Commission proposed a reform to address these limitations. The Commission has three goals: to protect consumers; secure energy supply; and incentivize investments in low/zero-carbon technology and infrastructure.

## Protecting the consumer and guaranteeing affordability for households

The crisis in 2022 highlighted the vulnerability of households as prices soared and energy poverty in the EU rose to 9.3% in 2022, a situation in which excessively high energy bills negatively impact a household's health and well-being. To protect consumers, the Commission has proposed the following:

### Ensure fixed-price contracts remain available

Currently, the Electricity Directive does not stipulate access to fixed-price contracts. As a result, during the 2022 energy crisis, suppliers prematurely terminated fixed-price contracts or stopped offering them altogether. These consumers were forced to close more expensive variable contracts, with prices in 2022 in some Member States between €0.40/kWh and €0.49/kWh for power and over €0.12/kWh for gas. To compare, in 2019, the prices for power and gas were at roughly €0.30/kWh and €0.04/kWh respectively. The Commission's proposal aims to give consumers the right to access to fixed-price contracts with stable prices. Moreover, suppliers will not be allowed to terminate fixed-price contracts prematurely or amend contractual conditions throughout the contract term.

Fixed-price contracts generally carry more risk for the supplier because the energy is purchased in advance on the wholesale market, without the certainty that the contracts on the retail market will remain intact. Consumers can switch suppliers against a relatively cheap early-termination fee and leave the supplier with the purchased energy.

Some Member States have already implemented the Commission's proposal. For example, the Dutch Authority for Consumers and Markets (ACM) introduced new rules in June 2023 to incentivize fixed-price contract offerings. Fixed contracts must remain unchanged but the previously low early termination fee can now match the loss incurred by the supplier. Consumers will still have 14 days to annul the early termination, if they consider the fee too high.

### Facilitate renewable energy sharing

The Commission intends to make it easier to share excess renewable energy among households. Prosumers currently sell their excess power back to the grid. However, with the focus on grid balancing, generated power is ideally directly consumed. The Commission therefore wants to make energy sharing easier: Prosumers will be able to share their excess power directly with their neighbors and can set the price themselves, even offering it for free.

It will be the responsibility of the Member States to provide an IT structure for the price calculation based on generation and consumption and ensure that transmission system operators (TSOs) and distribution network operators (DSOs) monitor, collect, validate, and communicate (metering) information. The Agency for the Cooperation of Energy Regulators (ACER)/Council of European Energy Regulators (CEER) are generally in favor of energy sharing but note the need for smart meters.

## Securing supply through an efficient and interconnected market

The Commission aims to achieve security of supply by improving efficiency and interconnection. The market must be prepared for the further influx of renewables with flexibility and power should flow across borders more freely. Concretely, the Commission proposes the following measures:

### Establishing national flexibility objectives

Generally, to enhance flexibility in the EU, as of 2025, Member States must submit biennial reports to ACER where they assess their flexibility needs. TSOs and DSOs must support Member States by providing the information needed for the reports.

Member States must also set national objectives to meet those needs. Where the objectives set are insufficient to meet the flexibility needs, Member States can utilize flexibility support schemes to incentivize investments. European Power exchange (EPEX) SPOT calls for market-based and technology-neutral flexibility support schemes so that price and dispatching signals are not negatively affected.

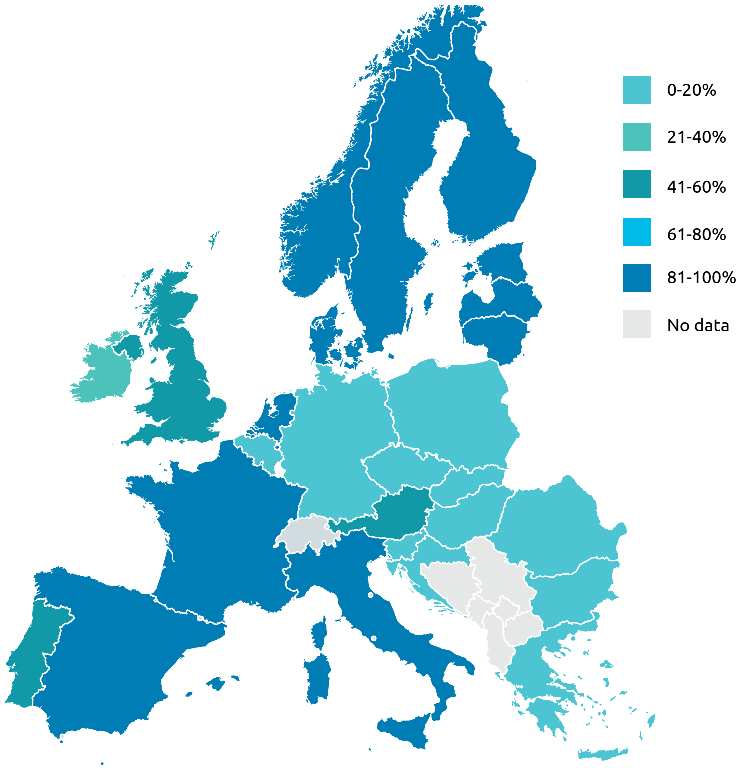
### Dynamic pricing contracts for demand-side flexibility

Besides fixed contracts, dynamic contracts should be another option for consumers. While dynamic pricing is climbing up the agenda in Europe, several U.S. states like California have experimented with and expanded such schemes over the last decades. Dynamic contract customers usually regulate their own consumption more closely (e.g., through smart energy monitoring devices) and can tailor their energy use to the actual energy prices. This user group is particularly useful for DSM and can help improve power system flexibility.

However, dynamic pricing requires accurate and real-time meter data. The further roll-out of smart meters is therefore necessary. On average, only 54% of European households have a smart meter, with some countries (such as Germany) even below 20%. The target for smart meter roll-out was set at 80% by 2020 in the Electricity Directive but the implementation depends on the outcome of cost-benefit analyses conducted by national authorities, causing the pace in roll-out to vary among Member States. Comparatively, the roll-out of smart meters in the United States was at 69% in 2021 and is supported by policy and legislation, since smart meters are considered pivotal to create a smart grid and address today's challenges in the energy sector. According to the United States Federal Energy Regulatory Commission (FERC), regulators even support diverting from a traditional cost-benefit analysis and allow alternative approaches for the calculation, showcasing a proactive form of state involvement to speed up the roll-out of smart meters.

**FIGURE 1**

Share of European households with smart meters (Dec 2021)




Source: CEER

**Improving interconnection and liquidity**

The Commission aims to enhance interconnection in the EU by requiring transmission rights to be available for longer periods (at least one year), to improve inter-zonal transmission capacity. It also wants to increase liquidity by shifting from bidding zones (BZ) to a hub. A regional virtual hub (RVH) should aggregate BZ prices and provide a single reference price to market participants. These prices would be particularly useful for forward contracts and hedging. Although the RVH is not an exchange, its derivatives could be traded on exchanges or bilaterally. By pooling the liquidity of several BZs in a hub, the liquidity of the forward market should increase, which in turn should lower bid-ask spread and risk premium for market participants.

It is important to note that a similar hub already exists in the Nordics (the Nordic System Price) but it has not solved the illiquidity in the Nordic markets. It is recommended that we examine what can be learned from the Nordic System Price.

**Shorter lead times on cross-zonal intra-day markets**

Since renewable energy generation is intermittent, trading and delivering directly once it is produced can alleviate uncertainty and reduce imbalance. The intraday cross-zonal gate closure time (IDCZGCT) is currently 60 minutes ahead of real-time, except at the Finnish-Estonian border where it is 30 minutes. However, by January 1, 2028, the IDCZGCT in the entire EU must be reduced to 30 minutes, according to the Commission's plans.

To compare, the national gate closure time in Member States is much closer to delivery. Some Member States (e.g., Belgium, the Netherlands, Germany) already have a five-minute lead time, and Finland is even piloting 0-minutes.

The European Network of Transmission System Operators for Electricity (ENTSO-E), however, has warned that TSOs would have less time (only up to 30 minutes) for balancing, and it would exclude flexibility resources that require more than 20 minutes to activate (e.g., the replacement reserve and TERRE). Moreover, costs and $CO_2$ emissions would increase, as the resources with short activation time are more expensive and have higher emissions.

Still, increasing the granularity in the short-term markets to enhance flexibility and efficiency is no novelty. From a global perspective, Australia has been a front-runner, introducing five-minute dispatch periods in the 1990s. For the day-ahead market, the California Independent System Operator (CAISO) has proposed moving from hourly to 15-minute scheduling, so generation can follow the load curve more closely.

## Incentivizing investment in low-carbon infrastructure

To meet the energy transition and climate objectives, investments in renewable energy are needed in the EU. As Figure 2 shows, Europe and most other parts of the world have recently seen a decline in RES investments (e.g., due to faltering policy support and permitting challenges). To ensure that the energy transition does not slow down, creating the right environment for investments is pivotal. The Commission aims to incentivize investments with the following:

**Incentivizing roll-out of Power Purchase Agreements (PPAs)**

The Commission also aims to incentivize (green) PPAs, which are agreements between a renewable energy generator and an off-taker, where prices and supply are locked in for a period of 10-15 years. As generators are assured of long-term supply and constant revenue, it becomes more interesting to invest in renewable projects. It is also attractive to off-takers, as they have stable prices for longer periods.

***In January 2023, 65 corporate PPA deals were closed in Europe, increasing the cumulative volume of corporate PPAs by 19% compared to Q4 2022.***

Countries outside Europe have also embraced PPAs. For example, in the U.S., big tech corporations like Amazon, Microsoft, and Meta are driving PPA demand. South Korea, also introduced PPAs to the otherwise monopolistic electricity market only in 2021. An existing concern with PPAs was that the PPA market is currently only accessible to large consumers. Therefore, the Commission stipulates that Member States take measures to make PPAs accessible to smaller off-takers such as SMEs, as these currently struggle to enter the PPA market, mainly due to creditworthiness constraints. Member States must remove barriers (e.g., through support or guarantee schemes or certain tender evaluation criteria that include SMEs). According to ACER/CEER, it is still uncertain how interesting it will be for smaller off-takers to lock in prices for a longer period, but at least the PPA market will be accessible for SMEs.

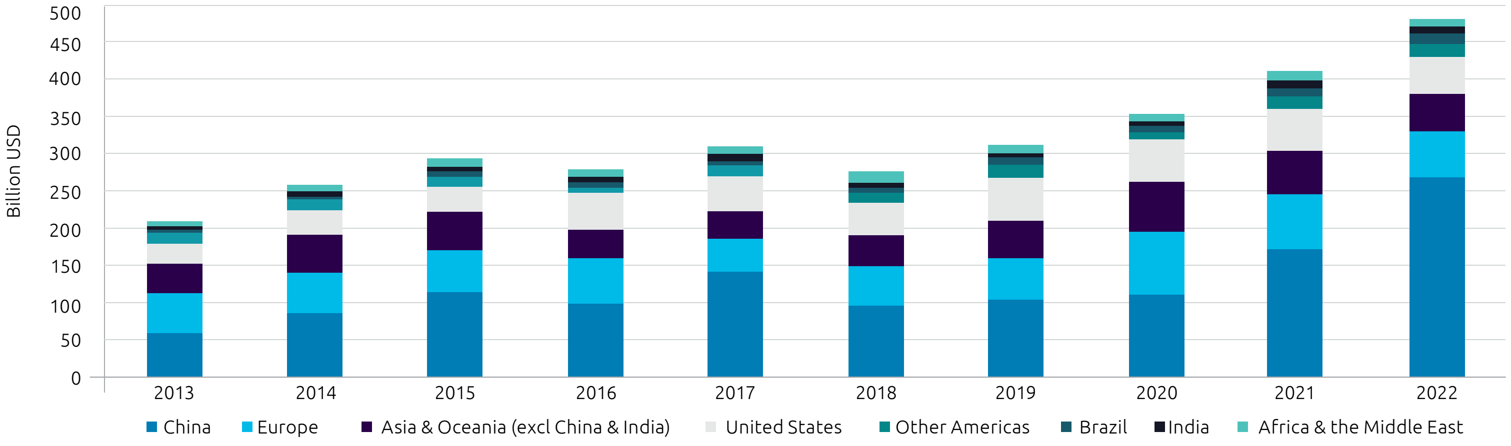
**Introducing two-way Contracts for Difference (CfD)**

Currently, governments financially support investments in renewable projects through one-way Contracts for Difference (CfDs). The Commission has now proposed financing through two-way CfDs, similar to the CfD design introduced in the U.K. in 2014. Generators will still receive compensation when energy prices are low, but excessive revenue in times of high prices will be channeled back to the public, either through direct redistribution, the financing of direct price support schemes, or extra investments to reduce electricity costs. This way, CfDs will provide additional revenue to Member States when energy prices are high and affect consumers. The distribution of excessive revenue must be proportionate to the investment and consumption of end-users, and should still leave some price exposure for consumers to incentivize demand reduction.

While the proposal also mentions companies besides household consumers as beneficiaries to receive excess distributions that the state generates, so far it is not specified who would ultimately receive payouts and if state-owned energy producers would be included. Additionally, it remains unclear whether existing power generation assets (especially nuclear power generation) should be eligible to be included in the CfD scheme.

**FIGURE 2**

Investments in renewable energy per region




*Note: Europe including non-EU countries; Hydropower projects larger than 50MW not included. Source: BloombergNEF, „Energy Transition Investment Trends 2023"*

Although ACER/CEER and ENTSO-E generally support the two-way CfDs, ENTSO-E advises decoupling CfD remuneration from the generated output. EPEX SPOT advises making two-way CfD an option for Member States but allowing them to also choose other forms of support schemes.

**Compensations and transparency for new projects**

Further investments and scaleup of offshore renewable energy projects is slowed down due to challenges connecting to the onshore, interconnected markets. In the future, if an offshore plant operator is not able to export its full capacity to the onshore network, the TSO responsible for the lost capacity must compensate the offshore plant.

Onshore projects require grid information about the area that is being considered for a project. For example, an area can already be congested, making it a less attractive location for developers. Therefore, TSOs and DSOs must publish information about the available capacity and be transparent to developers regarding the connection requests.

## Conclusion

Since the EU Commission's proposal to reform the electricity market design in March 2023, the Energy Ministers, as well as the EU Energy Committee, discussed ways to create the desired interconnected European electricity network.

In July 2023, the EU Energy Committee once more stressed extending the utilization of PPAs and CfDs in order to ensure reliable revenue for renewable energy producers and subsequently improve price stability for consumers. The European Commission, in collaboration with the Nominated Electricity Market Operators, was instructed to establish an EU database and market platform for PPAs by the end of 2024.

However, much remains to be done as central market players such as ACER/CEER, ENTSO-E, and EPEX SPOT have raised concerns and reservations how measures like the increased use of PPAs or the establishment of RVHs could affect the liquidity in the market.

Additionally, after months of negotiations between Member States there is still no consensus on whether CfDs should also apply to existing assets – in particular, nuclear reactors. While a group of members in favor of nuclear power led by France welcomed the initial proposal that supports existing nuclear capacities, other Member States, such as Germany and Austria, sent a distortion of competition. This is because nuclear assets are often already amortized and thus could benefit disproportionately from (potentially) higher CfD striking prices, which are meant to incentivize investments in renewable energy.

Since the European parliament is expected to publish a formal stance on the reform later this year, Member States have plenty of upcoming negotiations ahead to deliver on the proposed customer-centered, secure, and sustainable redesign of the electricity market.

# EUROPEAN PLAYERS - PRIORITIES, INVESTMENTS AND FINANCIAL RESULTS

DEBARGHYA MUKHERJEE, INDIA
TORBEN SCHUSTER, GERMANY

## Energy & Utility companies' performance in their financial fiscal year, the reactions, and Europe's strategic priorities

**Market players' reaction to the established market design, their financial performance, M&A, and investments in the European Energy & Utilities market**

Many energy companies and associations agree that market reform is needed. However, they warn against market interventions, taxing windfall profits, or forcing a mandatory contract for difference (CfD) on existing power plants, as this could deter much-needed investment in renewable and low-carbon electricity. **According to an alliance of major European energy companies (including Vattenfall, EnBW, E.ON, RWE, and Uniper), adopted emergency measures to counteract very high or very low prices should not be confused with a structural market reform.** The alliance proposed the following:

- Long-term contracts, such as power purchase agreements (PPAs) and CfDs, must remain voluntary and well-designed to maintain competition and deliver long-term investment signals.
- With long-term contracts, energy consumers are better shielded from high prices and extreme volatility.
- The incentives for final customers and retailers should be aligned to respect the different needs of both domestic and industrial customers.
- Regulatory stability and long-term price signals are needed to foster future investments. Any reform effort must focus on setting the right investment signals in the market to ensure massive renewable and low-carbon investments that the European Union (EU) needs – without a retroactive effect.
- A well-designed market is needed. That includes the tools to tackle different kinds of crises, guaranteeing consumers' protection and confidence from investors.

## The reaction from key stakeholders and market players on reforming the design of the EU's electricity market

> *A reform of electricity markets can only help if the root causes of the crisis are also addressed and if the objectives for such reform are made clear upfront. Market design changes alone won't cut our dependence on fossil fuels, solve nuclear reactor issues, or prevent droughts hitting hydropower generation."*
>
> **Jean-Michel Glachant**
> President of the International Association for Energy Economics

> *While CfDs could initially be good for hedging new power generation deals, one should think twice about how much of a role states should play. One has to think carefully whether the state's intervention in the market is really necessary, because, among other things, it can cost taxpayers and above all customers a lot of money. Moreover, it was important that the reform ensures predictability and investment."*
>
> **Frank van Doorn**
> Head of trading at Vattenfall

**The German Renewable Energy Federation (Bundesverband Erneuerbare Energien or BEE) has criticized key elements of the EU proposal to reform the design of the bloc's electricity market.** The lobby group claimed that strict rules about the shape of future subsidies for new low-carbon electricity generation facilities were not the best route forward for Germany's renewables industry. They also believe that the reforms could have similar effects to a mechanism that took away revenue from producers during the energy crisis, which led to high costs for them, as well as distortions in the market.

Other reactions in Germany were less critical. An industry association from Bundesverband der Deutschen Industrie (BDI) and energy industry lobby group, Bundesverband der Energie- und Wasserwirtschaft (BDEW), welcomed the fact that no drastic changes to the system were proposed.

> *The proposal contains small steps in the right direction but is not enough to spread the benefits of renewables to consumers. While Austria agrees that on the way to a renewable, climate-friendly electricity system, pricing must also be improved and people should also benefit from cheap green electricity from Europe, the reform falls short of expectations"*
>
> **Leonore Gewessler**
> Austrian minister for climate action

France wants the EU's electricity market reform completed by the end of the year. France hopes that the deal will draw on the European Commission's recent renewable energy law that recognizes the role of nuclear energy.

> *[the proposal is] a gift for the nuclear industry, as it supplied massive subsidy promises to the industry, even though it is not compatible with a future, flexible electricity system; more possibilities for low-income households to get cheaper electricity contracts, and to rather empower the people to produce and store electricity than support fossil corporations."*
>
> **Michael Bloss**
> Green Party member of the European Parliament

**Eurelectric –** the federation of the European electricity industry – issued its policy recommendations, 'Electricity Market Design: Fit for Net Zero' at the end of March 2023. It proposed an evolution building on the existing market structure, with three new pillars: to empower consumers; incentivize clean energy investments; and ensure security of supply. It supports the use of long-term instruments (such as PPAs and CfDs), together with improved liquidity in forward markets. Rather than top-down hedging obligations, it calls for a flexible resilience framework to ensure supplier robustness, ease collateral regulations, and enhance cross-border hedging opportunities. It also pleads for the removal of legislative barriers from long-term instruments such as private PPAs, and favored state-backed CfDs.

**SolarPower Europe** welcomes the proposal as it maintains the foundation of EU electricity markets and allows easier access to PPAs for homes and businesses, which de-risks schemes for long-term energy supply contracts. SolarPower Europe also states that "only new solar projects which benefit from state support will be put under government-organized two-sided CfDs." They also welcome the provisions outlining the legal framework for electricity sharing, and support grid flexibility and the recognition of electricity grids, as this facilitates access to green energy and connects solar to the grid.

> *It has been a tumultuous time for the European electricity market, after the energy crisis sparked a flurry of market interventions. However, the time has come to coordinate and harmonize efforts to restore regulatory stability and investor confidence"*
>
> **Maria Popova**
> director for carbon neutrality and renewable electricity at the European Federation of Energy Traders (EFET)

## Financial situation of major European utilities

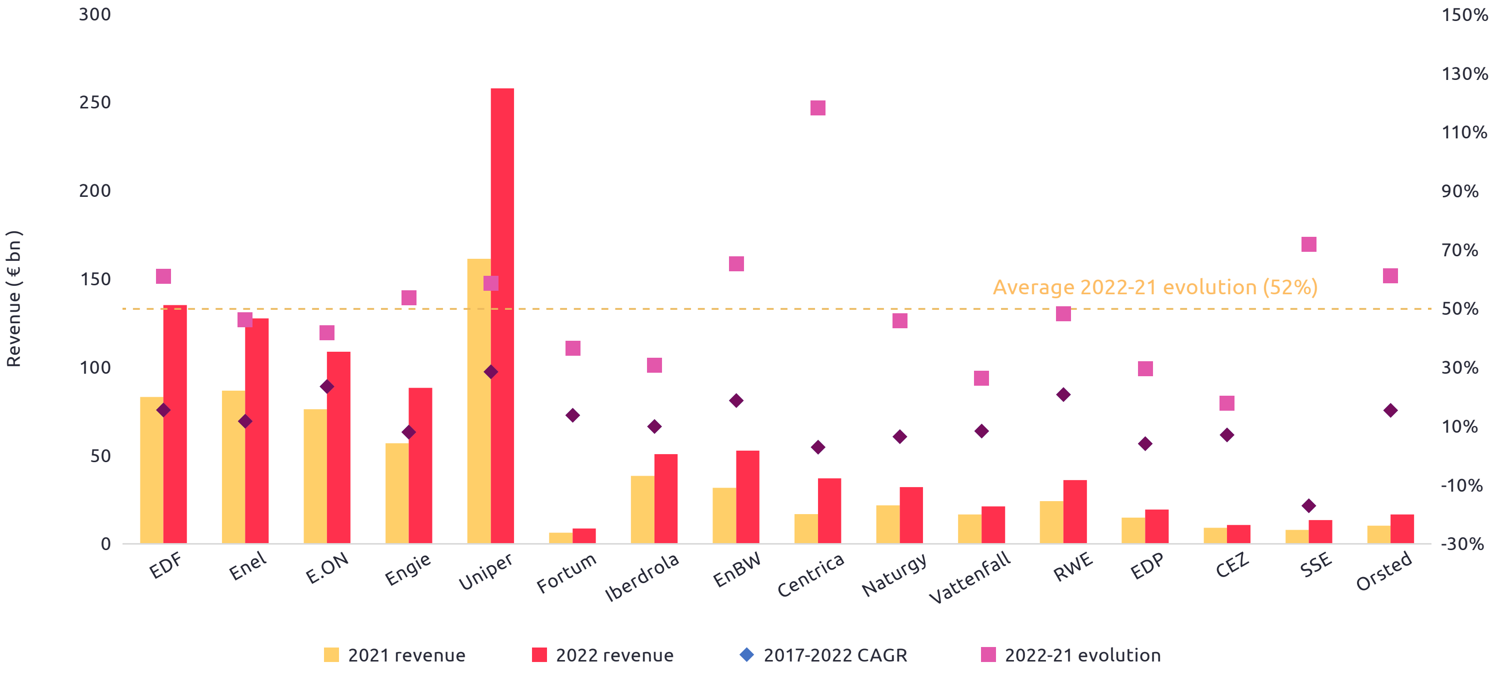
The financial statements of large European utilities indicate higher revenues resulting from steep fossil fuel and electricity prices in 2022 compared with 2021. However, unlike for oil and gas majors, higher revenues for European utilities have not always translated into profits in recent months because utility companies have diverse business profiles, allowing them to compensate losses in one business segment with profits from another. Europe's major energy utilities see renewables and decarbonization as a way out of the dueling energy and climate crises.

EDF revenue grew more than 60%, with 12% growth in their wind and solar project portfolio and 3% growth in their customer portfolio. Uniper's significant increase in revenues resulted primarily from the higher average market prices in the power and gas business. Centrica's growth is driven largely by the impact of higher wholesale commodity prices on ENERGY MARKETING & TRADING AND UPSTREAM business unit, and the impact of higher wholesale prices on retail tariffs in British Gas Energy, Bord Gáis Energy, and Centrica Business Solutions.

Enel's growth was driven by increasing average prices, the volume of energy produced and traded, and volumes sold (mainly in Italy and Spain). Furthermore, tariffs were adjusted in Brazil, and higher volumes of electricity were distributed in Latin America. The exchange rate also had a positive effect.

**FIGURE 1**

2021 and 2022 revenues and CAGR 2017-2022




*Note: Uniper higher revenues mainly due to the higher own-use contract prices and spot-market transactions, a significant portion of this increase is attributable to the contracts involving physical settlement that Uniper enters into (failed own-use contracts), which are presented at the spot price applicable on the settlement date*

Source: Thomson Reuters EIKON, Secondary sources

The average 2022 earnings before the interest, taxes, depreciation, and amortization (EBITDA) margin was less compared to 2021. This is mainly due to the significant decline in EBITDA margins for major players like Vattenfall, EDF, Uniper, and Engie.

Vattenfall's decline of operating profit is partly attributable to lower achieved electricity prices in the Nordic countries, higher gas prices, and operating expenses.

For EDF, despite a significant increase in sales supported by electricity and gas prices, EBITDA was down significantly in 2022. In France, this decrease is essentially explained by the decline in nuclear output linked to corrosion under constraints and related maintenance, as well as a government price capping decision to limit price increases for consumers in 2022. Low-capacity availability and significant demand obliged the Group to purchase electricity at a time when market prices were very high.

Uniper's profitability was impacted by direct effects on earnings arising from the loss of Russian gas supplies and the need to purchase corresponding replacement volumes directly on the market at a significantly higher price level as a result of the supply cuts. The German government provided support measures and took over 99% of the company in order to secure Germany's energy supply.

As their profitability soars, SSE plans to spend £40 billion over the next 10 years in vital low-carbon energy infrastructure.

**FIGURE 2**

2021 and 2022 EBIDTA margins


Source: Thomson Reuters EIKON, Secondary sources

## Leverage ratio is one of several financial measurements that look at how much capital comes in the form of debt and assesses the ability of a company to meet its financial obligations.

For EDF, 2022 group cash flow amounted to -€24.6 billion, down significantly from the -€1.5 billion of 2021. Net financial debt reached €64.5 billion in 2022. EDF is now aiming to reduce the ratio of net debt to EBITDA to 2.5.

Enel's net financial debt at the end of 2022 totaled €60.1 billion, which reflects financial needs for capital expenditure in the period, the payment of dividends, the acquisition of ERG Hydro S.r.l., and the negative effect of exchange rates.

Engie's economic net debt stood at €38.8 billion, up €0.5 billion compared to 2021, mainly due to the increase in asset retirement obligation provisions and other variations.

Fortum's financial net debt in 2022 was €1,084 million. The company has set long-term financial targets, aiming for a net debt-to-comparable EBITDA ratio of 2.0-2.5 times.

Centrica had adjusted net cash of €1.3 billion at the end of 2022, compared to adjusted net debt of nearly €4.5 billion three years ago. The reduction reflects an ongoing strong focus on capital discipline and cash generation.

**FIGURE 3**

Leverage Ratios for 2021 and 2022

| | Leverage ratio 2021 | Leverage ratio 2022 | Evolutions |
|---|---|---|---|
| EDF | 2.39x | - | ↑ *19% |
| ENGIE | 2.25x | 2.67x | ↑ |
| ENEL | 3.14x | 3.82x | ↑ |
| Iberdrola | 3.22x | 3.16x | ↓ |
| EnBW | 2.09x | 2.44x | ↑ |
| EDP | 4.92x | 4.34x | ↓ |
| SSE | 3.84x | 2.01x | ↓ |
| Vattenfall | 0.03x | - | ↑ *18% |
| Centrica | 0.98x | - | ↓ |
| Orsted | 1.71x | 1.61x | ↓ |
| CEZ | 1.75x | 1.41x | ↓ |
| Fortum | 4.71x | 2.30x | ↓ |
| Naturgy | 3.14x | 2.42x | ↓ |
| **Average** | **2.63x** | **2.62x** | |

*Note:*
*1. Leverage ratio = Net debt/EBITDA;*
*2. *Long term debt evolution 2022-2021*

Source: Thomson Reuters EIKON, Secondary sources

## 2022 Standard & Poor (S&P) credit ratings

For most actors, the credit rating remains stable:

- S&P Global Ratings affirmed the BBB credit rating of EDF; outlook is stable.
- Vattenfall's outlook changed from stable to positive with a BBB+ rating.
- Centrica's outlook changed to BBB with a stable outlook.
- S&P affirms Uniper's long-term credit rating at BBB-, with a negative outlook in 2022.
- SSE's credit rating updated to BBB+ positive outlook. This reflects the continuing resilience of SSE's business mix and its ability to create value and respond to volatile market conditions.

**FIGURE 4**

Standard & Poor (S&P) credit ratings

| Company | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|
| EnBW | A- | A- | A- | A- | A- | A- |
| CEZ | A- | A- | A- | A- | A- | A- |
| EDF | A- | A- | A- | BBB+ | BBB | BBB |
| Engie | A- | A- | A- | BBB+ | BBB+ | BBB+ |
| SSE | A- | A- | BBB+ | BBB+ | BBB+ | BBB+ |
| Vattenfall | BBB+ | BBB+ | BBB+ | BBB+ | BBB | BBB+ |
| Ørsted | BBB+ | BBB+ | BBB+ | BBB+ | BBB+ | BBB+ |
| Iberdrola | BBB+ | BBB+ | BBB+ | BBB+ | BBB+ | BBB+ |
| Enel | BBB | BBB+ | BBB+ | BBB+ | BBB+ | BBB+ |
| Centrica | BBB+ | BBB+ | BBB | BBB | BBB+ | BBB |
| Fortum | BBB+ | BBB | BBB | BBB | BBB | BBB |
| E.ON | BBB | BBB | BBB | BBB | BBB | BBB |
| Naturgy | BBB | BBB | BBB | BBB | BBB | BBB |
| Uniper | BBB- | BBB | BBB | BBB | BBB- | BBB- |
| EDP | BB+ | BBB- | BBB- | BBB- | BBB | BBB |

Source: Thomson Reuters EIKON, Secondary sources

## M&A and investment trends

The upward trend in M&A among renewables developers is occurring in multiple regions. Europe has experienced the highest deal activity globally in the past four years—with roughly 40% of deals involving a Europe-based target. North America is the second-largest market, with growth accelerating in 2022; there were 17 deals, representing nearly $6 billion in combined deal value. The Asia-Pacific region (APAC) and the rest of the world have also experienced growth, reaching a total deal value of $1.4 billion in the first half of 2022.

Although traditional sources of debt capital today are more expensive and harder to obtain, strengthened balance sheets from high commodity prices—plus alternative sources of supply, such as credit funds—will enable management to pursue acquisitions.

**Utilities and IPPs acquire ~10 GW of offshore wind assets in Europe, YTD May 2023**

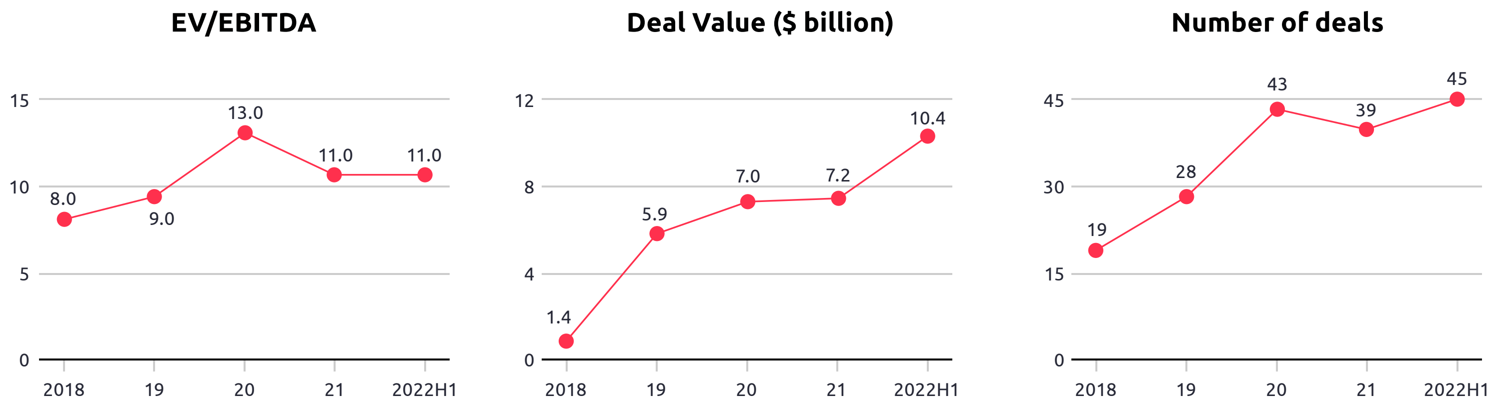
Europe has witnessed a surge in acquisitions for offshore wind assets by utilities and independent power producers (IPPs), with the region collectively accounting for 50% of the M&A activity. This is a significant rise compared to the activity observed during 2022, during which utilities and IPPs accounted for ~30% of the deal volume. The rest of the activity was driven primarily by European private equity (PE) firms, such as Copenhagen Infrastructure Partners (CIP), The Renewables Infrastructure Group (TRIG), Greencoat, and Global Infrastructure Partners (GIP).

A surge in interest in offshore wind assets is attributed to improvements in the financing and project development environment, which is a result of recent measures taken by the EU. The measures include the European Investment Bank's (EIB) $21 billion budgetary guarantee, InvestEU, which enhances utilities and IPPs' access to development capital at low interest rates.

Equitix Group recently acquired a 50% stake in a 2.4 GW operating offshore wind portfolio in UK from Macquarie Group. Other major transactions in the current year include Daiwa Securities' farm-in to the 1.2 GW Hornsea 1 offshore wind farm and INPEX's acquisition of a stake in the 950 MW Moray East wind farm.

**FIGURE 5**

Aquisitions of wind and solar developers




***Note: EV/EBITDA = Enterprise value to EBITDA multiple***

Source: McKinsey, Enerdatics, Energy Monitor, Secondary sources

Northland Power divested a 24.5% stake in the 840 MW Spiorad na Mara and 1.5 GW Havbredey offshore wind projects in the U.K. to Irish utility ESB. The deal aligns with Northland's selective partnership strategy to sell interests in certain development projects on or before financial close. The company intends to utilize non-recourse project-level financing as the primary source of funding, with its equity requirements expected to be supported by cash on hand, proceeds from sell-downs, asset sales, the use of corporate hybrid debt, and equity issuances under its at-the-market (ATM) equity program.

Further, recent EU regulations limit the permitting period for offshore wind projects to two years, reducing risks associated with development and construction and further improving operators' access to non-recourse financing. The combined effect of both policies helps debt-reliant buyers offset the impact of cost inflation and increases their appetite for capital-intensive projects with a long lead time.

The $1.7 billion acquisition of Hitachi Energy by Hitachi: ABB has reached an agreement to divest to Hitachi, Ltd. (Hitachi) its remaining 19.9% equity stake in the Hitachi Energy joint venture that was formed from ABB's Power Grids.

Siemens Energy gets go-ahead for full integration of Siemens Gamesa: In May 2022, Siemens Energy launched a €4.05 billion takeover proposal for the remaining third of shares that it did not already own in the turbine maker.

Gren agrees to acquire 11 heat and power generation assets in the U.K. The acquisition of these U.K. assets supports Gren's expansion into one of the fastest growing district heating markets in Europe. Gren will play a key role in helping the U.K. decarbonize its energy sector.

**European Investment Bank (EIB) has agreed to lend €450 million (~$485 million) to Portugal-based energy company Redes Energéticas Nacionais (REN) for renewable energy integration and upgradation of the transmission network.** This financing will contribute to REN's five-year investment program, which aims to increase the efficiency of Portugal's electricity transmission network and integrate 4.2 GW of new renewable energy sources by 2026. It would also enable REN to maintain the reliability and quality of the electricity supply.

The green loan committed by the EIB is part of the wider REPowerEU Plan to boost green energy and support the EU's autonomy and competitiveness. The total €30 billion EIB contribution to REPowerEU is expected to mobilize over €115 billion of additional investment by 2027 in support of green technologies and Europe's energy independence.

**Iberdrola Secures $1 billion from EIB to build 19 solar power plants and three onshore wind farms in Spain, Portugal, and Germany with a total installed capacity of 2.2 GW.** In addition, the project will have an innovation component, as it will facilitate the integration of renewables into grids, undoubtedly one of the great challenges in achieving Europe's climate objectives.

Some of the photovoltaic projects will include hybridization with wind power and battery systems for energy storage.

The new installations will generate sufficient energy to power more than one million households with electricity annually, with 70% of the projects deployed in rural areas, areas affected by the industrial transition to net zero, and cohesion regions. A part of EIB's financing package supports the European Union's REPowerEU plan; the collaboration will accelerate Europe's efforts to completely cut dependence on fossil fuel imports while boosting supply security.

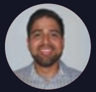
**Serbia gets its first commercial PPA and financing is secured for Krivača wind farm.** The PPA was signed with Swiss renewables producer and trader Axpo. Serbia's MK Group and Slovenia's ALFI Green Energy Fund have secured €155 million for the Krivača wind farm project from a consortium of lenders led by Erste Group. It will be the first renewable energy project in Serbia with a commercial PPA.

**EIB to finance modernization of ČEZ's distribution grid and connection of new renewable energy sources with a record-breaking loan of €790 million.** The loan will promote the Czech Republic's energy independence by enabling ČEZ to connect around 2.2 GW of new renewable energy sources, upgrade and expand the country's electricity distribution grid, and help provide a more reliable electricity supply for businesses and households across the Czech Republic.

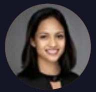
*Utility businesses are optimizing their portfolios, including shedding non-core assets and funneling more capital towards energy security, decarbonization, and energy-transition areas. As the market moves to an electric future, utilities will continue to focus on several areas: generation and storage, heating decarbonization, electric vehicle charging, hydrogen infrastructure, technology to maximize existing infrastructure, and relocating renewables.*

# NORTH AMERICAN PLAYERS - PRIORITIES, INVESTMENTS AND FINANCIAL RESULTS

TORBEN SCHUSTER, GERMANY



ALEXANDER RODRIGUEZ, USA



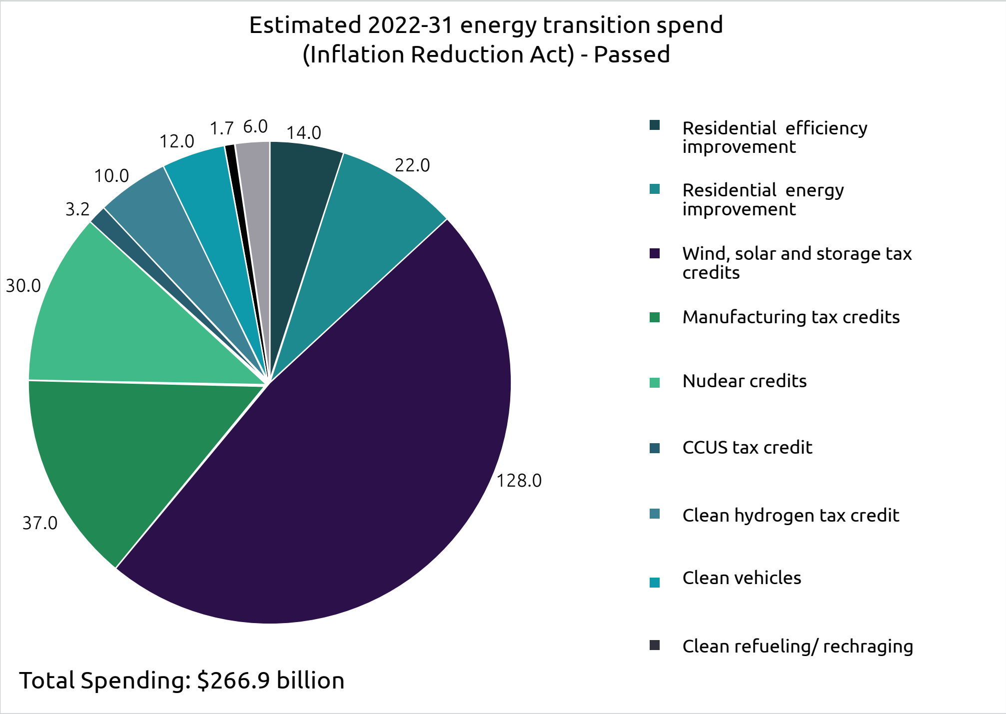
SARA STRITHARAN, USA

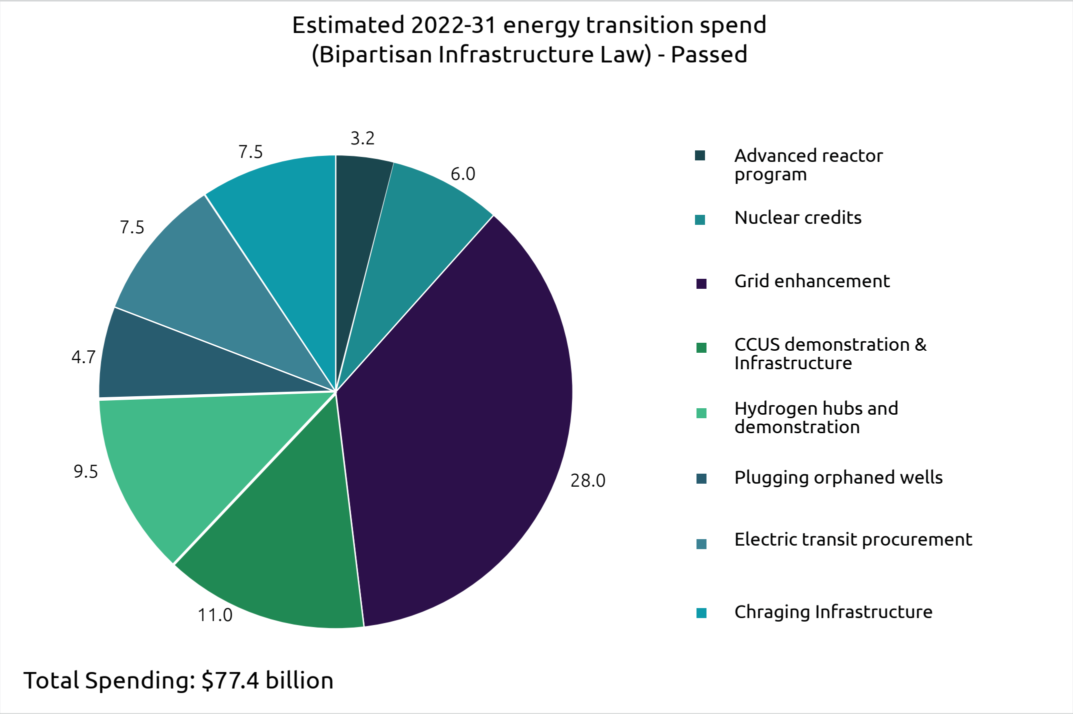
## The Inflation Reduction Act (IRA) would provide at least $369 billion in support to energy transition technologies

- Inflation Reduction Act contains Wind, solar and storage tax credits of $128 billion, Nuclear credits of $30 billion, and carbon capture, usage, and storage (CCUS) tax credit of $ 3.2 billion and clean hydrogen tax credit of $13 billion.
- The law aims to place the nation closer to the Biden administration' s ambition of halving economy-wide $CO_2$ emissions by 2030 (vs. 2005) and in 2023 and 2024, the Treasury Department targets to write many of the rules in 2023 on how these and other tax policies are to be implemented.
- While the IRA is considered to be the most significant, it is not the sole piece of climate legislation to be passed during the 116th Congress. The Bipartisan Infrastructure Bill (Infrastructure Investment and Jobs Act) of 2021 and the CHIPS and Science Act of 2022 both contained significant support for climate-related sectors.
- Prior to the IRA being passed, many wind solar and storage projects were put on hold by operators and utility companies. Since August, there has been an uptick in demand for battery energy storage systems and this is put a strain on the supply chain as well as contractor availability. As a result, the cost of these projects has increased.
- IRA domestic content requirements has created a race to move manufacturing of BESS components to the US. Various technology providers are entering into agreement with local manufacturing to complete assembly of their product. As a result, we are going to see money flowing into US based BESS manufacturers, integrations, EPC, etc.

FIGURE 1

U.S.: Tax credits and clean energy investment-2022




Source: BNEF ~ Sustainable Energy in America Factbook, 2023

## U.S. utilities revenue: In 2022, utility companies have continued to demonstrate revenue growth and were focused on making significant investments in clean, safe, reliable, and affordable energy to their customers

**Global investment in the low-carbon energy transition totalled $1.1 trillion in 2022, which is considered to be a new record and a huge acceleration from the year before, as the energy crisis and policy action drove faster deployment of clean energy technologies, according to Bloomberg NEF.**

**Despite 2022's impressive results, global investment in lower-carbon technologies remains woefully short of what is needed to confront climate change. Bloomberg NEF estimates that for the world to get on a 2050 "net-zero" CO2 emissions trajectory, such investment must immediately triple.**

- American Electric Power has achieved an increase of 17% in the total revenue of 2022 as compared to 2021, with the company being one of the largest electricity producers generating around 31,000 megawatts of electricity, including over 6,900 megawatts of renewable energy.
  - Julie Sloat, President and CEO of American Electric Power has stated that their strategic vision focuses on delivering clean, and reliable energy and aims to make significant capital investment of $40 billion in transmission, distribution and renewable energy, from 2023 through 2027.
- According to Southern company, they experienced another remarkable year in 2022 with an increase of 26.7% in operating revenue primarily driven by higher fuel costs. The company believes that the positive outcomes were also due to their employees' efforts in providing clean, safe, reliable, and affordable energy to their 9 million residential and commercial customers.
  - The company has transitioned from fossil fuels to clean energy sources and its electric generating mix consists of 22% coal and 51% natural gas in 2022. This transition has partially been feasible with the company retiring over 6,700 MWs of coal-fired generating capacity since 2010.
  - In addition, the company's capacity mix comprises over 11,500 MWs of renewable and storage facilities through ownership and long-term PPAs.
- According to John W. Somerhalder II, the board chair, interim president and CEO of FirstEnergy, the company executed transformative equity investments to strengthen their financial position and drive their customer-focused investment strategy in 2022.
  - The company attributes the increase in financial results to their customer-focused regulated investments of over $3.2 billion, higher investment income, lower interest expense and increased customer demand as compared to 2021.
- Duke Energy attributes the increase in company's revenue as of 2022 over 2021, to higher electric volumes and favorable weather, in addition to rate case contributions.
  - Further, in its efforts to clean energy transition, the company is investing in major electric grid enhancements and energy storage and exploring zero-emission power generation technologies such as hydrogen and advanced nuclear. In view of this, the company states that its five-year capital plan increases to $65 billion with over 80% funding investments in the grid and clean energy transition.

**FIGURE 2**

U.S.: Revenues and associated CAGR (average), 2018-2022 ($billion)

# Exploring the Resilient EBITDA Margins of Major U.S. Energy Players

**Most U.S. and Canadian utilities continued to see a decline in their recurring EBITDA margin in 2022, as compared to 2021. It has been observed that many of the profitable U.S. and Canadian utilities recorded a negative year-over-year change in recurring EBITDA in 2022.**

**American Electric Power's earnings before interest, taxes, depreciation and amortization (EBITDA) for 2022 was 36.3%, as compared to 37.2% in 2021.**

- American Electric Power witnessed a $253 million increase in cash from Net Income, after non-cash adjustments including depreciation and amortization, Rockport Plant, Unit 2 lease amortization, deferred income taxes, and amortization of nuclear fuel.

**There has been a marginal decrease in EBITDA of Duke Energy in 2022 (42.6%) as compared to 46.7% in 2021.**

- There has been a $320 million increase in net income after adjustment for non-cash items.
- This increase can be primarily attributed to higher revenues from rate cases in various jurisdictions, favorable weather and volumes, partially offset by an estimated impairment on the Commercial Renewables Disposal Groups.

**Southern Company's earnings before interest, taxes, depreciation and amortization (EBITDA) for 2022 was 33.5%, as compared to 39.7% in 2021.**

- Consolidated net income attributable to Southern Company was $3.5 billion in 2022, an increase of $1.1 billion, or 47.3%, from 2021.
- The rise was mainly driven by higher earnings from retail electricity, stemming from rate adjustments, increased sales, and greater revenue from natural gas due to base rate hikes and ongoing infrastructure upgrades. However, this increase was partially balanced out by higher non-fuel operational and maintenance expenses, as well as increased interest costs.

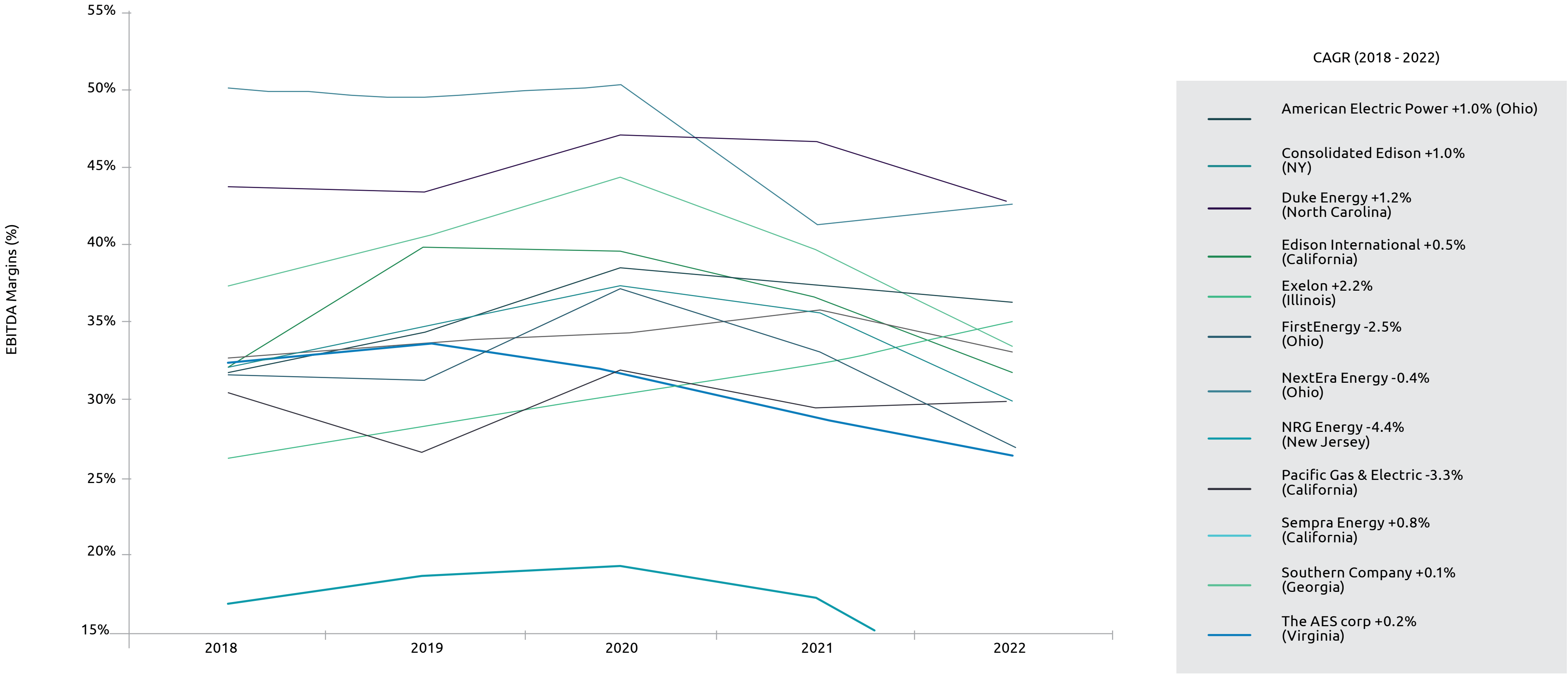
When the energy giants posted huge profits, benefiting from surging natural gas and fuel prices that have boosted inflation around the world and led to fresh calls to further tax the sector. It has been observed that the U.S. President Joe Biden slams the energy companies.

In 2022, the sheer size of the profits has revived calls from politicians and consumer groups to impose more taxes on the companies to raise funds to offset the hit to households, businesses, and the wider economy from higher energy costs. They have also criticized the major energy companies for not doing enough to raise production to offset rising fuel and heating costs.

Equinor Chief Executive Anders Opedal has stated that the Russian war in Ukraine has changed the energy markets, slashed energy availability and intensified prices.

**FIGURE 3**

U.S.: EBITDA margins and associated CAGR, 2018-2022



# U.S. utilities relied less on debt in 2022 for capital needs, as the sector manages energy transition costs and an influx of federal funds from U.S. President Joe Biden.

**Holding companies, including NextEra Energy Inc., Exelon Corp., and DTE Energy Co., and operating companies, including Pacific Gas and Electric Co. and Duke Energy Progress LLC, had some of the largest amounts of debt maturities occurring in 2022, according to S&P Global.**

- AES Corporation had a leverage (debt/equity) ratio of 14.7 in 2022, as compared to 9.48 in 2021.
  - This increase in the leverage ratio indicates that AES has a significant amount of debt. The company states that they had approximately $23 billion of outstanding indebtedness on a consolidated basis, as of December 31, 2022.
  - Most of the debt of AES Corporation's subsidiaries is secured by substantially all the assets of those subsidiaries. A considerable portion of cash flow from operations must be used to make payments on their debt.
- American Electric Power had a leverage ratio of 1.71 in 2022, as compared to 1.63 in 2021.
  - The increase in the leverage ratio can be attributed to an increase in debt taken on to support distribution, transmission, and renewable investment growth, as well as increased working capital needs due to higher deferred fuel costs.
- Southern Company had a leverage ratio of 1.89 in 2022, as compared to 1.93 in 2021.
  - Southern Company has witnessed an increase of $2.5 billion in total equity primarily related to net income and the issuance of common stock to settle the purchase contracts entered as part of the Equity Units
  - There was also an increase of $2.7 billion in long-term debt related to new issuances
- Sempra Energy had a leverage ratio of 1.1 in 2022, as compared to 0.98 in 2021.
  - This can be attributed to the increase in long-term debt, offset by a decrease in short-term debt and increase in equity primarily from comprehensive income exceeding dividends and the sale of non-controlling interest (NCI).
  - They rely on long-term debt to fund a significant portion of their capital expenditures and repay outstanding debt. Additionally, they rely on short-term borrowings to fund a significant portion of day-to-day business operations.
  - Sempra may also seek to raise capital by issuing equity or selling equity interests in their subsidiaries or investments.
- **International Energy Agency (IEA) estimates that around $2.8 trillion will be invested in energy in 2023. More than $1.7 trillion is going toward clean energy, including renewable power, nuclear, grids, storage, low-emission fuels, efficiency improvements and end-use renewables and electrification.**
- **Clean energy investments have been boosted by a variety of factors, including improved economics at a time of high and volatile fossil fuel prices; enhanced policy support through instruments like the US Inflation Reduction Act and new initiatives in Europe, Japan, and China.**

FIGURE 4

U.S.: Leverage (debt/equity), 2021-2022 evolution

| Utilities | 2021 | 2022 | Evolution |
|---|---|---|---|
| American Electric Power (Ohio) | 1.63 | 1.71 | ↑ |
| Consolidated Edison | 1.22 | 1.15 | ↓ |
| Duke Energy ( North Carolina) | 1.42 | 1.56 | ↑ |
| Edison International (California) | 1.98 | 2.32 | ↑ |
| Exelon (Illinois) | 1.23 | 1.62 | ↑ |
| First Energy (Ohio) | 2.75 | 2.13 | ↓ |
| Next Era Energy (Florida) | 1.47 | 1.66 | ↑ |
| Pacific Gas & Electric (California) | 1.59 | 1.74 | ↑ |
| Sempra Energy (California) | 0.98 | 1.1 | ↑ |
| Southern Company (Georgia) | 1.93 | 1.89 | ↓ |
| The AES Corp (Virginia) | 9.48 | 14.70 | ↑ |

## Canadian utilities have continued to demonstrate revenue growth in 2022, with electricity generation in the country edging up 2.0% from 2021 levels to 640.3 million MWh

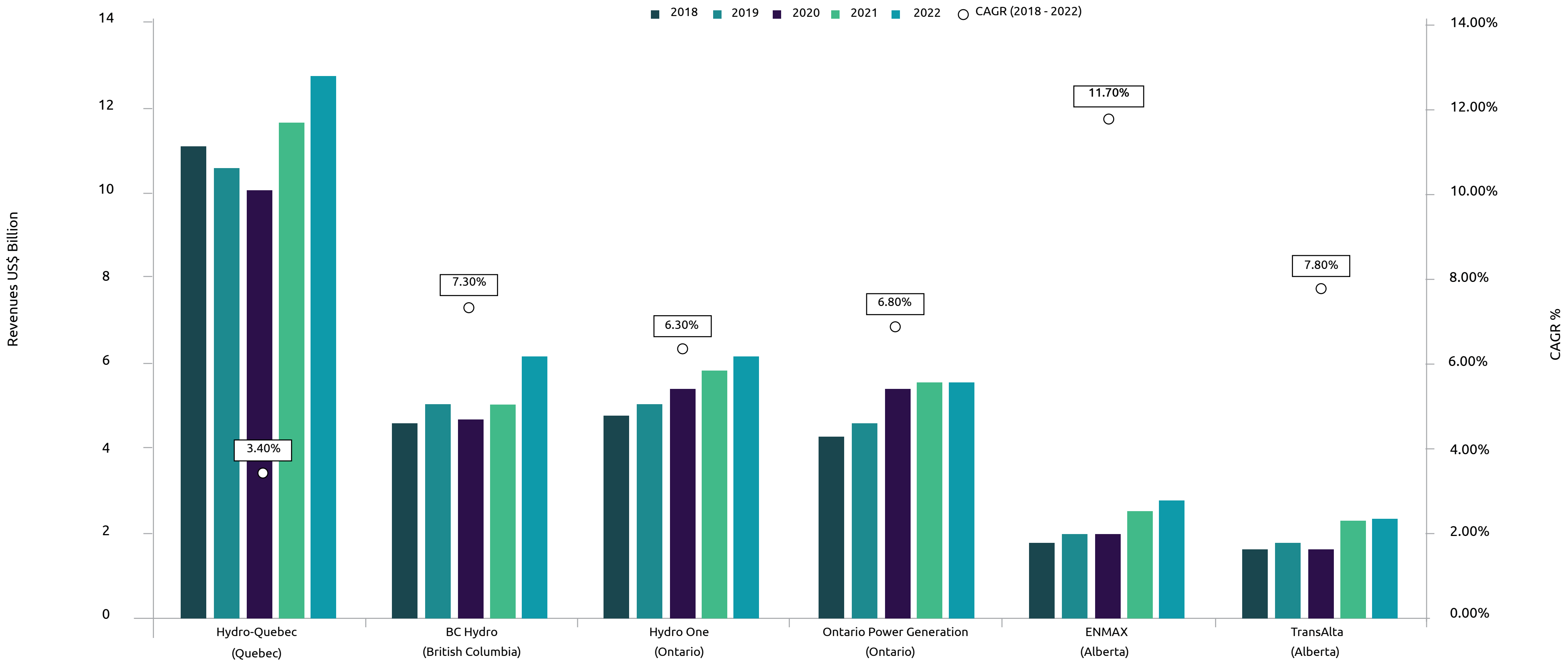
**Electric generation from renewable energy sources, including hydro, wind, solar and others increased 4.1% from 2021. While generation from nuclear (-5.8%) and combustible sources (-0.8%) decreased year over year, largely due to refurbishment and maintenance activities at Ontario and New Brunswick's nuclear generating stations.**

- The increase in the total revenues of Hydro One in 2022 can be attributed to the significant increase in transmission and distribution revenues by 13.9% and 5.6% respectively, as compared to 2021.
    - The increase in transmission revenues were primarily due to higher revenues resulting from Ontario Energy Board (OEB) approved 2022 rates and greater peak demand. While the increase in distribution revenues were driven by higher purchased power costs, higher revenues resulting from OEB-approved 2022 rates and a lower deferred regulatory adjustment associated with the Earnings Sharing Mechanism in 2022.
    - Hydro One continued making capital investments of $1.5 billion in 2022, to expand the electricity grid and renew existing infrastructure. The company's recently approved 2023–2027 Investment Plan aims to reduce the impacts of power outages, renew or restore critical transmission and distribution infrastructure, enable economic growth and prepare for climate change.
- According to Ken Hartwick, President and CEO of Ontario Power Generation (OPG), the company achieved strong operational results in 2022, with hydroelectric generation accounting for over a third of total electricity production and significant progress across its nuclear fleet.
    - Ontario Power Generation's total capital expenditures increased by 23.3% in 2022, as compared to 2021 driven by higher expenditures for the Regulated-nuclear generation business segment.
    - In particular, the capital expenditure of the Regulated-nuclear generation business segment increased by $115 million mainly for the higher refurbishment activities at the Darlington GS. While, the capital expenditure of this segment, excluding the Darlington Refurbishment Project increased by $196 million.
- British Columbia Hydro and Power Authority states that the increase in the revenue in 2022 was primarily driven by higher trade revenues and higher domestic revenues.

HOME

**FIGURE 5**

Canada: Revenues and associated CAGR (average), 2018-2022 (USD $billion)



# There has been an increase in the net income contributing to a better EBITDA for Canadian Utilities in 2022

### Hydro-Québec's net income was $3.40 billion in 2022, an increase of $1.0 billion, or 28%, from 2021.

- The significant increase in net income has contributed to a strong EBITDA in 2022.
  - Hydro-Québec states that favourable conditions in export markets had a major impact on the profit improvement (an increase of 60% in the export revenue).
  - There was an increase in domestic demand which consequently led to an increase in the revenue from sales to Quebec-based customers.

### The EBITDA margin of BC Hydro was 37.9% in 2022, as compared to 39.4% in 2021.

- The decrease in EBITDA margin can be attributed to a decrease in 2022 net income compared to 2021.
- The lower net income was primarily due to higher operating costs as a result of higher than planned project and asset write-offs that were not subject to deferral to regulatory accounts.

### The EBITDA margin of Ontario Power Generation increased to 29.0% in 2022, as compared to 28.7 % in 2021.

- The increase in EBITDA margin can be attributed to a significant increase in net income.
  - Ontario Power Generation's net income rose by 22.8% in 2022 compared to 2021.
  - There was also an increase of 19.5% in the earnings before interest and income taxes in 2022, as compared to the previous year.
  - This increase in earnings before interest and income taxes was primarily due to lower operations, maintenance, and administration (OM&A) expenses from the Regulated- Nuclear Generation business segment.

In 2022, Energy corporations in Canada have effectively been allowed to reap super profits as most Canadians were left to manage a cost-of-living crisis. During the 12-month period preceding the second quarter of 2022, the rise in industry-wide margins were led by the energy and mining sectors where soaring prices fuelled an increase in margins. The considerable impact of higher commodity prices, particularly energy, and supply chain disruptions that began at the onset of the pandemic persist across Canadian industries resulting in the current inflation rates.

The rise in profit margins necessitates specific price regulations to control how much companies can gain from disruptions in sector-specific areas, such as the energy industry. This could include measures like excess profit taxes, which would then be used to provide fiscal support for consumers..

FIGURE 6

Canada: EBITDA margins and associated CAGR, 2018-2022

## U.S. and Canadian dividend per share (DPS): Utility dividend growth in 2022 can be attributed to the increase in revenue and positive cashflow

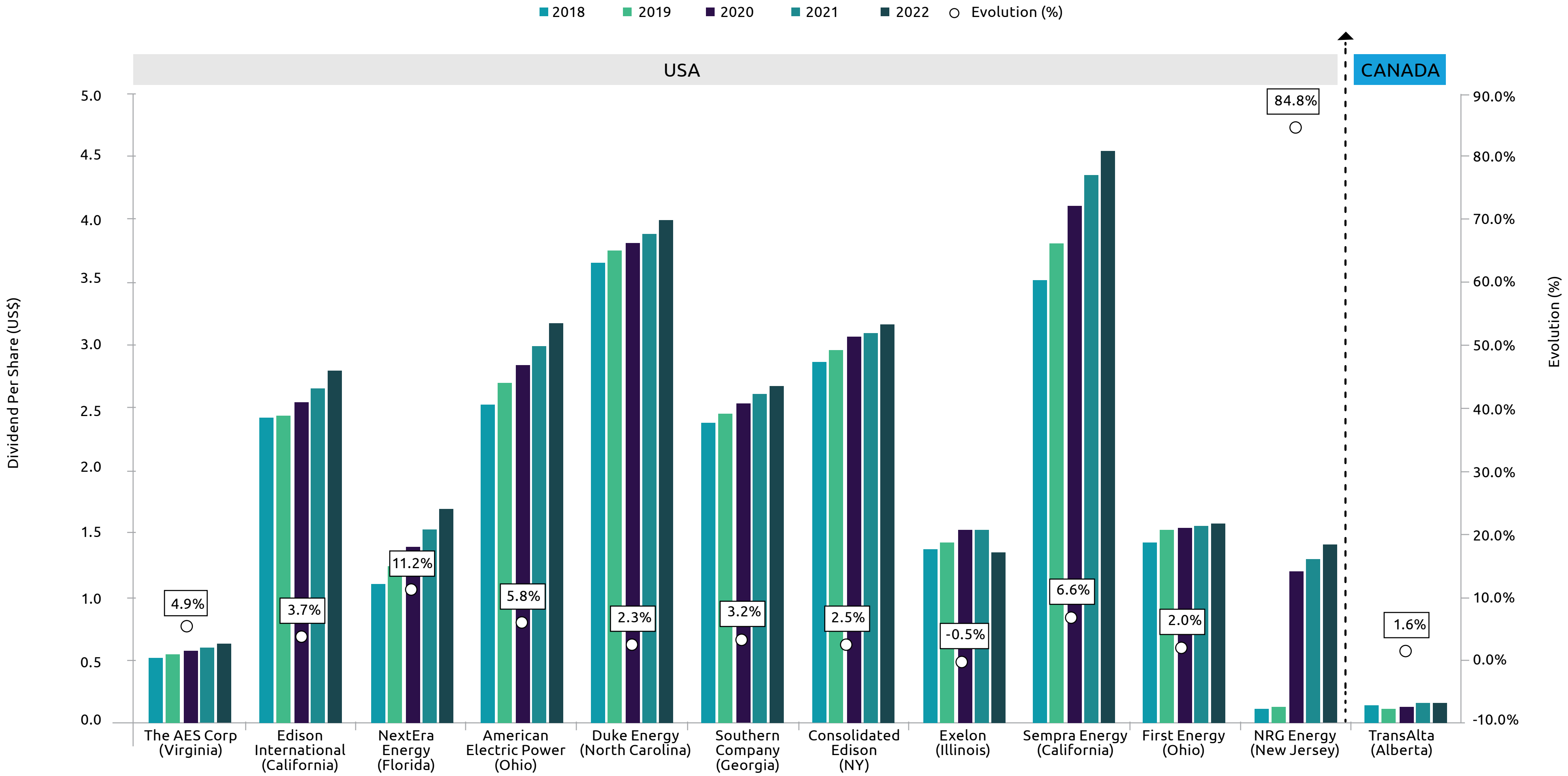
- Edison International declared a dividend of $ 2.80 per share in 2022, which is an increase of around 6% as compared to 2021.
  - In December 2022, Edison International declared a 5% increase to the annual dividend rate from $2.80 per share to $2.95 per share.
  - Edison International states that timing and amount of future dividends are dependent on several other factors including the company's requirements to fund other obligations and capital expenditures, and its ability to access the capital markets and generate operating cash flows and earnings.
- Sempra Energy declared a dividend of $ 4.54 per share in 2022, which is an increase of around 4% as compared to 2021.
  - Sempra Energy states that they have achieved strong financial results in 2022, while continuing to support a growing dividend.
  - The company also states that Sempra's ability to pay dividends largely depends on cash flows from their subsidiaries and equity method investments.
- Duke Energy declared a dividend of $3.98 per share in 2022.
  - Duke Energy increased the dividend by approximately 2% annually in both 2022 and 2021, and the company remains committed to continued dividend growth.
  - Additionally, the company aims for a dividend pay-out ratio of between 65% and 75%, based on the adjusted EPS.
- TransAlta declared a dividend of $0.16 per share in 2022, an increase of 7% over 2021.
  - The company attributes the increase in dividend to a solid financial position with over $1.6 billion in liquidity.
  - TransAlta increased their annual dividend by 10%, starting in January 2023, which represents their fourth consecutive annual increase.

**Majority of the energy utilities reported impressive earnings for 2022 and reaffirmed their growth outlooks. There is a forecast of 6% average annual EPS and dividend growth for U.S. utilities during the next three years, according to a report by Morningstar, Inc.. This steady growth along with dividend yields that have stuck near 3.5% suggests attractive total returns for most utilities.**

**The report also states that it is unlikely that energy utilities stocks will finish 2023 with a performance like 2022 when they outperformed the market by 21 percentage points. However, an 8% total return from utilities, including dividends, should make investors happy after three years of mostly flat returns.**

**FIGURE 7**

U.S. and Canada: Dividend per share (USD $) and 2018-2022 evolution



# AUSTRALIAN PLAYERS - PRIORITIES, INVESTMENTS AND FINANCIAL RESULTS


VINNIE NAIR, AUSTRALIA


GAUTAM GANDHA, AUSTRALIA

## The electricity market is changing

**The National Electricity Market (NEM) in Australia is undergoing significant and unprecedented change. Since 2016, market participation has quadrupled and by 2024 a further increase of 40% is expected, bringing the total number of participants to over 500.**

**However, it is not so much the number of participants which is a cause for scrutiny, but rather the type of participants drawn to the market.**

**As incumbent large-scale generators diminish, small generation aggregators are becoming much more influential. This is largely driven by an uptick in distributed energy resource usage, aggressive emissions targets, societal inertia, and opportunities. As a result, we are approaching an age of wholesale change. In this environment, utilities will be required to determine how small generation aggregators survive and how they can thrive.**

## So, who is in the market now?

Traditionally, participation in the NEM has been reasonably static. The way that the market operated was predictable and was dominated by incumbent players, both on the regulated and unregulated side. This is no longer the case, as smaller players are increasingly having a seat at the table, particularly to facilitate the energy transition.

In the past two years, six new participants have entered the NEM in the virtual power plant (VPP), battery, and demand response categories. Their flexibility, responsiveness, and inherent efficiencies from a cost perspective has enabled them to offer largely lower prices, encouraging traditional generators (such as black coal generators) to also drop prices. They can therefore compete when economically viable.

Additionally, service offerings such as Frequency Control Ancillary Services (FCAS) have attracted further investment from smaller businesses. These investments have displaced some gas and coal generation, with grid-scale batteries being the most common provider of these services.

The mix of supply is also increasingly being augmented by new entrants. Up from 1% between 2017–18, large scale solar now supplies approximately 5% of the NEM's electricity requirement. New South Wales (NSW) has now overtaken Queensland in output, with 6.4% generation from NSW's solar farms. The increase in large scale solar penetration is only expected to hasten, with another eight solar projects to be commissioned across the NEM sometime between 2022–23.

Despite the influx of new entrants, the majority of investment into the NEM is backed in some way by the government. As investors await more concrete examples of cost recovery, it seems as though confidence in investments is not purely market-led yet.

For instance, since 2020, the Clean Energy Finance Corporation (CEFC) has invested up to AUD $20 million to support Phase 3 of South Australia's VPP. The program is also supported by a AUD $5 million grant from the Australian Renewable Energy Agency (ARENA), a AUD $12 million equity contribution from VPP operator Tesla, and AUD $6 million from the South Australian Government's Grid Scale Storage Fund (GSSF). Below, we can see the investment profile of the government which helps speed up the implementation of clean energy technology. As further investment in the sector continues, Distributed Network Service Providers (DNSPs) will be forced to respond with their own investments to retain their position, and take advantage of opportunities.

## How is the market behaving?

In addition to responding to investments made in the sector, market participants also need to be aware of other participant behavior which could be impactful.

The latest Australian Energy Market Operator (AEMO) report sheds light on participant activity in the market. Here are some key trends which we have observed:

- **Pricing pressure:** New entrants provide pricing pressure
- **Pricing manipulation:** Participants display behavior consistent with economic withholding
- **Physical withholding:** Participants are withdrawing capacity from the market entirely
- **Rebidding conduct:** Rebidding by participants is contributing to higher prices

Let's now look at the market from a retailer perspective.

In 2022, three large retailers, The Australian Gas Light Company (AGL), EnergyAustralia, and Origin, still held significant market share and continued to have considerable cost advantages over smaller retailers.

In the long run, high and volatile wholesale electricity spot prices (coupled with other financial headwinds) will cause prices to rise. This is because retailers will have limited ability to pass through increased costs, due to the price cap on standing offers or Default Market Offer (DMO).

Six retailers have either exited the market or are no longer seeking new market growth. This has resulted in consumers moving from small and very small retailers, to large retailers. Subsequently, market concentration has increased.

In the last six months alone, the rising cost of capital and lack of liquidity in the market is hurting innovation, stifling the start-up ecosystem, and raising the bar for new entrants in the market in the long run. However, market participants must still pay attention to existing new entrants who are offering innovative services and keep a close eye on further disruptors.

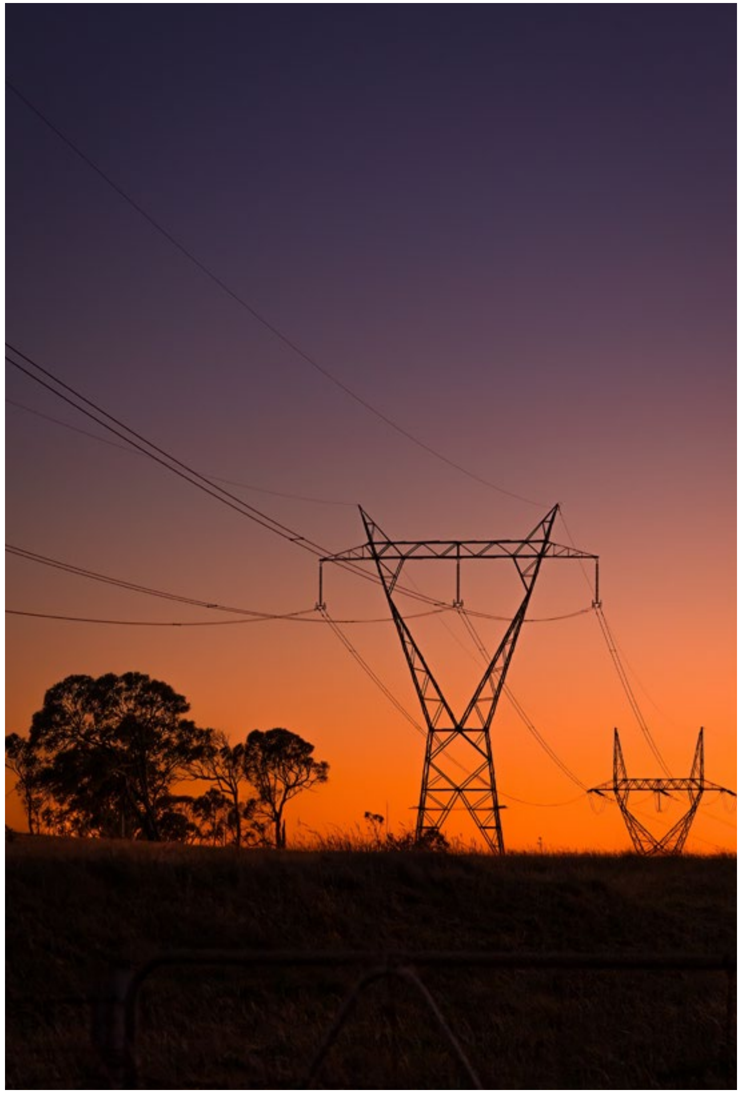
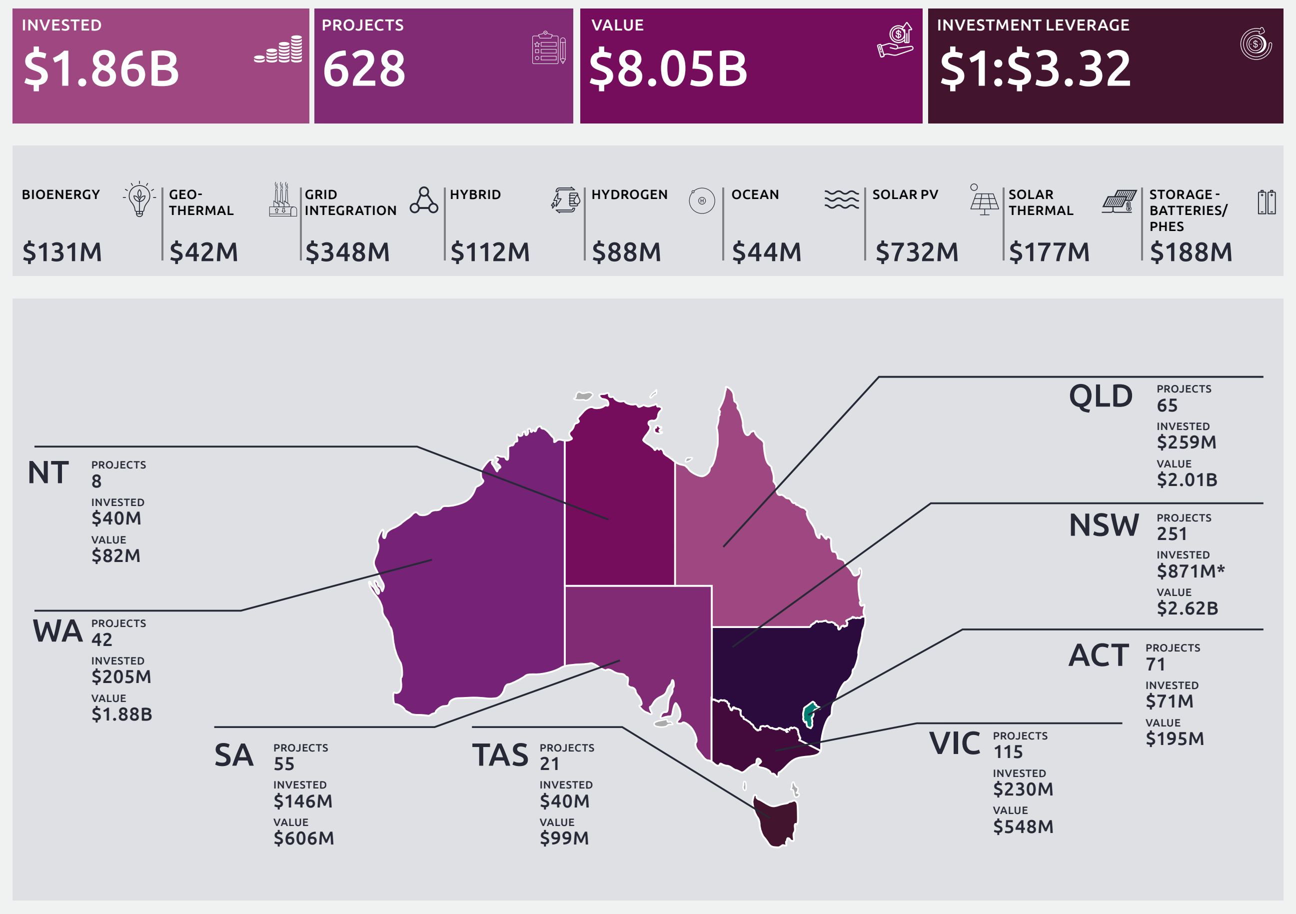


**FIGURE 1**

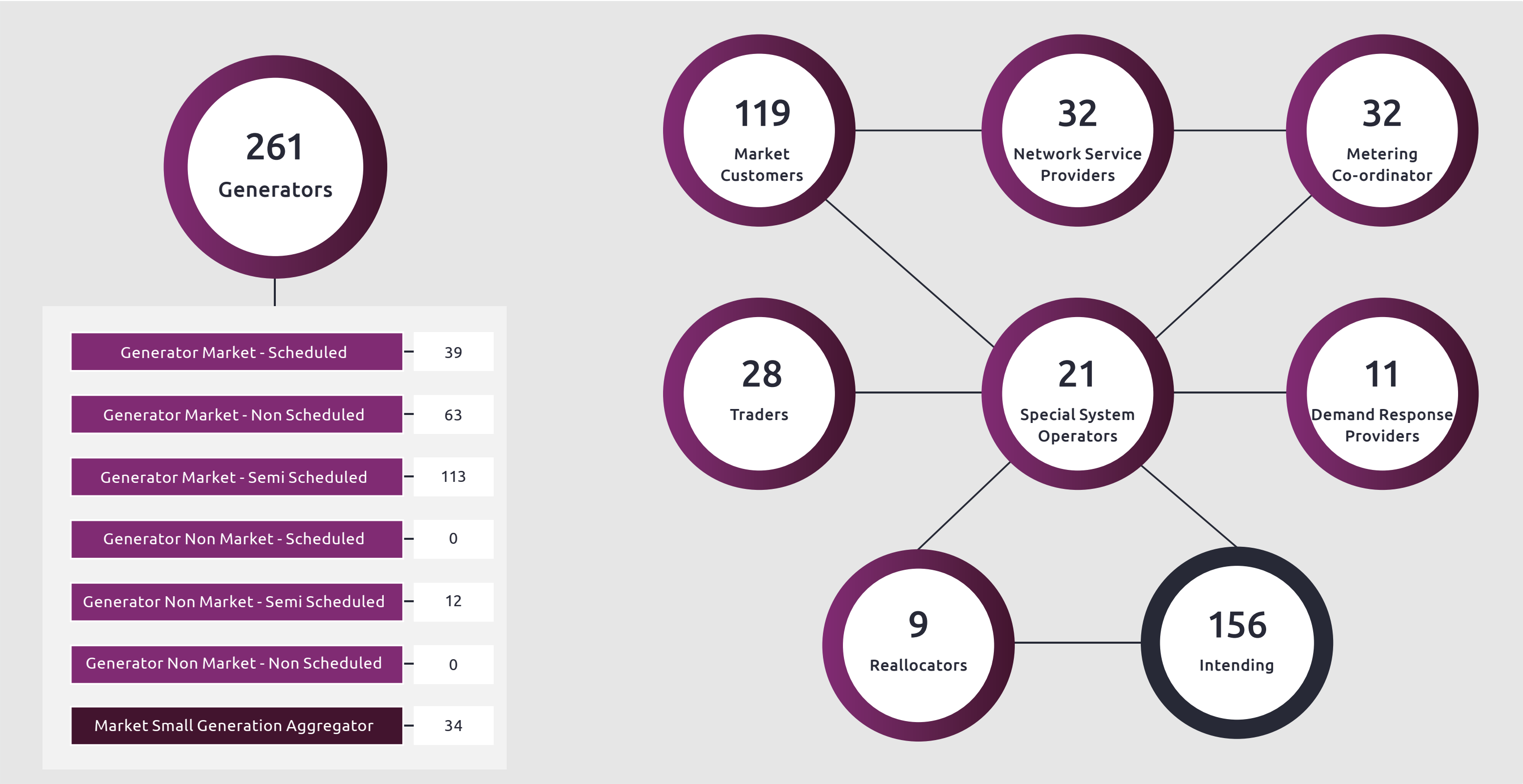
Investments in Australia




* Includes $567 million contributed to projects inherited by ARENA in 2012.

**FIGURE 2**

Participants in the NEM



## Partnership opportunities

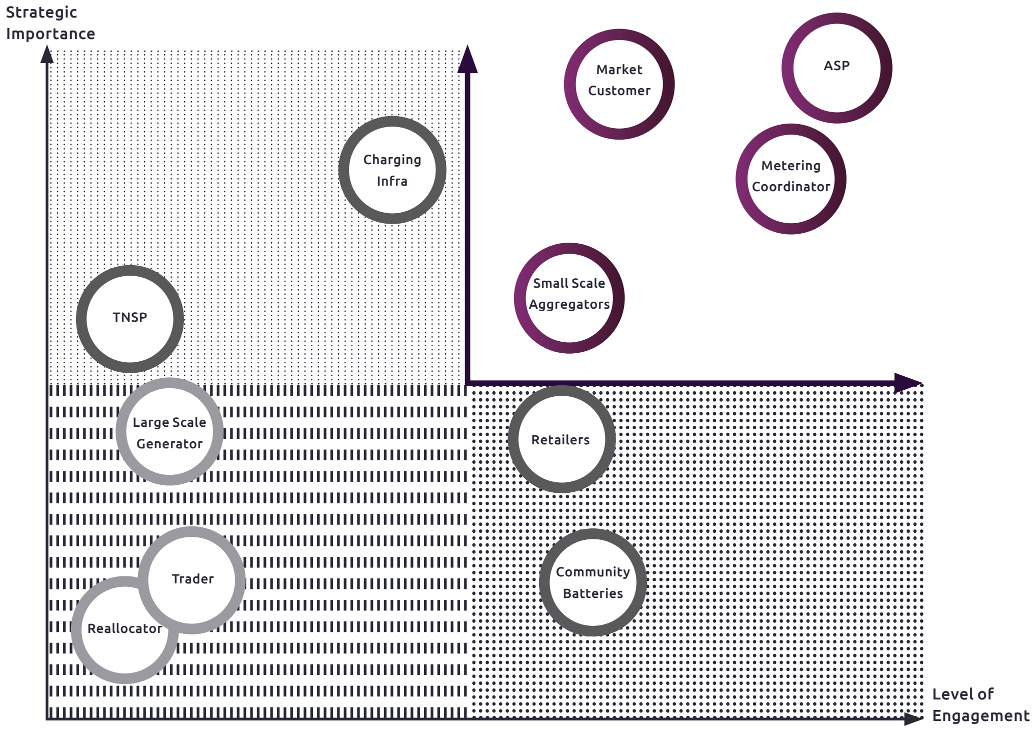
To combat the volatility in the market generated by increased investment and dynamic new entrants, Capgemini recommends that utilities should consider partnership opportunities and understand the types of partners that exist.

- **Partners:** A utility may consider partnering with a company due to one or both parties not having sufficient capabilities, or the regulatory overhead being too great for one party to to compete the job on their own.
- **Frenemies:** A company might choose to partner with a utility to help them provide a service. For example, the company may be looking for a technology uplift at a reasonable cost base, which also allows the utility to quickly expand in areas such as the unregulated revenue space.
- **Friends:** A company could partner with a 'friend', whereby the two parties exist in some sort of a symbiotic relationship. The utility and the company in question would therefore work together in a mutually beneficial relationship.

Below are some helpful considerations for utilities when deciding how best to invest in opportunities:

- **Partners:** Mining giants suffering from high energy prices might want to take matters into their own hands to manage escalating energy costs. [1] Therefore, mining giants may want to partner directly with Transmission Network Service Providers or Distributed Network Service Providers (DNSPs).
- **Frenemies:** Partnering with a 'frenemy' gives aggregators an opportunity to scale up their customer base, as well as ramp up hardware (including IoT) and software sales. This can be achieved through value-add services (such as tariff arbitration), flexible exports, and locational demand response services. Australian Energy Regulator (AER) is undertaking a significant step forward with the network tariff reform. [2]
- **Friends:** There are also opportunities for DNSPs to form a three-way partnership, for example, between a fossil fuel operator, a DNSP, and an infrastructure charging operator. This is suitable for fossil fuel operators registering themselves as electricity retailers in the NEM. [3]

FIGURE 3



# Investment opportunities

Utilities will need to make material investments in enabling technologies or in partnership options (as mentioned previously). This ensures they are equipped with the capabilities required to respond to an increasingly evolving market.

### Friends

DNSPs + Charging Networks + New Retailers

- DNSPs: Ausgrid, SA Power Networks, Essential Energy
- Charging Networks: Jolt, Evie
- New Retailers: Bharat Petroleum, Ampol, Shell

**Cost of Doing Nothing**

- To enable access to new services, DNSPs need to seriously consider partnerships with charging networks and new retailers.
- DNSPs are unable to secure retail licenses; in addition, tremendous capability exists in the market regarding charging networks. Failing to capitalize on these opportunities puts the onus on DNSPs to solve fundamental issues in isolation.

### Partners

Mining Giants + DNSPs

- Mining Giants: BHP, RioTinto
- DNSPs: Ausgrid, SA Power Networks, Essential Energy

**Cost of Doing Nothing**

- Mining giants can go it alone in building private networks due to the sheer amount of capital at their disposal. However, energy networks expertise is hard to come by.
- By partnering with mining giants and helping to develop and manage their private networks, DNSPs will greatly improve their Regulatory Asset Base (RAB).

### Frenemies

DNSPs + Small Scale Aggregators

- DNSPs: Ausgrid, SA Power Networks, Essential Energy
- Small Scale Aggregators: Reposit

**Cost of Doing Nothing**

- DNSPs currently partner with aggregators or similar ancillary service providers to access capabilities and technologies which do not exist internally. Without these technologies and capabilities, responding to an increasingly volatile network and changing customer behaviors becomes difficult.
- However, DNSPs will need to decide whether these capabilities are better developed internally to increase revenue and safeguard against external risk.

**DNSPs require the capabilities below. The question will be whether we choose to incubate them or source them through partners and the market.**

**Capabilities required** (Friends)

- Electric vehicle (EV) load management
- Future Combat Air System (FCAS) access
- DNSP demand response

**Capabilities required** (Partners)

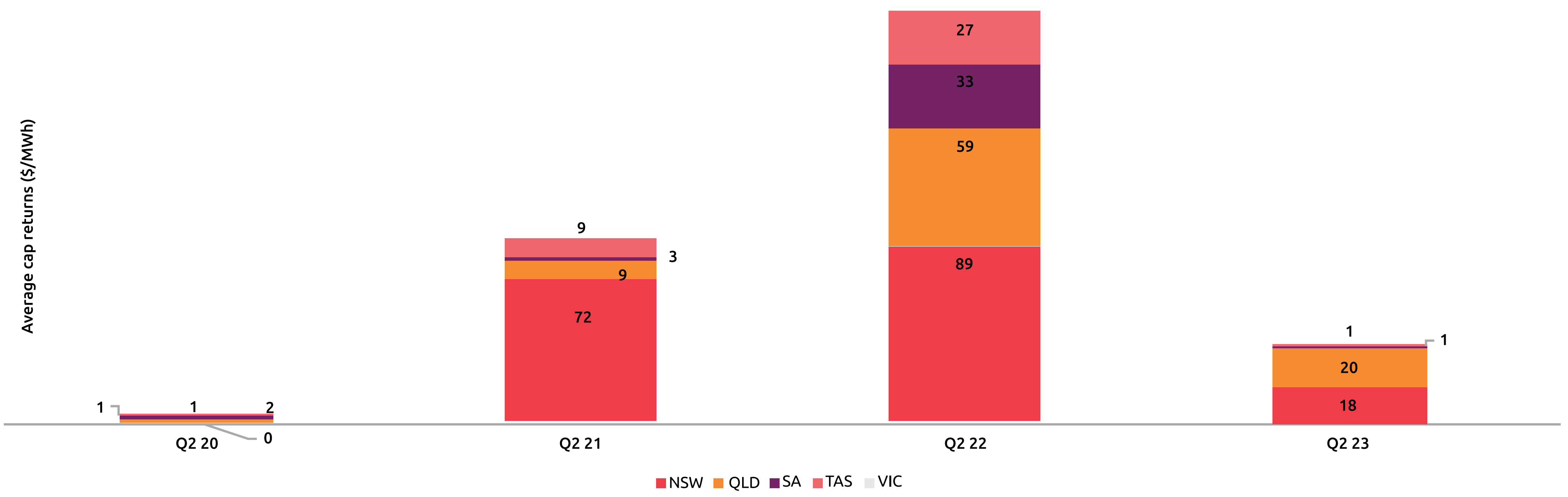
- EV load management
- FCAS access
- DNSP demand response

**Capabilities required** (Frenemies)

- Citizen energy community
- Scaling “Evolve” distributed energy resources (DER) trial project

**FIGURE 4**

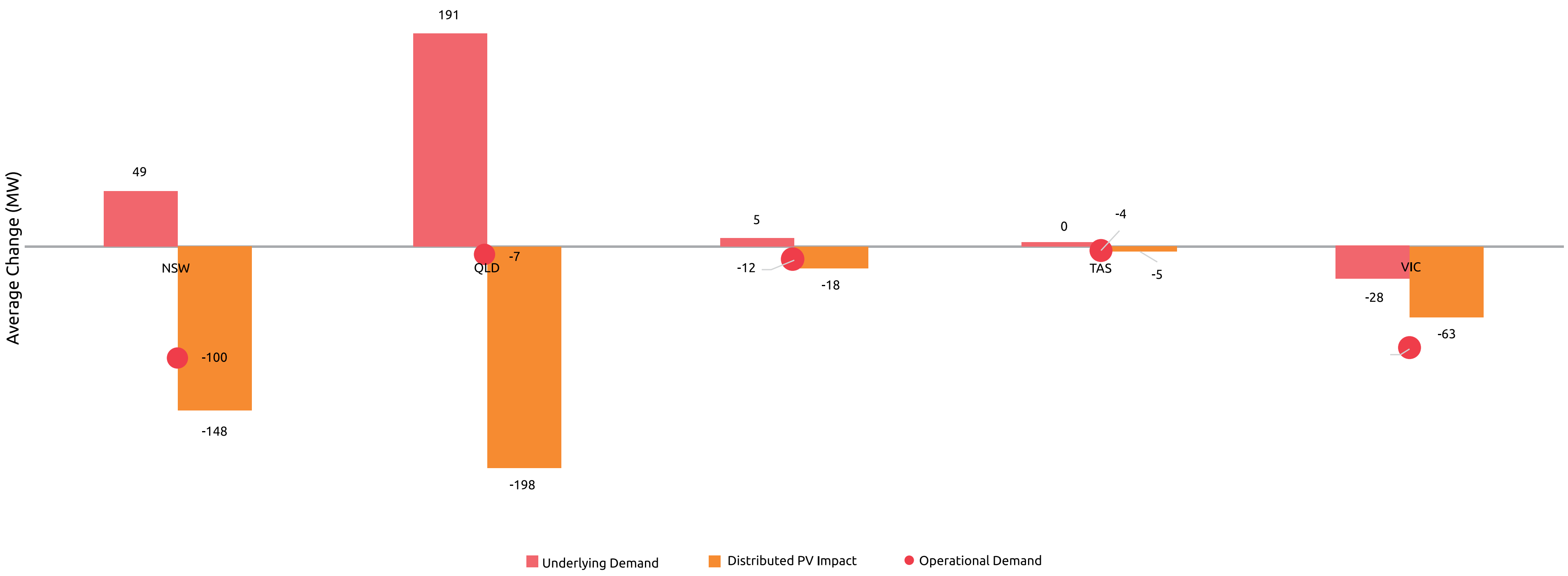
NEM average quarterly cap returns by region, Q2 2020 - Q2 2023




Source: AEMO: Quarterly Energy Dynamics Q2 2023
https://aemo.com.au/-/media/files/major-publications/qed/2023/qed-q2-2023-report.pdf?la=en&hash=719538BE6166CB79BE1BF6B9BE82A183

**FIGURE 5**

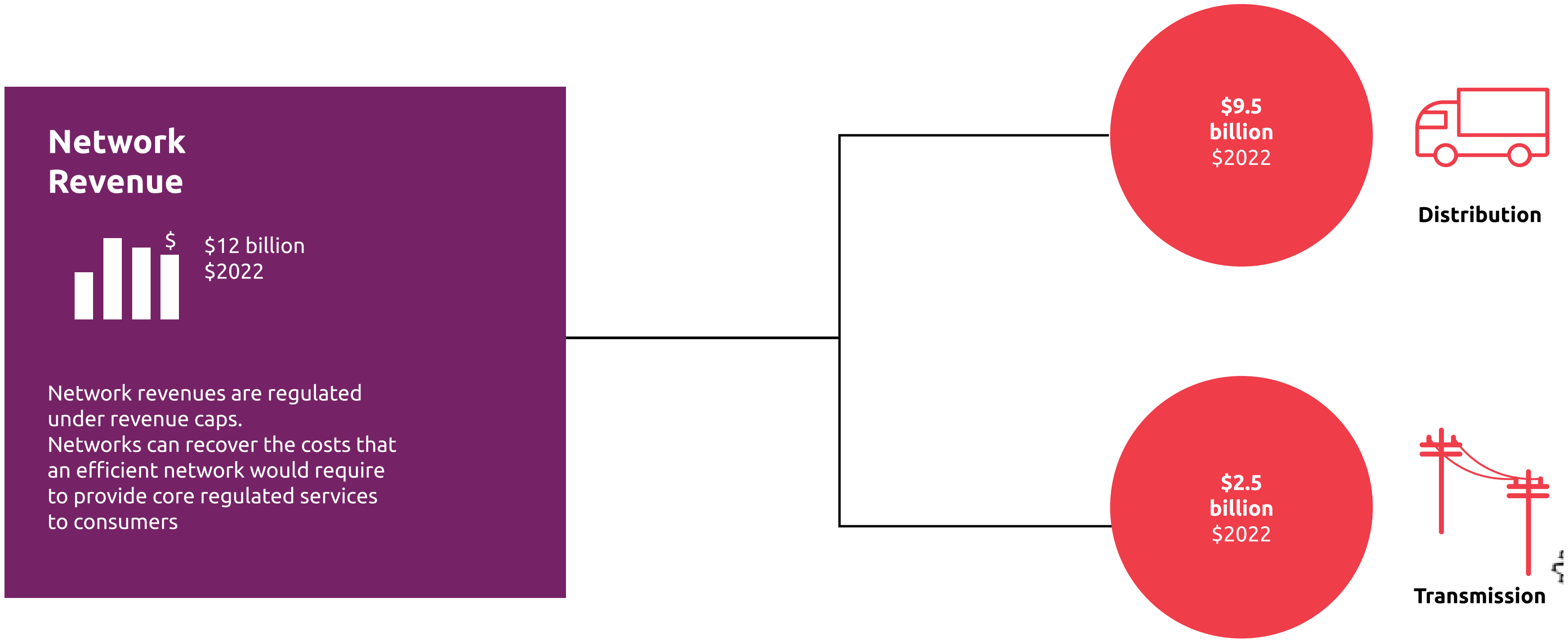
Changes in average demand components by region Q2 2023 vs Q2 2022




Source: AEMO: Quarterly Energy Dynamics Q2 2023
https://aemo.com.au/-/media/files/major-publications/qed/2023/qed-q2-2023-report.pdf?la=en&hash=719538BE6166CB79BE1BF6B9BE82A183

**FIGURE 6**

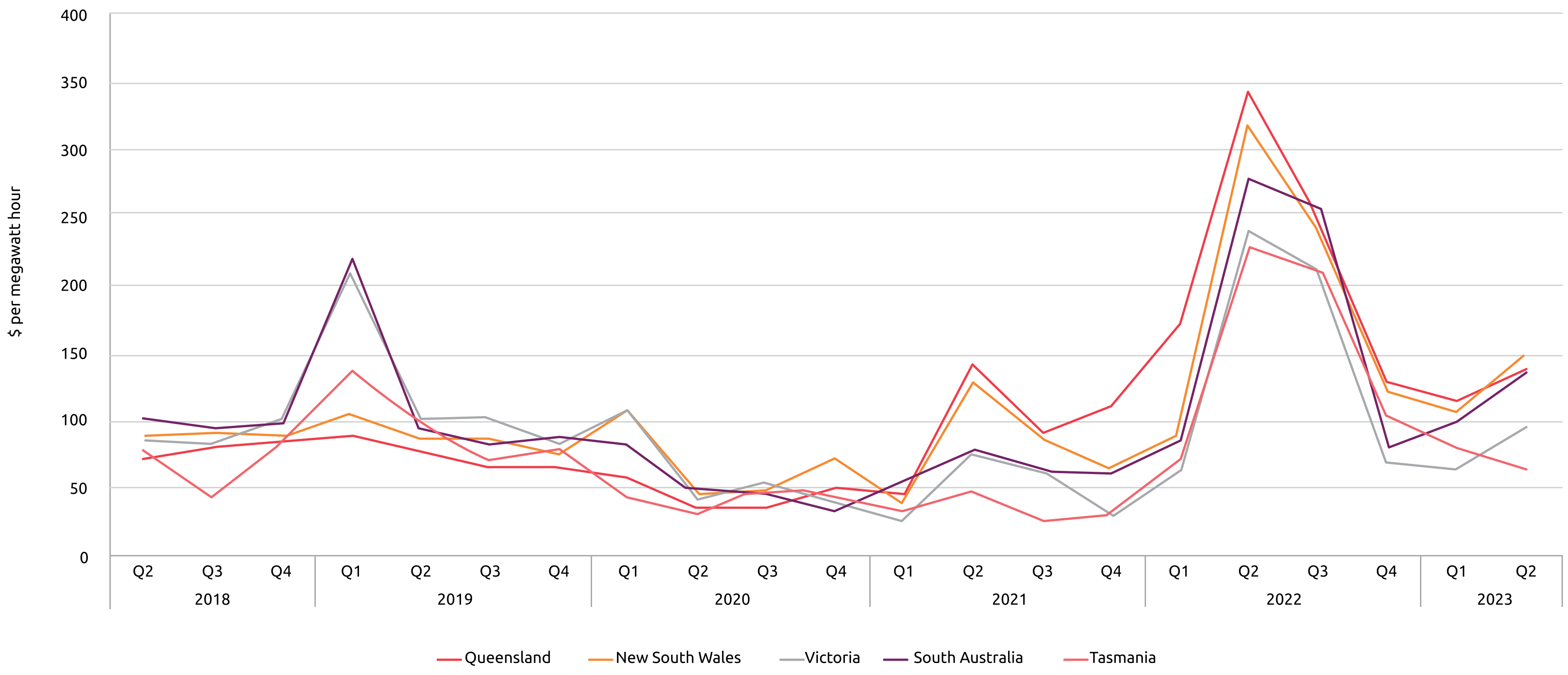
Electricity Networks performance in 2022




Source: AEMO: Quarterly Energy Dynamics Q2 2023
https://www.aer.gov.au/system/files/2023-Electricity-network-performance-report.pdf
https://www.aer.gov.au/system/files/AER%20-%20Infographics%20 %202023%20Electricity%20network%20performance%20report_0.pdf

**FIGURE 7**

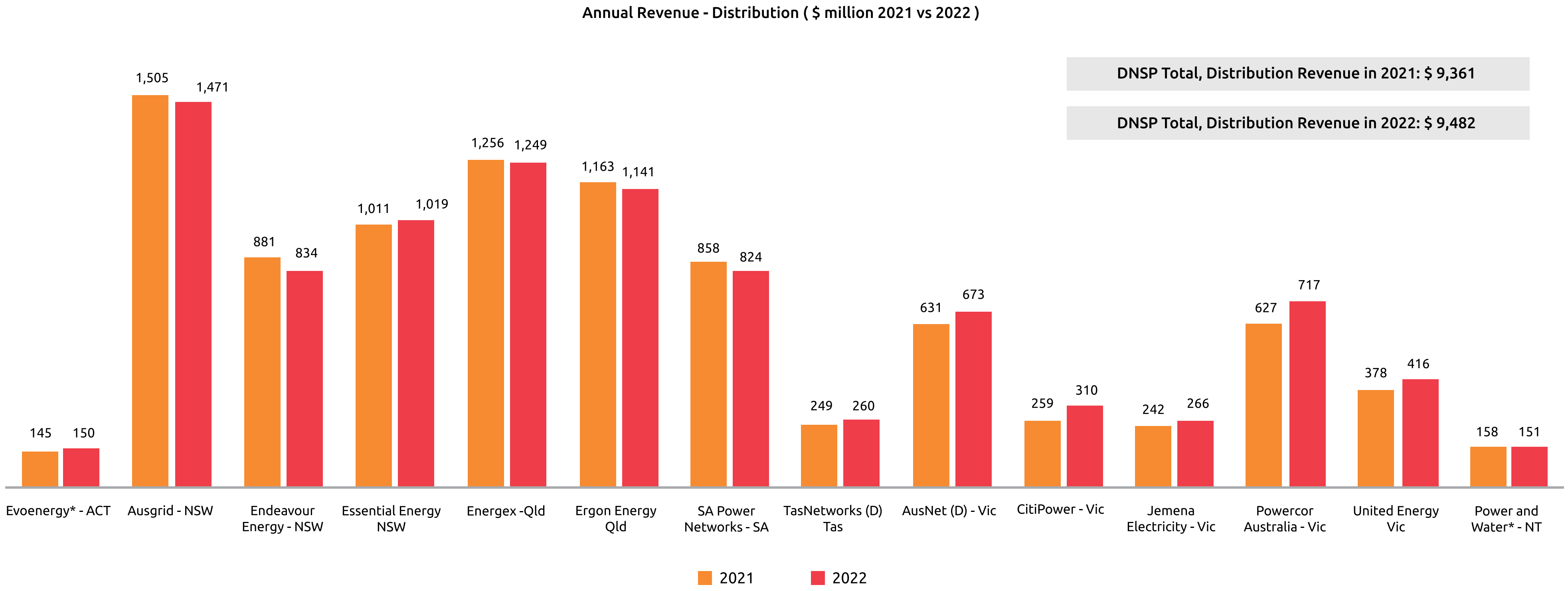
Quarterly wholesale spot prices across National Electricity Market regions, 2018 - 2023




Source: Australian Energy Regulator: Quarterly volume weighted average spot prices – regions
https://www.aer.gov.au/wholesale-markets/wholesale-statistics/quarterly-volume-weighted-average-spot-prices-regions

FIGURE 8

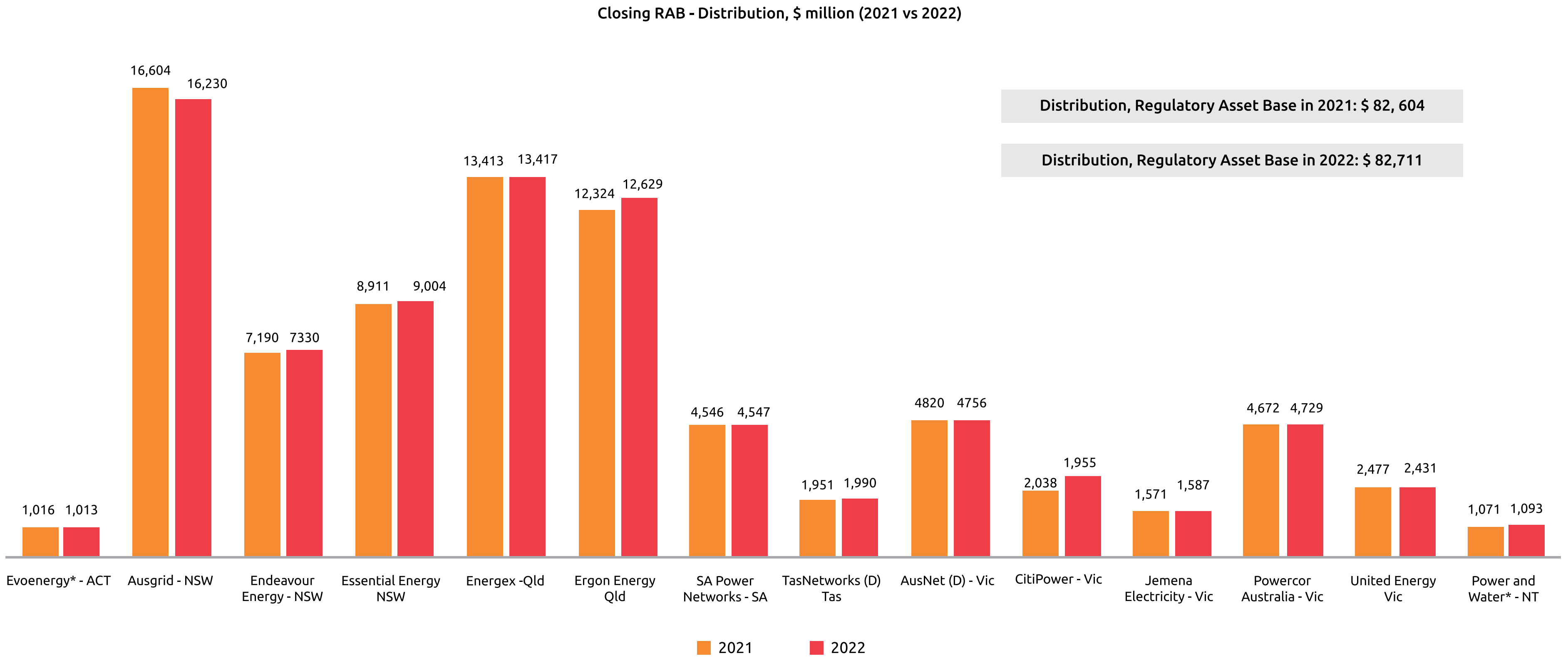
Distribution, Annual Revenue, $ million, (2021 vs 2022)




Source: AER - Electricity network performance report 2023
https://www.aer.gov.au/networks-pipelines/performance-reporting/electricity-network-performance-report-2023
https://www.aer.gov.au/system/files/AER%20-%20Electricity-DNSP-Operational%20performance%20data%202006-2022.xlsx

**FIGURE 9**

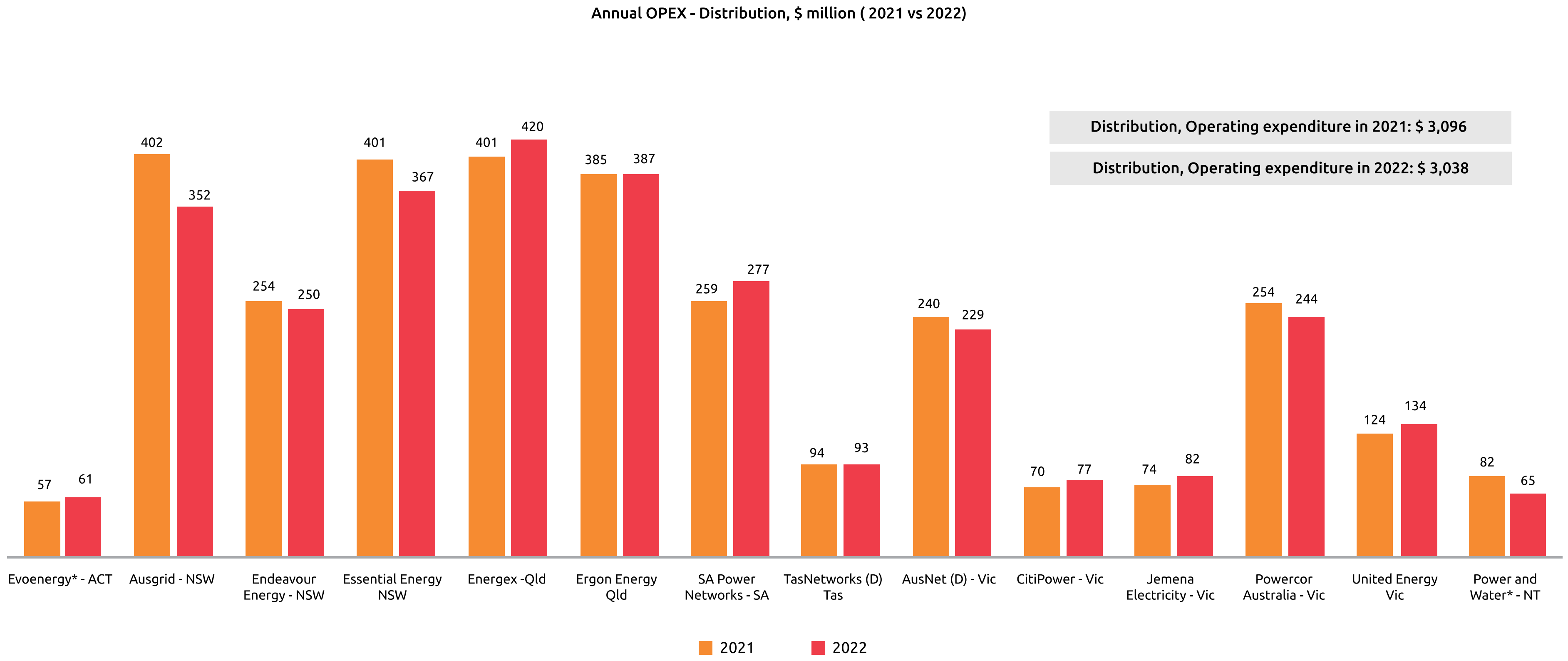
Distribution, Regulatory Asset Base, $ million, (2021 vs 2022)




Source: AER - Electricity network performance report 2023
https://www.aer.gov.au/networks-pipelines/performance-reporting/electricity-network-performance-report-2023
https://www.aer.gov.au/system/files/AER%20-%20Electricity-DNSP-Operational%20performance%20data%202006-2022.xlsx

**FIGURE 10**

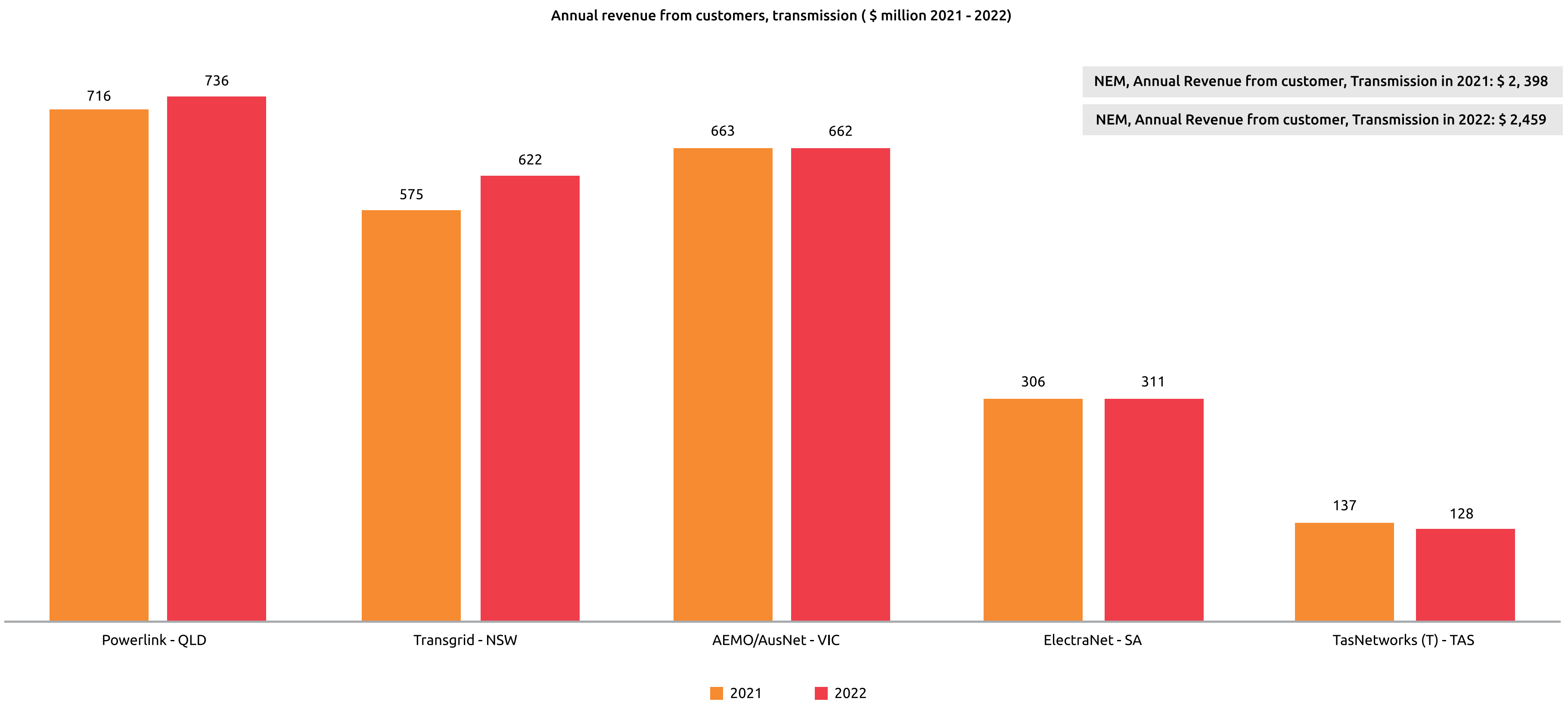
Distribution, Operating expenditure, $ million, (2021 vs 2022)




Source: AER - Electricity network performance report 2023
https://www.aer.gov.au/networks-pipelines/performance-reporting/electricity-network-performance-report-2023
https://www.aer.gov.au/system/files/AER%20-%20Electricity-DNSP-Operational%20performance%20data%202006-2022.xlsx

**FIGURE 11**

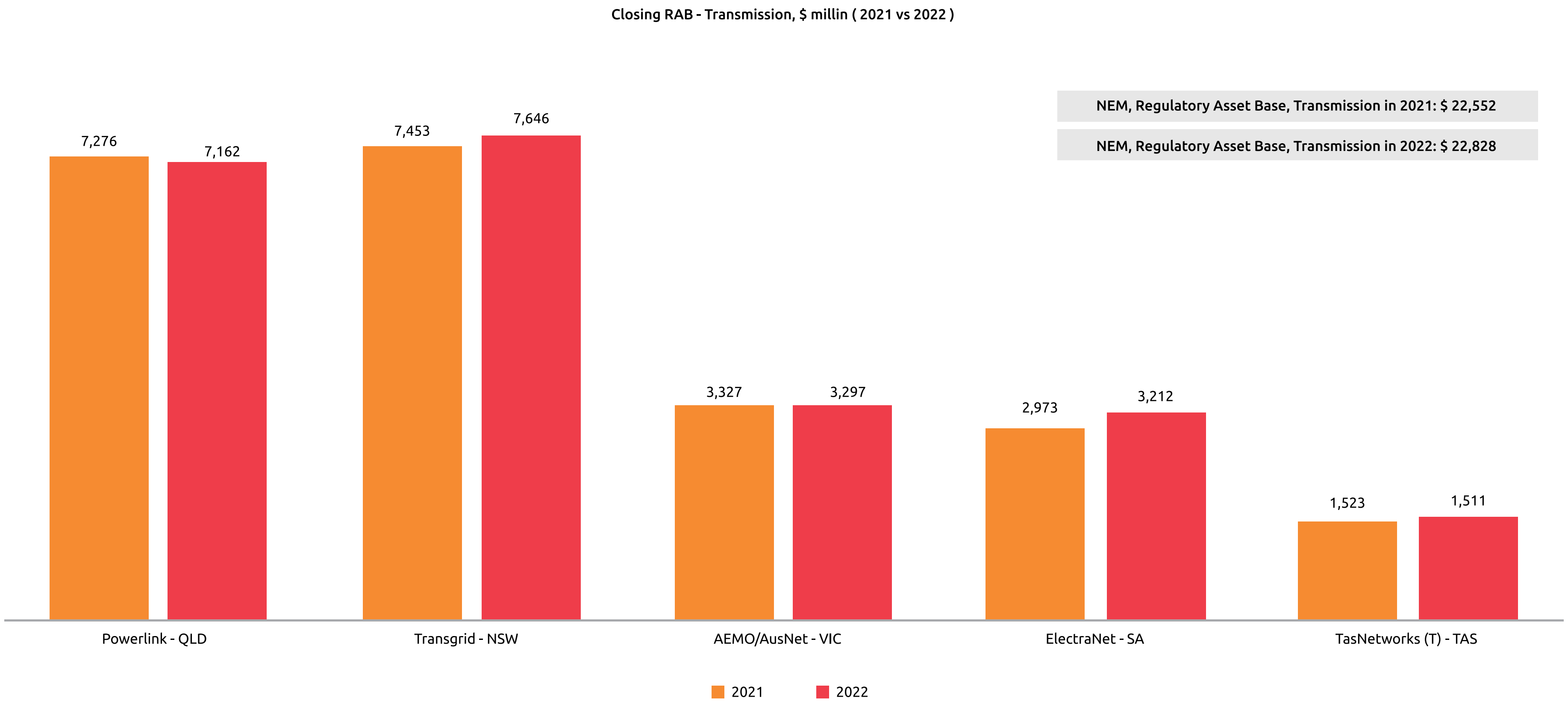
Transmission, Annual Revenue, $ million, (2021 vs 2022)




Source: AER - Electricity network performance report 2023
https://www.aer.gov.au/networks-pipelines/performance-reporting/electricity-network-performance-report-2023
https://www.aer.gov.au/system/files/AER%20-%20Electricity-DNSP-Operational%20performance%20data%202006-2022.xlsx

**FIGURE 12**

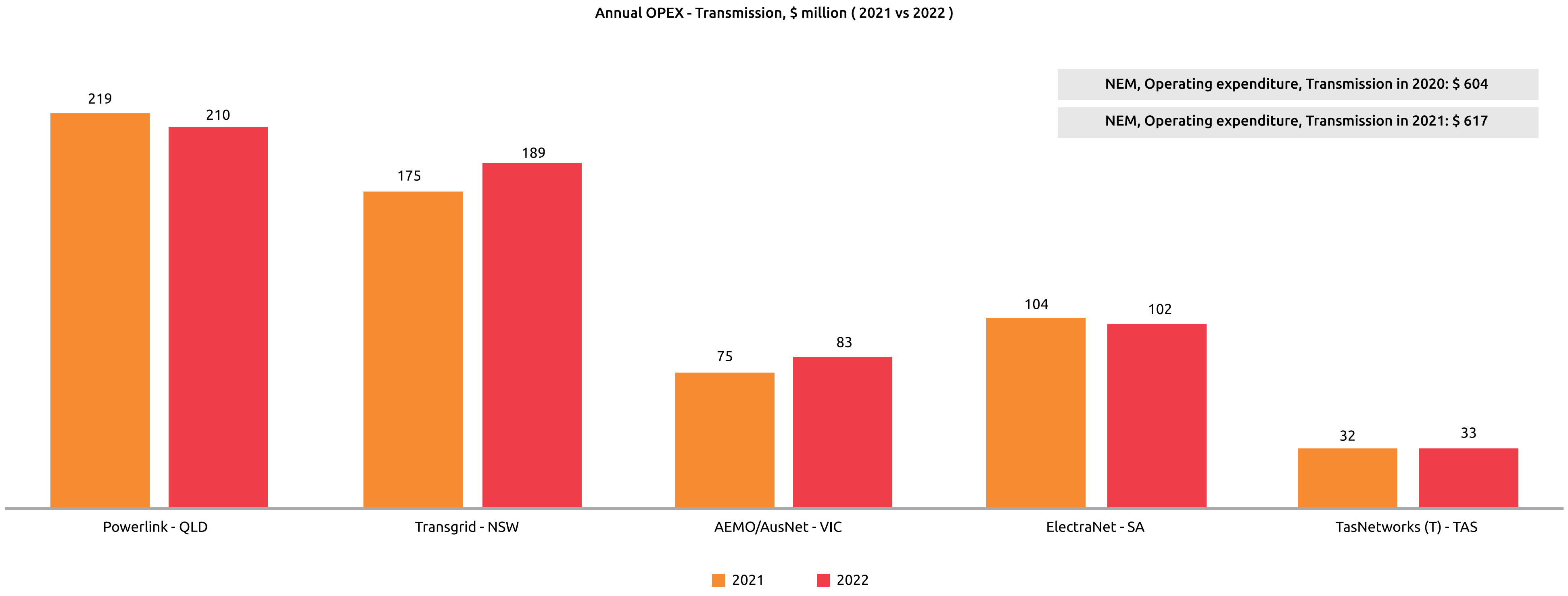
Transmission, Regulatory Asset Base, $ million, (2021 vs 2022)




Source: AER - Electricity network performance report 2023
https://www.aer.gov.au/networks-pipelines/performance-reporting/electricity-network-performance-report-2023
https://www.aer.gov.au/system/files/AER%20-%20Electricity-DNSP-Operational%20performance%20data%202006-2022.xlsx

**FIGURE 13**

Transmission, Operating expenditure, $ million, (2021 vs 2022)




Source: AER - Electricity network performance report 2022
https://www.aer.gov.au/networks-pipelines/electricity-network-performance-report-2022

# Conclusion

There are significant changes happening in the Australian energy market. This can be seen in the activity of investment, the behaviour of certain participants, and the investments required by DNSPs to maintain relevancy.

What is certain are the capabilities required to maintain relevancy, most notably:

- EV load management
- FCAS access
- Demand response
- Citizen-driven energy community management
- DER project trials

However, DNSPs will have to grapple with how they acquire these specific capabilities, whether they develop them in house, or they choose a partnership model with other participants in the NEM. This is a difficult and fundamental question, which ultimately depends on where the DNSP chooses to focus their efforts; scaling revenue in their unregulated businesses or focusing on their core mission statement of a reliable supply and steady return to investors.

# 05

# DIGITAL/ DATA FLOWS

# DATA FLOWS AT THE HEART OF THE FUTURE ENERGY SYSTEM

**RENE KERKMESTER**
Global Vice President Smart Grids

**The electricity system is adding new sources of data at an incredible pace.**

## Can we manage?

The conventional electricity system already uses lots of data to align the production, distribution, and supply of electricity.

Now we are witnessing a huge increase in data exchange and data applications while moving towards a (renewable) generation driven energy system. The increased unpredictability and volatility both on the production and demand side is creating new demands for data.

New sources of data were added during the introduction of smart meters. The next generation of meters will provide even more insights on both the customer and network end. Edge computing will also be introduced to enable faster decision making.

Where the Transmission System Operators (TSOs) already had insight in energy flows, all primary and secondary substations will be virtualized and further automated. They will produce even more data, providing more operational insights. Also here, edge computing will transform the current centralized network management approach towards a more distributed and local network management.

## Data is at the heart of our future energy system and the volume of data is exploding.

All actors in the energy system consume and generate data. Data sets will become available at more a granular level and in real time.

As we become increasingly dependent on the availability of renewable energy, the electricity demand will have to follow the electricity that is generated. This means that appropriate data should be available in real-time for demand response to take place and to secure the system balance at 50 Hz. Power quality management and congestions will further complicate the picture. TSOs and DSOs will need to align their information systems to optimize the energy system at a national level. Also, near and real-time weather and kWh price data will play an ongoing and instrumental role in our energy data system.

To manage this massive amount of data, modelling and AI are necessary to support humans in appropriate decision making. Both financial and operational decisions cannot be made without the support of this new tooling. As more and more computation will need to take place in real time, new technologies such as quantum computing need to be evaluated.

### All actors effected ...

To survive, every actor in the energy system will have to master this data challenge. The most successful and profitable players will be those who best master this game.

### ... and beyond ...

Data management will take place at company level and beyond. The system requires close collaboration and synchronization between all actors. Data will have to flow at a national or even continental level. Data spaces and data hubs are emerging. Standardization is a requirement and regulators will play an increasingly important role to spur action.

We can manage the increasing data volumes.

It requires a transformation for many companies to become truly data-driven organizations. Unlocking data, managing data, gaining insights, and making data driven decisions are core competencies everyone in the system needs to develop to survive.

### Five relevant articles

In this chapter, I am happy to present five relevant articles that provide insight into how new data sets will be unlocked and managed. In the first and second articles, we will explore industry changes as it relates to the next generation smart meters and new smart substations, respectively, and examine how edge computing will be applied. In the third article, we will offer more insights into the tooling and systems available to gain business insights from the huge stream of data. Article 4 will focus on the possibilities of quantum computing in the energy sector and also provide a concrete example of new tooling applied through digital twin technology.

I wish you an insightful read.

**Rene Kerkmeester**

# 05

1. NEXT-GENERATION AMI - BRINGS SIGNIFICANT BENEFITS FOR BOTH CUSTOMERS AND UTILITIES
2. EXPLOITING DATA AT THE SUBSTATION LEVEL. VIRTUALIZATION AND UTILITY EDGE COMPUTING: AN INDUSTRY GAMECHANGER
3. ENERGY OF DATA AND AI
4. THE ESSENTIAL ROLE OF QUANTUM COMPUTING IN THE SMART GRIDS OF THE 2040S
5. WHAT IS A DIGITAL TWIN IN THE CONTEXT OF LINEAR ASSETS: HOW DOES A UTILITY BENEFIT?

# NEXT GENERATION AMI BRINGS SIGNIFICANT BENEFITS FOR BOTH CUSTOMERS AND UTILITIES

RUPAK PATRA, SWEDEN

Demand for adoption of next-generation smart meters is growing across Europe, UK and US with market estimations projecting global penetration of smart meters will climb approximately 44% at the end of 2020 to 56% by the end of 2028, resulting in over 1.2 billion devices globally according to Guide house.

Smart meters are a part of the advanced smart grid ecosystem where utilities will be able to monitor their networks in real-time and provide greater and faster benefits to day-to-day operations.

Next-generation smart meter technologies have significant computing power and provide for growing source of customer data including network behavior. Availability of this new data shall enable accelerated development of decentralized energy systems and enable everyday consumers to have more insight and control into their home energy use.

## First-generation AMI had limited ability to support real-time customer engagement processes and growing needs of a digitized and smarter grid of the future.

Most of the smart meters installed today are of first generation which do not come with major compute capability nor real time data capture capabilities. Consumers need to wait up to 24 hours before they see their consumption details.

## Market evolutions are shaping and enabling new use cases for Next-generation AMI

**# 1 Intelligence is shifting to the edge** As new generation smart meters can leverage edge computing technology, more and more use cases can be computed on the smart meters, reducing the need for sending data to the cloud-based applications.

**# 2 New possibilities with digital technologies** Real time analysis of consumer behavior and network can be carried out using big data analysis. Artificial intelligence (AI) and machine learning (ML) systems can learn to reduce energy consumption.

**# 3 Emergence of the prosumer** Prosumers are a reality and suppliers need to respond to a wide range of additional resources used by them such as rooftop DERs, battery-based energy storage systems including EV charging.

## Next-Generation AMI enables consumers with more visibility and control

For consumers this means more control and empowerment. Smart meters will provide real time information on energy consumption and spends, making it easier to manage future energy costs.

Real-time data can be accessed from anywhere making it much easier for consumers to make better decisions about their choice of tariffs or suppliers.

## Utilities can provide superior customer experience

It costs many time more to attract a new customer than to retain an existing customer. Utility retailers can provide greater experience to their customers with more personalized tariffs, payment plans, targeted communications.

Similarly, better communications and customer engagement can be managed for maximized debt collection. Increased use of predictive analytics on customer and smart meter usage data can bring in newer insights such as which customers are likely to default on payments.

## A major Canadian utility is modernizing their smart metering hardware, network, and systems to keep pace with a rapidly changing energy landscape

Approximately 1.4-million-meters will be replaced to promote timely and accurate billing and enable more granular data for increased grid visibility, improved customer innovation, and consolidation of network, operations, and communication systems to drive cost savings.

The objective of the program is to enable broader grid and utility modernization, with the following target outcomes:

- Full end-to-end installation and integration of next generation AMI 2.0 edge computing smart meters
- Improved grid resiliency, visibility and maturation of OT systems
- Ability to provide customers with energy usage data, and improved customer experience
- Assist in the growing adoption of EVs in Ontario, Canada

## Digitized, modern and robust electricity networks are highly reliable and bring greater and faster benefits to day-to-day operations.

With Next-Generation AMI, grid companies can support:

- **Flexibility management:** peak load management, time of use tariffs, demand response management for smart EV charging, battery storage and other residential appliances. .
- **Promote sustainable behavior:** Micro grids for communities that share access to renewables with other users; savings to households in the form of reduced energy bills, reduced energy usage during peak times and balanced demand and supply of energy in the power grid.
- **Grid connection monitoring:** With real-time data and location identification, detection of grid faults becomes faster helping in reducing overall outage restoration time. Additionally, supply limitation at grid connection point supports grid stability.
- **Electrification of transport** is an important factor towards a fossil free future and can be enabled by a smart metering enabled grid which is prepared to support greater demands of fleet charging.

## European utility Enedis has set up a new control room service

Enedis is the main operator of the public electricity distribution network in France. ASGARD is their new service leveraging Smart Metering data for Network operation enhancement.

It operates 24 hours a day and monitors their low and medium voltage network aiming to improve the quality of the electricity supply and the responsiveness of interventions. Their key use cases for grid performance include:

- **Data Analytics for Distribution:** Machine learning for network cable renewal allows to prioritize investments on LV/MV networks (both overhead and underground) while predicting the network sections that are most likely to experience incidents.

  Using this, Enedis has already seen significant cost reductions due to avoided repairs and outages.

- **Predictive Maintenance.** Machine Learning for low voltage network assesses events from the AMI communication infrastructure to predict malfunctions that can several days or even weeks in advance. 99% of all suspected incidents raised using this have proven to be justified and allow for actions to be taken before failure.
- **Immediate location and fast repair of electrical faults on LV network.** Control room operator pings the group of meters which have sent electrical surge alarm and pinpoints the precise location of the fault, before the arrival of network crew.
- **Utility call center Instant diagnosis of Customer Outage.** Segregates network faults or customer issues and helps for providing optimized troubleshooting process immediately during the initial call.
- **Renewable asset integration into the grid.** Demand balance and voltage regulation in case of local constraints due to Solar/wind farm Generation

## The future is even more demanding

Next-generation AMI-based grid ecosystems will be cornerstone of evolution and emergence of newer possibilities to accelerate energy transformation

## Sustainability:

Edge computing for substations plays a significant role in sustainability by enabling efficient and intelligent management of energy infrastructure:

1. **Localized Data Processing:** Edge computing allows data processing and analysis to occur near the source, within the substation itself. This reduces the need to transmit large amounts of raw data to central data centers, minimizing network traffic and energy consumption.
2. **Real-time Monitoring and Control:** By processing data locally, edge computing enables real-time monitoring and control of substation operations. This improves the overall efficiency of the energy grid, optimizing power distribution and reducing waste.
3. **Predictive Maintenance:** Edge computing facilitates the implementation of predictive maintenance strategies by analyzing data in real-time. By detecting potential equipment failures or inefficiencies early on, substations can proactively address issues, preventing downtime, and reducing overall energy consumption.
4. **Enhanced Grid Stability:** With edge computing, substations can quickly respond to changes in energy demand and supply, optimizing grid stability. This leads to more reliable power distribution, minimizing power outages, and improving energy efficiency.
5. **Renewable Energy Integration:** Edge computing enables better integration of renewable energy sources into the grid. By processing and analyzing data at the substation level, energy operators can balance and manage the intermittent nature of renewable energy, maximizing its utilization and reducing reliance on non-renewable sources.

## Current Developments

Frontrunners are driving this important new development forward. Grid operators and OEM's are teaming up in global consortia to define global standards and trigger first implementations. The largest European DNO's, as well as some US ones, have started their transformation journey.

It will take a lot of collaboration across the wide spectrum of hardware and software providers to drive this change.

For this reason the Vpac consortium was established in North America whilst the E4s consortim was founded in Europe. The first use cases are being developed and we expect the first demonstrations to the public in H2 2023.

## Conclusion:

Virtualisation and edge computing presents tremendous opportunities for substations in the power sector. By enabling real-time data processing, enhancing cybersecurity, and improving situational awareness, it revolutionizes the way we operate and maintain substations. Embracing edge computing technology will undoubtedly contribute to a more resilient, efficient, and secure power grid.

Grid operators will have to define a roadmap to transition the substation to a virtualised, edge computer based solution. Starting with a first implementation, developed on a future proof architecture, they should embark on this journey rather sooner than later.

# EXPLOITING DATA AT THE SUBSTATION LEVEL VIRTUALIZATION AND THE UTILITY EDGE COMPUTING -AN INDUSTRY GAMECHANGER

STEPHEN LURIE, USA

RENE KERKMEESTER, NETHERLANDS

## Edge computing and virtualisation of substations

30 million electricity substations across the globe will need massive upgrade in the next decade to keep the grid manageable in the future renewable energy system. Substations are at the heart of the system change. Power quality management, fault detection, alarm generation are only some examples of applications that need simultaneous operations in a sub station. Virtualisation and edge computing is the only cost-effective way forward for grid operators to make that change.

Edge computing is revolutionizing how we handle data processing and analysis at the network's edge, bringing numerous benefits to the power industry. Substations serve as vital nodes in the power grid, connecting transmission and distribution networks. With the increasing complexity and volume of data generated by substations, traditional centralized computing models face latency, bandwidth, and security challenges. This is where edge computing comes into play. Edge computing involves deploying computational resources closer to the data source, reducing latency, and enhancing real-time data processing capabilities. By distributing computing power at the edge, substations can perform data analysis and decision-making locally without relying heavily on the centralized cloud infrastructure. This improves operational efficiency and enables rapid response to critical events.

One of the critical advantages of edge computing in substations is its ability to handle massive amounts of data in real-time. By processing data locally, substations can quickly detect anomalies, monitor equipment health, and identify potential failures. This proactive approach facilitates predictive maintenance, reducing downtime and enhancing overall system reliability.

Moreover, edge computing enhances cybersecurity in substations. By minimizing data transfer to the cloud, sensitive information remains within the secure boundaries of the substation. This reduces the attack surface and mitigates the risk of cyber threats. Additionally, edge computing enables localized encryption and authentication protocols, further safeguarding critical infrastructure.

Furthermore, edge computing empowers substations with enhanced situational awareness. Real-time analytics at the edge enable rapid identification and response to abnormal grid conditions, ensuring a stable and secure power supply. This is particularly crucial in scenarios like fault detection, power quality monitoring, and grid restoration after disruptions.

Virtualization in the utility edge brings cost optimization, resource efficiency, scalability, agility, resilience, and security enhancements, making it a valuable technology for optimizing edge computing infrastructure and meeting the demands of modern applications and services.

## A solution to address the most relevant of challenges.

### Challenge #1
Limited resources: Substations typically have limited computing resources, such as processing power, memory, and storage. Edge computing solutions need to be designed to operate within these constraints.

### Challenge #2
Harsh environmental conditions: Substations are often located in harsh environments with high temperatures, humidity, and electrical noise. Edge computing devices must be ruggedized to withstand these conditions and operate reliably.

### Challenge #3
Real-time processing requirements: Substations often require real-time processing and analysis of data to detect and respond to events promptly. Edge computing systems must be capable of handling and processing data in real-time to ensure timely decision-making and control.

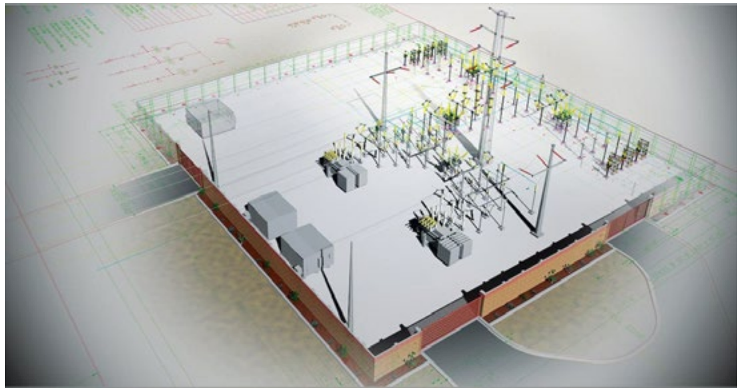
### Challenge #4
Network connectivity: Substations may have limited or intermittent network connectivity, especially in remote locations. Edge computing solutions need to account for potential network disruptions and should be able to operate autonomously or with limited connectivity.

### Challenge #5
Security concerns: Substations are critical infrastructure components and are potential targets for cyberattacks. Edge computing devices should have robust security measures in place to protect against unauthorized access, data breaches, and tampering.

### Challenge #6
Scalability: Substations are part of a more extensive power grid infrastructure, and the number of substations can vary widely depending on the grid size. Edge computing solutions should be scalable to accommodate the increasing number of substations and handle the growing volume of data generated.

### Challenge #7
Integration with existing systems: Substations often have legacy systems and equipment in place. Edge computing solutions should be designed to integrate with these systems seamlessly, ensuring compatibility and interoperability.

### Challenge #8
Maintenance and management: Deploying and managing edge computing devices in multiple substations can be complex. Remote monitoring, centralized management, and efficient maintenance processes are necessary to ensure the smooth operation of the edge computing infrastructure.



# ENERGY OF DATA AND AI


SERGEY PATSKO, NETHERLANDS


ISA WARSAME, UK


BRAGADEESH DAMODARAN, INDIA

## Data is all you need

**In the energy and utilities sector, vast amount of data generated from power generation, transmission, and distribution systems can be leveraged, using enabling technologies, especially AI, to reduce the cost of operations, improve work and asset efficiency, and enhance customer services.**

**Examples of realized business value from Data & AI in energy market are so inspiring that many utilities rushed to build AI applications overlooking data challenges they may face. Building strong Data foundations is one of the core pre-requisites for successful Digital Transformation in the energy sector.**

As utilities become increasingly data-driven, relying on real-time information, extracting actionable insights from data remains one of the major challenges in the energy and utilities sector. Most of the unexplored historical, legacy, and operational data from operational execution systems, resource planning and other systems contain a wealth of information with unexplored potential, that we cannot afford to miss. Only 20-30% of the value from such available data-at-rest is currently accrued. The main challenges of leveraging Data & AI in the energy and utilities domain are manifold. First, a robust IT/OT infrastructure must be created to collect, process, transform and visualize data. Second, we need trained personnel specialized in managing data e.g., data modellers, data architects, and data scientists. Third, we need standardization of data flows and data formats that can ensure data interoperability, be shared with ecosystem players, and be seamlessly integrated with legacy applications. Fourth, we would need a strong and secure communication network to manage huge volumes of data accurately, faster, and without data breach or loss. Fifth, the absence of a data and AI strategy and implementation roadmap for value-driven use cases is hindering the growth of data and AI in the energy and utilities sectors.

## Benefits of Data & AI for Smart Grids

IoT data can be used to optimize CAPEX and investments for intelligent grid modernization; artificial intelligence helps to derive value from existing grid data and reduce OPEX; and data and AI together fuel new data-driven business models to enable the transition from consumer to prosumer. Data sharing supports collaboration in the ecosystem and adds transparency with regulators to ensure compliance.

**FIGURE 1**

Solve Smart Grid Challenges with Fit-For-Purpose custom AI solutions in all four areas of Data-Driven Grid

| Custom AI Solution development with RAPIDE framework | Custom AI solution development based on local environmental conditions or other unique factors , e.g. proximity to shoreline, etc. RAPIDE framework to improve analytics quality and fast-track time-to-value. |
|---|---|


| RAPIDE | Readiness Assessment | Advance data screening | Pinpoint driving factors | Identify candidate algorithms | Develop powerful models | Evolve and embed solution |
|---|---|---|---|---|---|---|
| Industry-proven governance for data science professionals | Clear objectives and sufficient initial data | Demonstrate the predictive or diagnostic potential in the data | Isolate key features driving the behaviour of interest | Down-select most promising techniques to meet objectives | Determine the best hybrid data-driven and principles-based model | Refine the solution using evidence gained from in-service use |

Data & AI use cases within above mentioned four categories are driving major business benefits – from better network availability to reducing maintenance costs, optimizing grid upgrades, and generating new revenue streams from software-based business models.

Energy market leaders invest efforts into aligning their Data & AI Strategy to Business & Sustainability Goals, they then roadmap use cases and understand what data will be required to implement them, and they take care of scalability & security of the deployed solutions. For this, they architect future-proof Data Platform Architectures, data interoperability layers, and adjust organizational models and ways of working to ensure agility in solution development with a relentless focus on business value realization, ensuring collaboration among IT, data and AI, operations, and business stakeholders.

**FIGURE 2**

Data is an impactful lever to modernize grid design operations and enable new services

Data-Driven Grid suite of solutions covers all aspects of Smart Grid: from Advanced asset management, Grid Operations, to Network Instrumentation, Customer Services, and Regulatory Compliance

**DATA-DRIVEN GRID SOLUTIONS**

| Improve grid design and evolution (capex) | Improve grid operations performance (opex) | Bring new services to customers | Enable regulatory compliance |
|---|---|---|---|
| Leverage IoT Data to optimize CAPEX & investments for Intelligent Grid Modernization | Artificial Intelligence to derive value from existing Grid Data and reduce OPEX | Introduce New Data-Driven Business Models to enable transition from consumer to prosumer | Transparency with regulators through data sharing |

**SMART GRID DATA FOUNDATIONS**

Ensure high quality of data, scalability of AI solutions, self-service and value realization from Grid Data

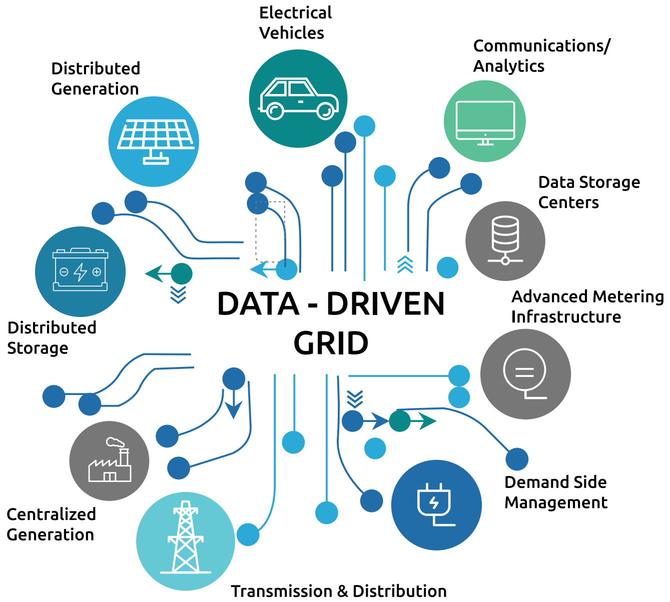


**FIGURE 3**

Data fuels the evolution of smart grid at scale

## OPEN DATA

Energy related data from third parties

1.Consumption evolution assumptions
2.Edge of the grid assets evolution
3.Capacity markets (from capacities to prices)
4.Weather conditions

## NETWORK DEVELOPMENT

1.Asset Lifecycle planning data (tech & finance)
2. Network Engineering data, PLM

## ASSET GRID MANAGEMENT

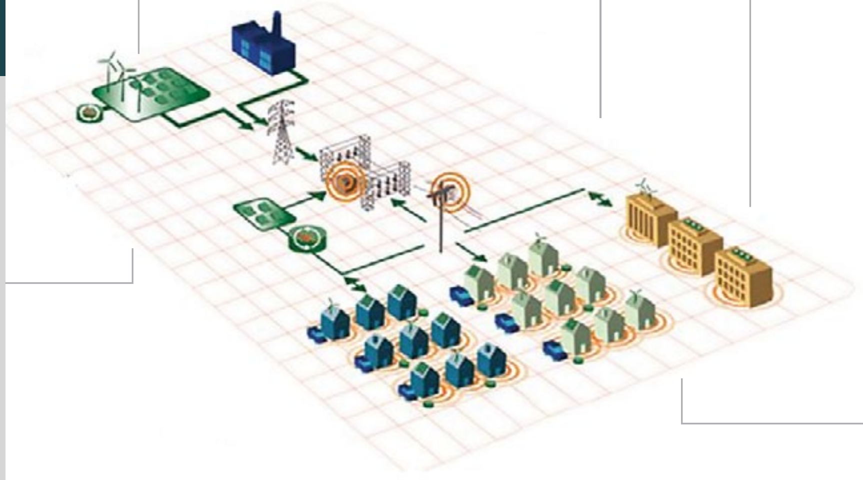
1.GIS network data
2.Asset characteristics
3.Asset history
4.Real-time Asset Health

## NETWORK OPERATIONAL MANAGEMENT

1.Maintenance and Field services data (incl. subcontractors' work orders)
2.Spare parts stocks data
3.Inspection data (incl. drone and satellite images)
4.Vegetation data
5.Flexibility data (Connected and realized capacities & Curtailment curves)
6.Network operations data
7.Energy balance and losses data (technical and non-technical)

## STAKEHOLDERS & ECOSYSTEM

1.Storage data (utility scale storage)
2.Producers and retailers' data exchanges
3.Carbon emissions footprint data
4.Market and societal development information (scenario planning of capacity needs etc.)
5.HR and Financials including asset values
6.Aggregated data for stakeholders communications
7.Quality and continuity of supply data – network balance and other regulation data



## BILLING/ CUSTOMER MANAGEMENT

1.Metering data
2.Contractual data
3.Consumers contracts (direct or through suppliers – third parties)
4.Connected consumer capacities to the network data
5.Load curves valorization & Billing data
6.Customer interactions data (complaints, new connections, work orders, security inspections, etc)

## Have you caught the Data wave?

Considering AI's value in Energy market, 92% of Energy & Utilities companies are either already invested in AI or will do so in the next two years, obtaining competitive edge. Two-thirds (67%) of energy executives are realizing AI benefits in creating better customer experiences, and more than a half (55% and 53%) in improved decisions making and innovating products and services.

## Proven Data & AI use cases in Energy

Data & AI enables multiple use cases across the value chain of the energy market. For example, in 2023, we observed a spike in interest to Grid Digital Twin. Companies develop and deploy Grid Digital Twins in production, at scale. Data & insights from Grid Digital Twin help to forecast peak consumption, predict outages, future demands, and organize system modeling with specific solutions, e.g., EV Charge Hub, Lighting as a Service, to integrate into a comprehensive model of the energy system. What are the categories of proven use cases that generate business value in energy sector?

### 1. Reduce the number of breakdown & outages

One of the challenges in the energy & utilities industries are detecting defects in the processes. Outages are costly for utilities in both financial and brand value. Hence, it is no surprise that 35% of energy executives are realizing AI's benefits in performing predictive maintenance and automating routine tasks (33%), as per the PWC report. AI image recognition and computer vision systems are cost-effective and process photos and videos of the assets to identify anomalies and sound an alarm if any anomaly is detected.

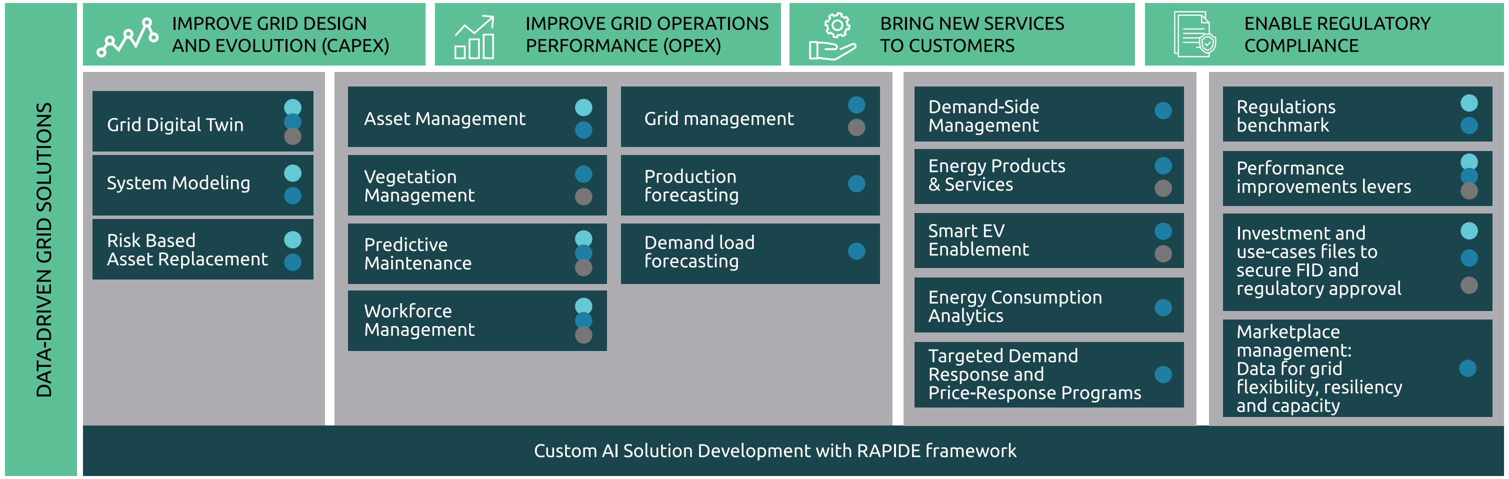
For example, Offshore wind plays a key role in our efforts to decarbonize and reach net zero. Capgemini utilized predictive maintenance to effectively extend the lifecycle of turbines' gearbox oil, increasing the maintenance interval by 40%, leading to substantial cost savings for the operator while also reducing its carbon footprint.

**For another client,** Capgemini explored and developed AI solutions running neural network models to forecast ice-sleeve formation and vegetation intrusion across the client's transmission lines. The solution enabled the TSO to accurately forecast and categorize risks and adapt its maintenance programs accordingly. This helps to address the reality of climate change as transmission operators are challenged by extreme weather conditions that add additional strain to their network.

**One more case was** about a huge amount of the inspection data from drones is analysed by ML models, which produces a birds-eye view of the grid, and its most critical parts. AI-generated detailed report for work crews highlight defects for human supervision, which allows to expedite the processing of up to 15%.

**FIGURE 4**

Data fuels the evolution of smart grid at scale



## 2. Ensure safety of operations

Pattern recognition algorithms, processing video streams, or AI image recognition can be used in terms of safety, flagging violations of adequate dressing for dangerous operations.

## 3. Address Prosumers challenges: Reduce Grid Congestion, and optimize pricing

With the growth of renewables and regulations favouring electricity consumers to become generators (Rooftop Solar, Wind, Biomass, etc.) not only for captive consumption, but also to export surplus energy to the grid. There are software applications available that track real-time data on energy availability and demand, time-of-use consumption, and factors affecting energy prices. Considering the intricacies of real-time electricity markets, AI/ ML tools can be applied for scenario modelling based on energy demand, load forecasting, pricing factors, etc. For Instance, Capgemini developed a machine learning model that offered a large windfarm operator, the ability to generate more accurate wind speed readings while reducing costs associated with maintaining offshore measuring towers. Accurate wind speed readings enabled the operator to generate more accurate and reliable power-curve models used for generation forecasting.

Also, the utility suppliers can predict with the help of AI consumption of energy and thus come up with dynamic pricing to offer super-low variants when there is excess capacity. Customer, concerned with the bill size, could adjust and regulate their utility consumption in the most rational way.

## 4. Stabilize Grid

The electricity grid is transforming rapidly to accommodate more renewable energies. The complexities of RE connections from various locations, and maintaining grid stability, security, and compliance must be tackled.

According to OFGEM, “the data landscape is evolving across the energy sector, and its effective use can provide valuable insight for grid operators, consumers and marketplace intermediaries.” Ofgem is encouraging more effective use of data, to improve efficiency in grid operations and customer services, while adhering to regulatory compliance and data privacy norms.

31% of energy executives are realizing AI’s benefits by analysing production scheduling scenarios using simulation modelling. The latest trend in energy efficiency suggests the usage of decentralized microgrids, combining several renewable and non-renewable sources of power, whereas traditionally energy supply chains are centralized and formed around the power plant providing the electricity to the end-users. Thus, AI technologies can predict the times when energy is effectively produced while the sun is shining or the wind is blowing. Then store the excess of it in their batteries at home because energy is cheap and selling it makes little sense for the supplier. AI can forecast the times of high energy usage and then sell accumulated energy as prices rise. The main idea of this AI enhancement is to maximize micro producers’ profit as well as reduce the expense for end-users.

## 5. Improve Sustainability

A key to reducing greenhouse gas emissions is through decarbonising of power, heat, and transportation which account for approximately 75% of global emissions. Decarbonising heat and transportation can be achieved through electrification and introducing cleaner sources like hydrogen into the gas blend. In parallel, replacing conventional power generation sources with renewable energy sources will decarbonise power. To accommodate these low-carbon technologies (LCT), significant network modifications are required.

Electric vehicles (EV) will need a network of charging infrastructure; analytics and AI are currently used by industry to identify optimal charging locations based on transportation patterns and consumer behaviour. To enable network accommodations for EVs, it is important to identify locations of the network that will observe a higher rate of EV uptake by analysing consumer demographics.

To accommodate these advancements, grid operators need to decentralize their networks and utilize analytics and AI for intelligent decision-making when making network modifications. Capgemini helped National Grid address this issue with the use of machine learning and spatial graph technologies to clean network data. The solution addresses the vast network uncertainties by offering enhanced network oversight to deliver data-driven infrastructure investment. Capgemini did a study that looked at comparing affluence with EV uptake and how this can be useful for the network.

## 6. Provide Flexibility Management

As grid operators transition to a decentralised network, data plays a key role in facilitating grid flexibility. Technology integration is part of the roadmap to flexibility, introducing smart meters, advanced sensors and monitoring systems that form the crucial foundations for data science and AI. AI enables grid flexibility by optimising grid response. AI analyses energy patterns and consumer behaviour, feeding into the concept of Smart Grids Optimisation, which coordinates the utilization of distributed energy resources, storage systems, and EVs.

Capgemini delivered a consulting project for the development of a home demand-response system that reduced peak network usage while reducing consumer energy spend and providing appropriate heating provision. The solution generated home usage profiles by monitoring 1000 electric boilers to determine which boilers could be switched off during peak hours while minimising disruption.

## 7. Address Regulatory Challenges & Data Privacy

Data democratisation is a growing topic within the utilities, concepts like Open Data in the UK and the Green Button Initiative in the US introduce the use of data by third parties to service the utilities and drive innovation. With these advancements, concerns regarding privacy and security arise among regulators and consumers who seek clarity on data storage and handling practices.

Despite the concerns, data democratisation is an enabler in the utilities' drive to modernise and decentralise. Privacy-enhancing data management methods have been gathering interest across the industry to protect sensitive data benefiting from the valuable insights generated by AI and data science applications. Federated learning enables the deployment of ML models across devices while protecting sensitive data. This technique is useful for developing predictive maintenance models and load forecasting algorithms. While edge AI enhances privacy, it provides additional benefits to grid companies like real-time insights and local decision-making, while also boosting sustainability by reducing energy-intensive data transfers.

Capgemini played a role in a UK-based grid operator fulfilling its regulatory requirements with the Office of Gas and Electricity Markets (OFGEM). As part of the client's ED2 business plan, Capgemini delivered the client's data strategy and the roadmap to its digital transformation journey.

# Pre-requisites and recommendations for value realization from Data & AI

Whole-systems management is becoming increasingly relevant for data-driven operators across their utilities. The concept of whole systems thinking focuses on integrating and coordinating interconnected systems across the entire value chain of utilities, including generation, transmission, distribution, customer services, and information systems. It takes a comprehensive approach to optimize the performance and efficiency of the utility infrastructure.

Data enables Digital Continuity across all these systems, and AI allows for automated response and optimization.

What are the prerequisites for efficient use of Data & AI in the energy transition?

| Challenge | Description | How to Solve? |
|---|---|---|
| **Insufficient or poor-quality data and difficulties in exchanging data with other players in the value chain** | Utilities face challenges in augmenting and correcting legacy data for assets, often installed decades ago. Data quality improvement initiatives are often complicated by the fact that utilities are often located underground. | Assess the **Utility's current maturity in Data & AI** within the dimensions of Organizational setup, Competencies, Technology landscape, Data and Leadership. **Gap analysis** becomes the basis for improvements.<br>To enable connected systems to leverage data from multiple sources and facilitate advanced analytics and AI for real-time decision-making, **Data Strategy** should be developed with an implementation roadmap, followed by setting up a robust data governance and management practice. Evaluate Utility's **maturity of Data Governance and blueprint Data Trust Foundations:** Data ownership, Data Quality, Master Data Management, Meta Data Management, Privacy & Security.<br>**Formulate Data Ecosystem strategy** and define **Data Sharing mechanisms** to enable stakeholders and 3rd parties' access to data to fast-track value realization and Energy Transition<br>CALLOUT1 |
| **Data is locked in silos** | Data is generated and stored in multiple IT and OT systems, which makes it difficult to extract, govern, and use for AI. | Integrate information and communications technology (ICT) with operations technology. **IT-OT integration** improves real-time situational awareness of the grid and the customers, accounting for the energy flow at a more granular level, to take informed decisions on resource and cost optimization, manage operational constraints and promote sustainability. IT-OT integration benefits the following applications:<br>Fault and Outage Management<br>Network Quality and Efficiency improvement<br>Asset Management – Network Planning<br>DER management and Integration |
| **Hard to find data** | Myriads of legacy data exist in hand-drawn blueprints, pdfs, maps and handwritten notes that need to be found/located, digitized and interpreted by data and engineering experts. | **Knowledge Graphs & Ontologies** can be leveraged to create **Data Catalogues** alongside **Generative AI models** (LLMs) to extract data from digitized documents and organize company-specific, proprietary knowledge retrieval systems. For example, Generative AI can be used for corporate information retrieval for R&D or for marketing content generation. Invest in the necessary IT infrastructure, such as Data Platforms and Generative AI portals which may involve upgrading hardware, utilizing new cloud services, and in Generative AI solutions by cloud leaders Microsoft, Open AI, Google, AWS, and Adobe, as well as challengers like Cohere, Anthropic, Stability AI, and Hugging Face. |

| | | |
|---|---|---|
| **Disparate legacy data landscapes and a lack of modern data platforms** | Legacy data is collected in multiple legacy systems that are loosely integrated but are often completely disparate. This creates challenges in determining systems of records and drives data discrepancies. | Innovative Data & AI solutions require modern and **scalable Data Platforms for data ingestion, processing, cataloging, and AI deployment.** |
| **Data Interoperability** | Data formats, types, and naming conventions vary across multiple IT/OT systems and across value chain players. | Detail interoperability layers of the Utility organization **CALLOUT2 and leverage Utility-specific information models, data models, and ontologies** such as IEC CIM (incl. CIM-Market), Flexoffer, IEC 61850, USEF, OpenADR, DLMS/COSEM, SAREF4ENER, CGMES, IEC-62559 |
| **Challenges in use-case prioritization** | With a broad selection of use cases available, utilities are tasked with balancing regulatory requirements with business benefits but lack a repeatable, data-backed process | Define a value-driven Utility's **strategic vision for Data & AI and identify prioritized Smart Grid use cases** with high potential. Develop a **Data & AI roadmap** on strategic, operational, tactical levels, and a common way to execute. |
| **Difficulties to transition from POC to AI in production at scale** | To derive tangible benefits from data, Utilities need to progress from Proof of Concepts to deployment of AI/ML application in production at scale. | This requires a change in Data Management, Processing, choice of Platforms, and MLOps.<br>A fully integrated, secure, and scalable Smart Grid Data & AI platform in a hybrid cloud context able to deliver trusted data and analytics solutions at scale into production. Accelerated Deployment of Data & AI Platform, Data Mesh, and Data Products - seamless integration, sharing, and processing of heterogeneous data and industrialized deployment of Data-driven Grid solutions |

# QUANTUM TECHNOLOGY
# ITS ESSENTIAL ROLE IN SMART GRID 2040

JULIAN VAN VELZEN, NETHERLANDS

## In the ever-changing world of energy, quantum computing offers exciting prospects for tackling key issues in energy grids.

Alain Aspect, a distinguished Nobel laureate of 2022, suggests that using quantum simulators to balance energy grids could be one of the earliest applications of quantum computers. As the energy sector adjusts to fluctuating energy supply and a surge in connected smart devices, the immense computational power of quantum computers becomes highly desirable.

The shift towards sustainable energy sources presents significant challenges for energy grids. These grids increasingly rely on variable energy sources and must accommodate a growing number of connected devices. Such changes create computational obstacles that impact the stability and reliability of the grids.

Amidst the hype surrounding quantum computing, it is essential to examine its true potential. By investigating how quantum computers can be applied in energy grids, we aim to understand the advantages, limitations, and feasibility of leveraging this transformative technology. Through this exploration, we hope to uncover the possibilities that quantum computing holds for shaping the future of energy grids and their crucial role in an interconnected and sustainable world.

## Key trends and challenges of smart grids

A changing world is driving change in energy grids, with challenges in development and operation as a result. Firstly, there is a growing investment in the energy transition and green energy, resulting in an increasing share of renewable energy sources on the grid. While this shift is crucial for sustainable energy generation, it presents challenges in maintaining grid stability and balance due to the intermittent nature of renewable sources. Managing peak loads becomes more complex as the two-way energy flow requires sophisticated grid management systems. Secondly, grid operators are actively working to reduce transmission and distribution losses, improving overall efficiency. However, these efforts often require higher capital investments per kilowatt-hour to deploy more efficient energy generation technologies. Thirdly, the decentralisation of the grid, driven in part by prosumers who both consume and produce energy, introduces complexities in grid management and makes it challenging to detect and accurately predict faults and outages accurately.

Additionally, the increasing adoption of electric mobility, such as electric vehicles, adds to the demand for energy and highlights the need for increased storage technologies like batteries to accommodate fluctuations in supply and demand. Lastly, the energy market itself is becoming increasingly volatile, necessitating adaptive pricing mechanisms and strategies.

Addressing these challenges will be essential for the successful implementation and modernisation of smart electric grids in order to unlock their full potential in supporting a sustainable and resilient energy future.

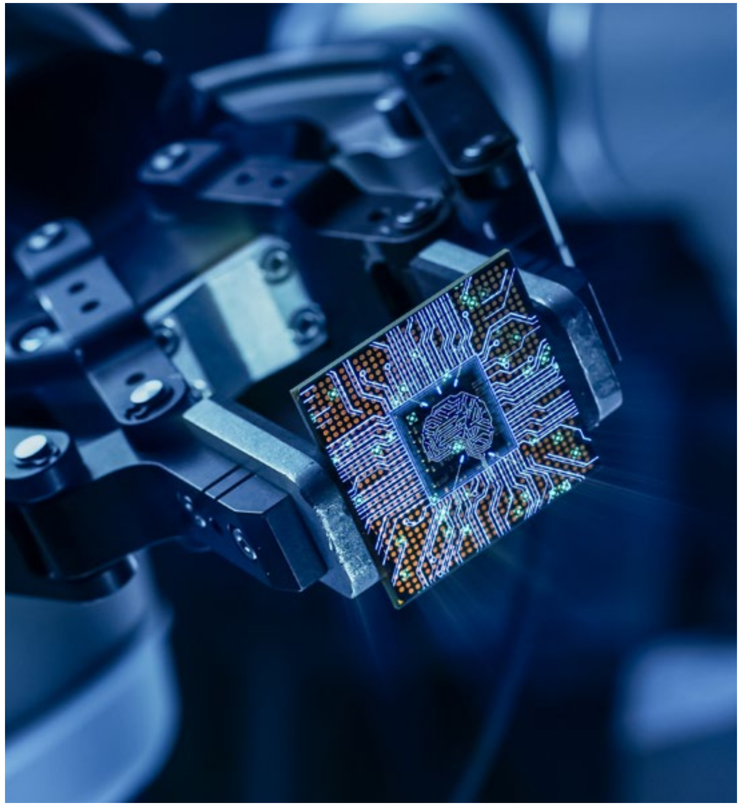
## Exploring the impact of quantum computing

Quantum computing, deeply rooted in the intricate principles of quantum mechanics, presents unparalleled computational advantages, particularly in domains demanding high-performance computing and those that align with the subtleties of quantum mechanical systems. While the precise applications of this technology continue to evolve, the energy sector is increasingly recognizing its potential impact across the spectrum of compute-intensive activities, including in generation, transmission, distribution, and consumption of energy.

In the realm of energy generation, renewable sources such as solar and wind, while promising, come with inherent limitations. To overcome these constraints, advanced energy generation systems are imperative. However, the development of such systems often hinges on complex material modeling at the nano and micro scales. Classical computers, though powerful, frequently struggle with these intricacies, resorting to approximations that fall short of capturing the full spectrum of quantum behaviors in molecules and materials. Quantum computers, on the other hand, exhibit a unique prowess in simulating the exact quantum behavior of molecules and materials. This transformative capability has the potential to revolutionize technologies like solar cells, hydrogen production methods, and the quest for nuclear fusion as a clean energy source. For instance, a noteworthy collaboration in 2022 saw EDF partnering with Quandela to employ photonic quantum computing for simulating the structures of hydroelectric dams, showcasing the tangible application of quantum computing in the energy generation sector.

In the context of energy transmission and distribution, the integration of unpredictable renewable sources into the energy grid introduces significant challenges related to grid stability and efficient energy distribution. Quantum computing holds the promise of optimizing complex processes such as transmission and distribution, fault assessment, and overall grid management. Industry leaders, including E.ON, Eni, and EDF, have embarked on the journey of harnessing quantum computing's capabilities to bolster energy delivery efficiency and ensure grid stability, heralding a potential transformation in how energy grids are managed and operated.

Turning our attention to energy consumption, quantum computing emerges as a pivotal tool for addressing key challenges. It offers the potential for more precise demand and load forecasting, enabling efficient resource allocation and utilization. Moreover, quantum computing's role in the development of advanced energy storage solutions, such as next-generation batteries, is of paramount importance. In 2022, IonQ, a prominent player in the quantum computing industry, forged a partnership with GE Research to explore the advantages of quantum computing in modeling multi-variable distributions for risk management. This collaboration exemplifies the expanding horizons of quantum computing, particularly in enhancing energy consumption modeling and addressing the intricacies of risk management in a dynamically evolving energy landscape.



# Significant challenges remain before the full potential of quantum computing is realised.

## The Energy Quantum story just begins.

While the energy sector offers numerous potential use cases for quantum computing, the reality is that current-day quantum computers are not yet capable of performing useful computations. Present quantum computers face several limitations, making them comparable to computer mainframes from the 1960s rather than mature commercial machines.

One notable constraint is the slow operational speed of quantum computers. Their gate speeds are thousands of times slower than classical computers, significantly impeding their computational efficiency. Moreover, fault-tolerant operations involving additional overhead for error detection and correction would make quantum computers millions of times slower, nullifying any potential speedup. Additionally, quantum computers have limited number of qubits, typically a few hundred on current-day machines. Although this size is approaching the level required to address real-world problems, achieving fault-tolerant qubits would necessitate thousands of physical qubits through error correction techniques. However, the most significant limitation lies in the quality of quantum computers, specifically the fidelity of two-qubit gates. Presently, state of the art exhibits error rates of approximately one percent for such gates. As a result, use cases of a few hundred gates produce unreliable results, rendering them impractical.

As near term quantum computers are severly limited, the full potential remains decades away. Nonetheless, first applications that cleverly deal with the limitation of available hardware are on the horizon. Academic institutions, innovative startups, and end-users are actively engaged in pioneering ways to extract the maximum benefit from the existing quantum hardware, inching us closer to harnessing the quantum advantage.

One key strategy involves a clever approach to managing the inherent errors and noise that plague current quantum systems. Researchers are developing techniques to mitigate these issues, improving the reliability and stability of quantum computations. Additionally, a selective approach is emerging, focusing on high-value applications that align seamlessly with quantum computing's strengths. Furthermore, efforts are underway to optimize quantum algorithms and software for specific applications, enhancing their efficiency and practicality. These collective endeavors mark the initial steps toward unlocking the immense potential of quantum computing, even in its nascent form.

# A quantum simulator for near-term quantum advantage?

One avenue that shows promise for a potential quantum advantage in the near future is the optimization of graph-related problems using quantum simulators. Quantum simulators are specialized machines designed to focus on specific applications, prioritizing simplicity over universality. These systems appear to be particularly well-suited for addressing graph-related problems, such as those encountered in energy grid optimization.

Several companies, including Parisian Pasqal and QuEra from Boston, are actively working on developing this technology and express optimism about discovering commercial applications within the next few years. However, as these systems operate on heuristic principles, the actual advantage they offer can only be determined through empirical observation. Additionally, the viability of commercial interest in the problem class that can be effectively addressed by these systems is a crucial factor to consider.

The energy sector is facing evolving challenges that require enhanced computational capabilities. Quantum computers offer the potential to exponentially speedup specific tasks and provide valuable contributions to use cases in energy production, distribution, and consumption. Many utilities players have started the thinking and some experimentations.

By carefully selecting applications, optimising quantum hardware, algorithms and software, startups, academics, and companies are bringing a quantum advantage closer. Additionally, specialized quantum hardware emerges as a promising solution for niche applications within the energy sector in the coming years.

Ultimately, quantum computing will be a vital role in the smart grids of 2024. To make that happen, continued research and development efforts are crucial to unlock the full potential of quantum computing.

# WHAT IS A DIGITAL TWIN IN THE CONTEXT OF LINEAR ASSETS: HOW DOES A UTILITY BENEFIT?

VINNIE NAIR, AUSTRALIA

GAUTAM GANDHA, AUSTRALIA

## How do you define a digital twin?

In the electricity industry, and when applied to linear assets, the term “digital twin” represents an accurate model of linear assets, zone substations, vegetation management, and other electrical assets.

Most recently, the application of this concept in the linear asset management space has gained significant traction and has consequently yielded significant benefits to utilities.

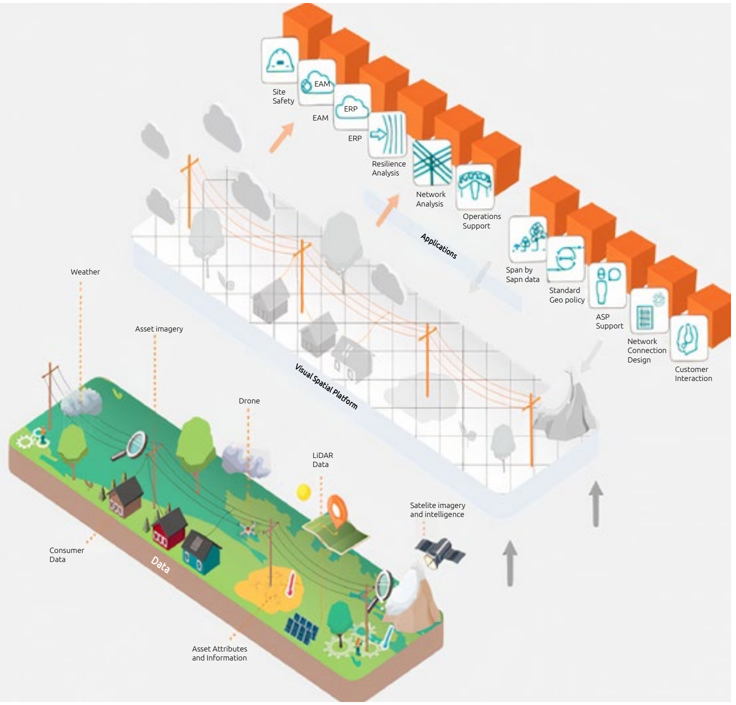
## Why linear assets?

For some utilities in Australia, linear assets form a significant proportion of the Regulatory Asset Base (RAB). For example, certain Distribution Network Service Providers (DNSPs) in rural Australia have a significantly high ratio of poles per customer, and therefore very few customers are serviced per kilometer of powerline.

Due to their rural and sparse geography, these utilities are also under pressure from customers, regulators and climate-related events such as bushfires and floods. Creating a digital twin from these assets can help these businesses shift from reactive asset management to an insight-led and data-driven approach.

**FIGURE 1**

Digital Twin in Action



# COMBATING CLIMATE CHANGE: FLOODS AND FIRES

## The Endeavour Energy story

Endeavour Energy is an electricity distributor serving Greater Western Sydney, the Blue Mountains, the Southern Highlands and the Illawarra region. With more than one million customers, enough length of underground cables to travel from Sydney to London and back, and an area served of over 25,000 square kilometers, Endeavour Energy is a significant player in the New South Wales Economy.

Endeavour Energy has been using Neara's digital twin software to accelerate its design process and fast-track ratings studies. However, in March 2021 Sydney experienced severe flooding, which is typically considered a 1-in-50-year event. Given the significant impact these floods were having on customer outages and the damage caused to power infrastructure, Endeavour Energy approached Neara for an urgent solution.

The Neara team was able to implement a floodwater simulator which used open-source government data. This development helped Endeavour Energy effectively pinpoint areas with electricity supply vulnerabilities, particularly in cases of flooding or when flooding posed a safety risk to communities by encroaching on live power lines.

Incredibly, within 48 hours of the emergency commencing, the Neara solution was able to provide visibility across the network and produce reports on flood activity. This was significant given that floodwaters were still in the process of rising at the time.

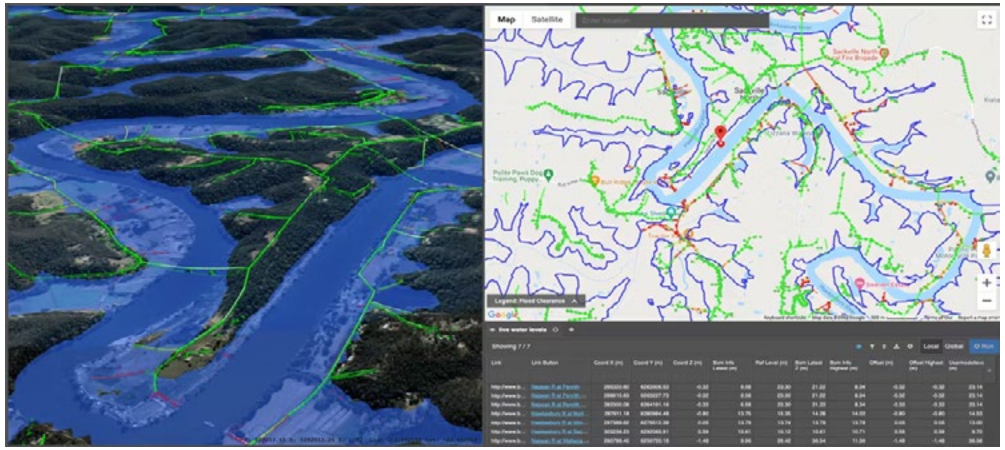
As the floodwater gradually subsided and the worst of the storm was over, Endeavour Energy was able to use the "flood mapping" feature to prioritize inspections to restore customer supply, as well as understand where potential hazards existed to increase safety for the crews dispatched.

## The bushfire story

Vegetation management typically is the highest-cost item for utilities. This is because vegetation requires continual cyclic treatment and can present one of the greatest wildfire risks.

Neara can quickly help detect vegetation encroachment within conventional clearance zones and highlight those violations across the network. Users have the power to redefine and iterate on the dimensions of these zones, and compare the resulting violation count, risk, and cost. At-risk locations can be detected and highlighted across the network, so the utility can identify and prioritize their at-risk assets and proactively address those issues.

They can also model the heightened probability of vegetation falling into the network using modeled vegetation fall-in arcs and terrain models. These models help identify areas that are more susceptible to wildfires that may spiral out of control. Currently Neara has been working with several utilities on bushfire mitigation strategies and implementation.



A Neara dashboard used by Endeavour Energy to prioritize their emergency response and recovery efforts. The dashboard integrates live river depth readings, historic flood maps, and dynamically calculated flood polygons to identify assets at risk of water contact.

# UNLOCKING GRID CAPACITY: INCREASING THE CAPACITY OF RENEWABLES ON THE GRID

## Essential Energy and additional capacity

Essential Energy is an energy distributor that supplies electricity to a remarkable 95% of the geographic area of New South Wales, despite having the smallest customer base among the three major distributors in the state. With up to 200,000 kilometers of power lines, Essential Energy plays a critical role in powering rural New South Wales and supporting the energy transition.

Due to Essential's extensive network, they have traditionally employed rudimentary standards to assess the network's capacity. This approach was necessitated by the limitations of older tools, which couldn't facilitate minute-scale analysis. However, recently they have partnered with Neara to digitally model each asset on the network and create a complete replica.

Through this solution, Essential Energy has been able to model each span of cable individually, allowing for detailed analysis. In many cases, engineers realized that the temperature certain lines had been operating at was much higher than previously known. As a result, capacity in some parts of the network was double than what had been applied.

Historically, grid constraints such as those originally understood to exist by Essential Energy have limited the amount of clean energy which can be injected into the grid.

However, with new digital technologies and a greater understanding of the network, requirements for export limits on rooftop solar and other large clean energy systems could be alleviated.

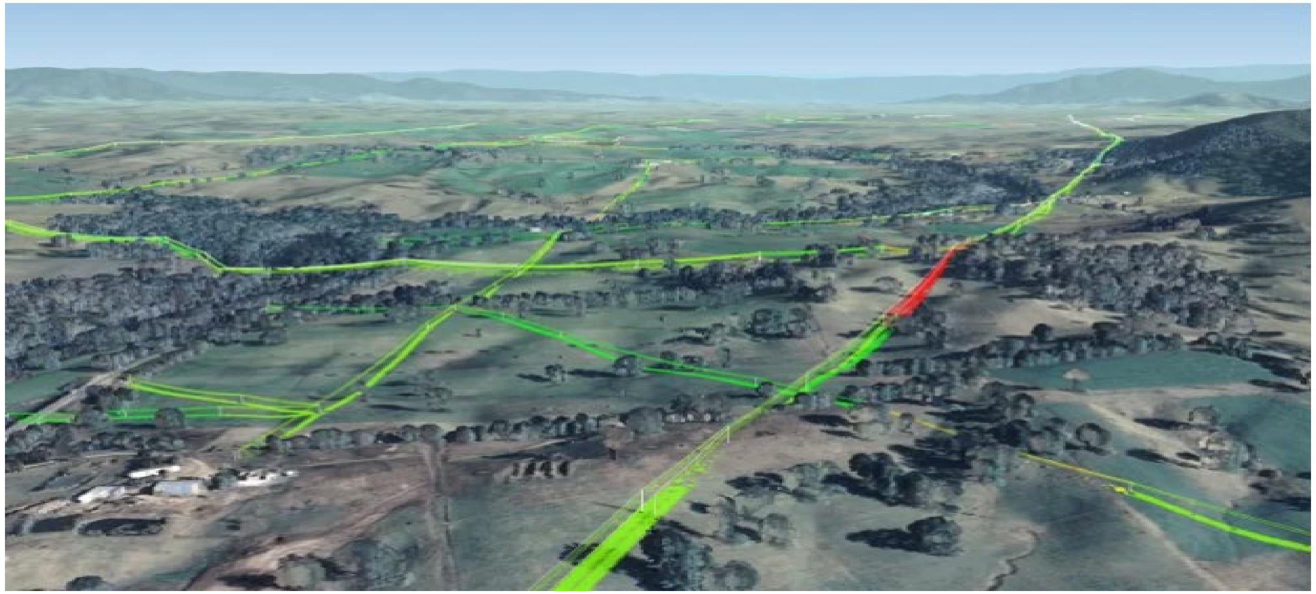
In Australia, the government has set a target of having renewable energy account for 80% of the country's energy mix by 2030. However, there is concern the transition is not occurring fast enough to meet those targets.

To reach this target, it is imperative that urgent investments are made in clean generation, as well as in transmission and distribution infrastructure.

By expanding the Essential Energy Neara use case, there is the potential for a more cost-effective and expedited transition. This is because new transmission and distribution infrastructure may not need to be constructed for the existing clean generation sources.

### How does all this help fast track renewables one might ask?

Statistics show that in NSW alone certain large connection application requests have a wait time of up to 60 months. In a high cost of capital environment, this level of efficiency is not palatable to investors and stakeholders associated with the connection applicant.



Neara digitally mapping the Essential Energy's supply locality.

# Conclusion and Recommendations:

## How can you leverage a digital twin?

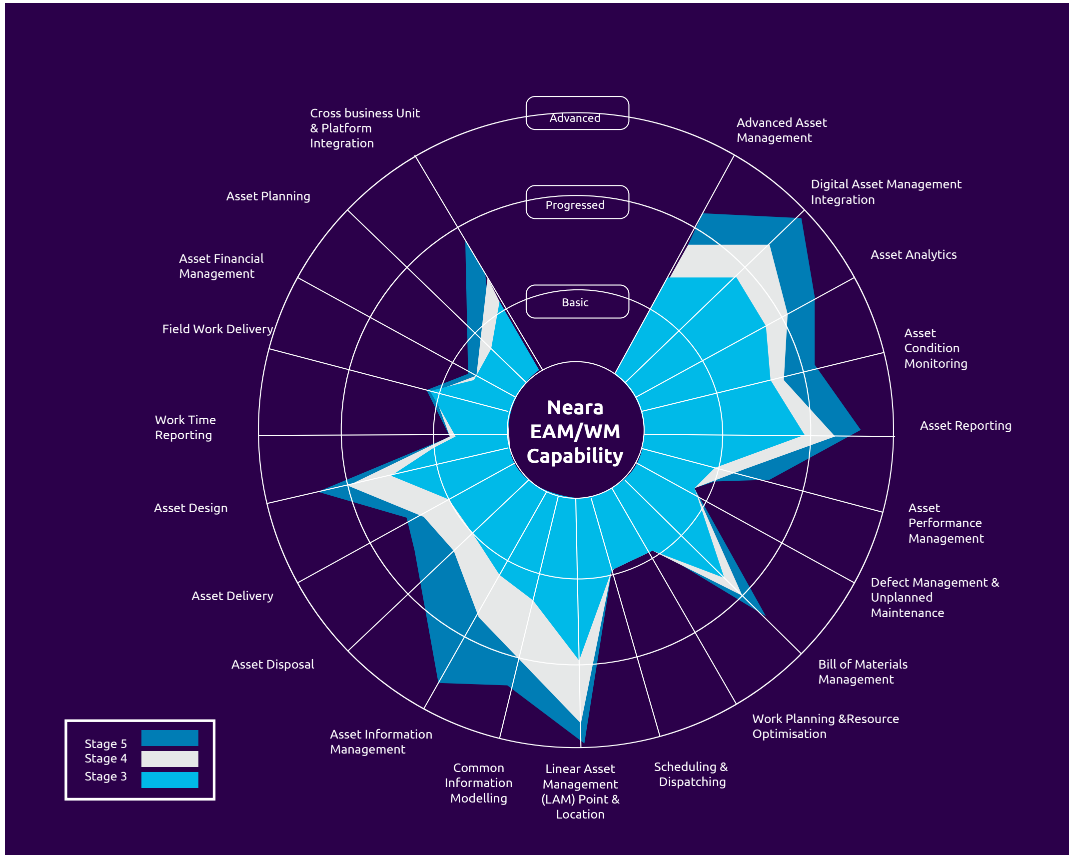
With a bit of creativity and imagination, a digital twin could reform the management of linear assets. The most beneficial use cases can be categorized under two major headings:

1. **Increasing safety:** The ability to simulate the impact of a natural disaster on the grid (such as bushfires or floods) to reduce the amount of time field crews spend in high-risk scenarios. This improves safety outcomes and metrics, such as lost time injury frequency rate (LTIFR). [5]
2. **Reducing operational expenditures (OPEX):** Through intelligent intervention and routing of work orders in the field, schedules per field crew are optimized, which can, in turn, reduce operational expenditure.

## How does a utility achieve this?

The key to successfully implementing a digital twin platform is integration. The digital twin platform should not be considered as a separate analytics tool used solely to provide insights and perform complex "what if" analysis. It should be considered a central part of the utility and treated no differently than any other core system within a utility's IT landscape, like GIS, ERP, Asset Management, and the Distribution Management System.

FIGURE 2



# 06

# THE CLIMATE BOTTOMLINE

# CAN WE SAVE THE PLANET?

**MIKE LEWIS**
Global Vice President Energy Transition

## We focus on climate in the chapter : What needs to be done to save the planet?

Earlier this year, the Intergovernmental Panel on Climate Change (IPCC) reported that there is insufficient pace and scale on climate action to tackle climate change. Unfortunately, this was no surprise to me, and I wanted to take this chapter to shine a spotlight on what needs to be done.

Energy continues to be the major emitter of greenhouse gases (GHGs). Here we look at how we can take steps to reduce these harmful emissions from energy production, as well as the three main pillars that consume energy: industry, transport and buildings.

How much will it cost to clean up our ever-growing demand for energy? Where would that funding come from? What will it take to develop the required clean energy capacity? And, as we transition to cleaner energy, how can we be certain that we are making significant progress in reducing carbon?

We also take a look at innovation for our most energy-demanding needs: heat production and industrial use of energy.

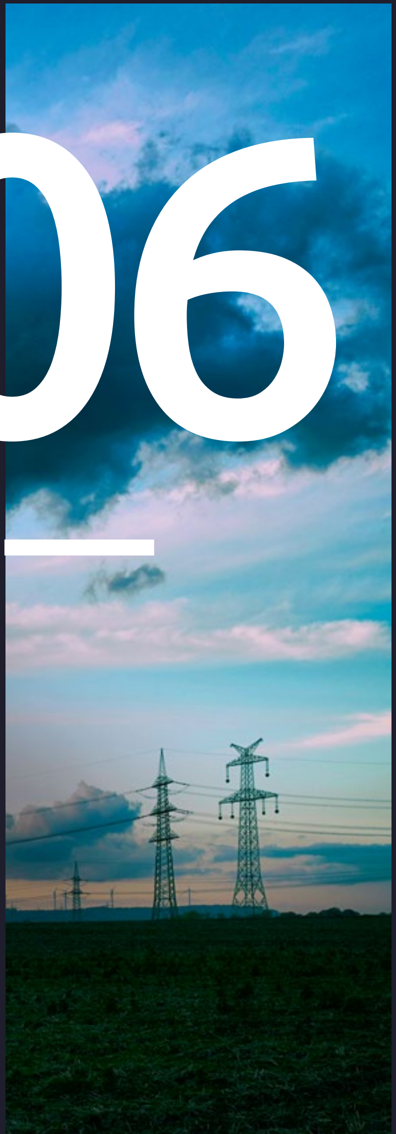
This chapter includes:

1. Funding the energy transition
2. Ensuring new energy is truly low carbon
3. Can we produce enough low-carbon energy globally?
4. How can heavy industry make the transition to low carbon energy?
5. Managing intermittency of low-carbon energy
6. Innovation for efficient ways to create heat
7. What needs to be done to create sustainable buildings?
8. How can we make better, "joined-up" decisions to progress climate action?

As stated by IPCC, we need to increase the pace and scale of our actions. There is hope and a business case.

We are now at a time for action.

# 06



# HOW CLIMATE CHANGE WILL IT BE FUNDED? THE ECONOMIC CASE

PHILIPPE VIÉ, FRANCE

MIKE LEWIS, UK

Because of recent significant global events, from COVID and Ukraine – Russia war to inflation and high interest rates, priorities, energy-wise, have been redefined and resulted in successive energy crises: it's urgent to accelerate on Energy Transition, while managing the Security of Supply, Sovereignty on energy production, equipment and resources and insuring energy affordability to avoid social and economy crashes. All these imperatives need to be successfully balanced considering the limited earth resources and their preservation.

Investments need to be massive, to save the planet. How to secure the funding required to deliver Energy Transition is covered within this article?

## The Energy Transition investment case, ~$7tn per annum

Analysts, participants in the COP process, energy players, public authorities, economies stakeholders and populations around the world agree on the need to accelerate the transition. In particular:

- Phasing out as quickly as possible all fossil fuels. In 2022, the world continues to invest $1tn in fossil fuels (still growing, albeit net-zero by 2050 means reducing emissions 5% every year)[1].
- Electricity covers only 20.4%[2] of the growing energy demand. There is a consensus within the energy transition scenarios on the fact that electricity should represent 50% of the energy demand by 2050. Massive electrification of Transportation, Heating/Cooling and Industry is expected to abate significantly GHG emissions.
- Electricity must be almost carbon free, with nuclear generation (in the nuclear friendly countries) and renewables. End of 2022, the share of Renewables in Electricity Generation is only 29.4%, when wind and solar energies accounts only for 12.2%[3] (% highly variable from one country to another). Hydro remaining the first renewable source.
- Other investments are being required, like Grids modernization to meet a higher share of intermittent renewable in the electricity mix as well as transport and distribute more electricity. IEA reports a global climate technologies investment of $1.7tn in 2022, including Renewables, Grids, but also CCS, Biofuels, nuclear, EV, Energy Efficiency and other scalable clean energy fuels and resources. IEA speaks of clean energy.

1 Source: World Energy Investment 2023 report, IEA

2 End of 2022 figure. Source: Enerdata 2023 yearbook

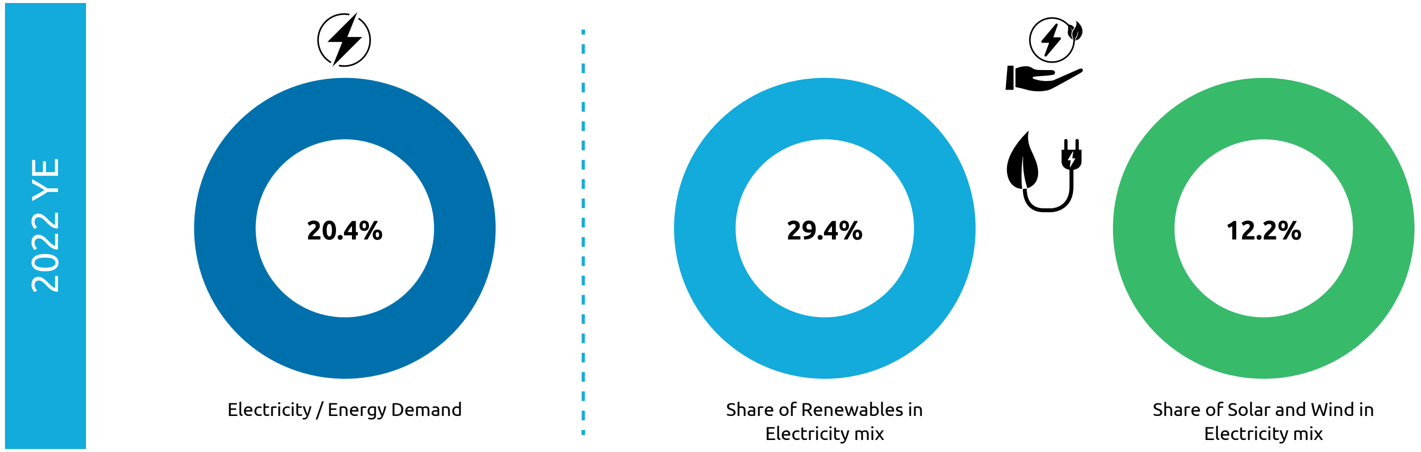
3 Source: Enerdata 2023 yearbook

- Accelerate investment into massive reduction of GHG emissions – through more intelligent energy use such as energy reduction, energy conservation, demand smoothing, material reuse and carbon absorption and extraction technologies.
- In 2022, with a GDP growth of 2.8%, $CO_2$ emissions have continued to grow (+2.5%) despite deployment progress in climate technologies and energy intensity per GDP units.

In the IEA NZS (Net Zero Scenario), the clean energy investment must triple (from now on and for the next decades up to 2050), from $1.7tn to about $5tn pa, and with additional costs on climate change adaptation, circular economy, or behavioral changes programs, we land on a consensus around **$7tn required investment per annum,** about 7% of the world GDP. Huge, and far from actual levels. Is this huge funding gap, from $1.7tn today to ~$7tn pa the soonest realistic?

**FIGURE 1**

Some energy figures as of YE 2022



## Eyes on the past and the present – what have we observed?

Recent government policies to secure supply of energy with sovereignty, while addressing climate concerns through clean technology has resulted in a complex range of funding incentives. Many of the incentives address very specific climate concerns from decarbonizing transport, making building more energy efficient, to decarbonising industrial processes. In many regions this has created a fragmented and complex portfolio – often resulting in increased pressure on electrification through banning carbon intensive fuels for these essential services (vehicle charging, heat pumps, industrial processes, etc.).

Many incentives have been relatively short lived and often complex to access the funds, while others are longer term and disrupted by changing political environments – not delivering the real cash as planned or intended to deliver a positive impact (i). This complex tapestry of incentives has made long term, strategic investment surprisingly risky for investors.

Some climate techs have matured and are now very competitive power generation options (Solar and Onshore Wind), enabling the cheapest way of generating electricity today. These technologies are now producing the Lowest Levelized Cost of Electricity (LCOE), with dramatic cost reduction from global competition and large demand of full-scale deployment.

Early subsidies to encourage creating this scale are now coming to an end, with tax incentives moving to power producers investing in renewables to deliver clean energy in the largest global markets (specifically China, USA, EU, Japan, Australia, UK, and Norway).

However, they also bring new challenges, requiring further funding – e,g, securing construction locations with approvals, connectivity to national infrastructure, managing intermittency, accurate forecasting of supply, storage of surplus supply.

More recently holistic funding incentives such as the Inflation Reduction Act in the USA, and the Green Deal Industrial plan in the EU, coupled with continued subsidies and tax incentives in Japan and China – has resulted in clearer investment opportunities. As a result, global spending in clean energy will increase by 24% between 2021 and 2023 to $1.7tn. Where new electricity generation capacity is concerned, an estimated 90% of spend from this category will be on Solar and Wind investments.

However, given the fact that spending in energy from fossil fuel continues to increase, surpassing pre pandemic levels, there is a clear need to find additional technologies which can scale to replace hard to abate industries, solve the challenges of intermittent generation from wind and solar and accelerate the path to Net Zero. Science also suggest that the time has passed where conversion to clean energy is no longer enough, and now there is additional need to support funding to scale innovation in technology that can remove GHG at source and from industrial processes.

Those incentives on "to be matured and scale-up fast enough technologies" are less clear, and not encouraging investment. Overall spending on clean technology is less than 5% of the traditional Oil and Gas upstream spend. Oil and Gas companies are well equipped to deliver new combustible gas solutions – and Low Carbon Hydrogen is seen to be a very promising fuel for hard to abate industries such as manufacturing aluminum, steel, cement & fertilizer. In 2022 this category of low carbon energy attracted only $1.1bn of investment. This is a 3X growth from 2021, however a long way to go to challenge traditional oil and gas investments.

Many global regions remain focused on Nuclear as the central source for low carbon, predictable electricity. With further investments in Small Modular Reactors – new nuclear options have been under review in recent years. Asia, Canada, USA, France, Sweden and UK have active studies into the safety and economic benefits of SMR's – and Russia having the first operational SMR in Yakutia.

Transformation, modernization and extension of the IEA suggest electricity grids in the USA, China, Japan the EU and India are attracting huge funding. This level of funding will not extend to countries who are less wealthy, and solutions to bridging these funding gaps have yet to be found. Concerns also on how the world can level up less wealthy countries, so they can also meet the global commitments to climate action – and fundamentally prosper from Energy Transition rather than be penalized by it.

Looking at decisions made from COP – in 2009 US$100bn per year was committed by developed countries for developing countries need to fight climate change. In a United Nations Climate Action report published this year, derived from 2020 data provided by OECD suggested only $83.3bn has been provided in total, with only 8% of that total going to low-income countries.

Creating clean power generation capacity takes time, even when the required funding is available. To bridge the time delay, investment has been flowing into innovations to enable smarter energy use. Essentially innovation to reduce energy need for existing services (energy efficiency), reduce energy and resources on new products (reuse, repurpose and recycle) and conserve energy through smart design e.g. (passive buildings).

Many of these innovations are "behind the meter" and installed for commercial consumers and homeowners by energy services organisation, and a growing trend of consumer installable devices (Google Home, Amazon Alexa, Apple Homekit,) enabling automation to reduce energy and move appliance use to time when energy is more abundant and potentially lower cost. Interoperability of behind the meter consumer appliances, and electric vehicles has helped grow the smart home space (according to Predence Research Smart Home market, excluding EV grew to US$98bn in 2023, expecting a CAGR of 21.88% to US$581bn in 10 years). This growth provides choice and more affordable solutions. However, harnessing this technology to deliver more intelligent energy systems in communities, regions &, cities, appears to be a difficult challenge to master.

In addition to innovation in energy saving devices, thermal enhancing solutions are constantly evolving and increasing opportunity to reduce the need for energy. However, these innovations can prove to be very difficult to retrofit into buildings and industrial processes. Efficiencies from high performing Insulation, heating appliances, windows and doors which significantly improved thermal properties of buildings can be very attractive for new construction – but costly, too long to payback, and disruptive for older property stock.

In recent times the fragmented incentives, energy crisis and increasing awareness of global climate events has secured investment in innovation and created new markets with economic benefits of new jobs creating and addition routes for taxes – delivering the beginning of broad clean energy market. Evidence does indicate where very large investments are needed, to deliver these significant benefits accessible and sizable incentives need to be offered and supported by major central government's policy (e.g. IRA, The Australian Government's Powering Australia plan, EU Green Deal Industrial Plan, etc.)

In recent times the impact of changing climate, disasters resulting from extreme weather is competing for funding. Data produced by NPR highlights that the USA registered 18 separate climate change disasters costing more than $1bn each, and a total of cost of $165bn in 2022 because of extreme weather, fueled by climate change.

At a global level - the World Meteorological Organisation produced a report in iiMay 2023 highlighted that the "most vulnerable communities bear the brunt of weather, climate and water-related hazards".

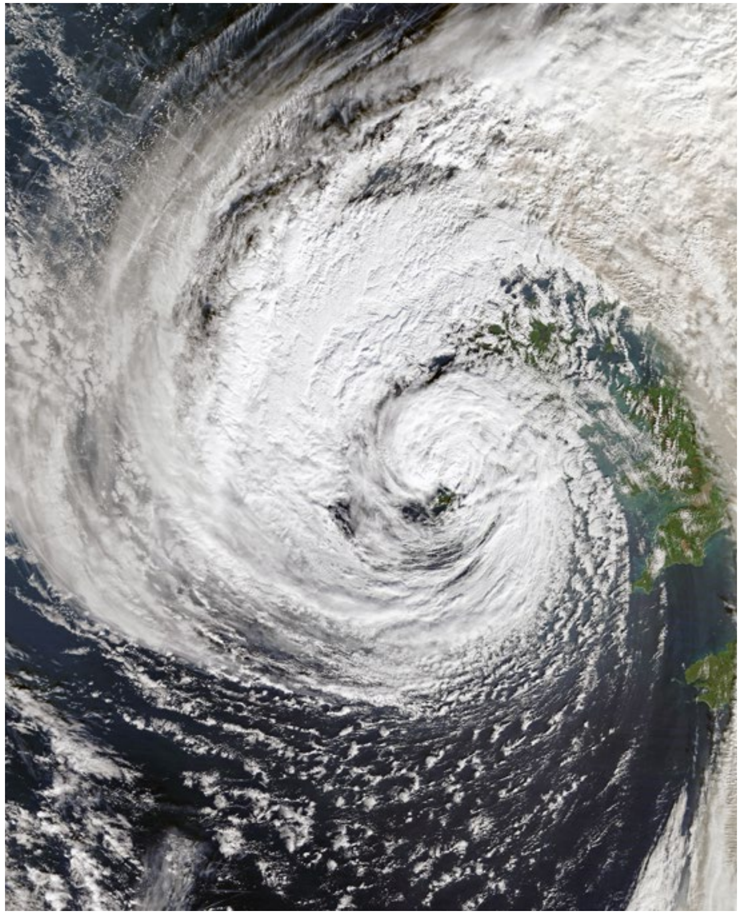
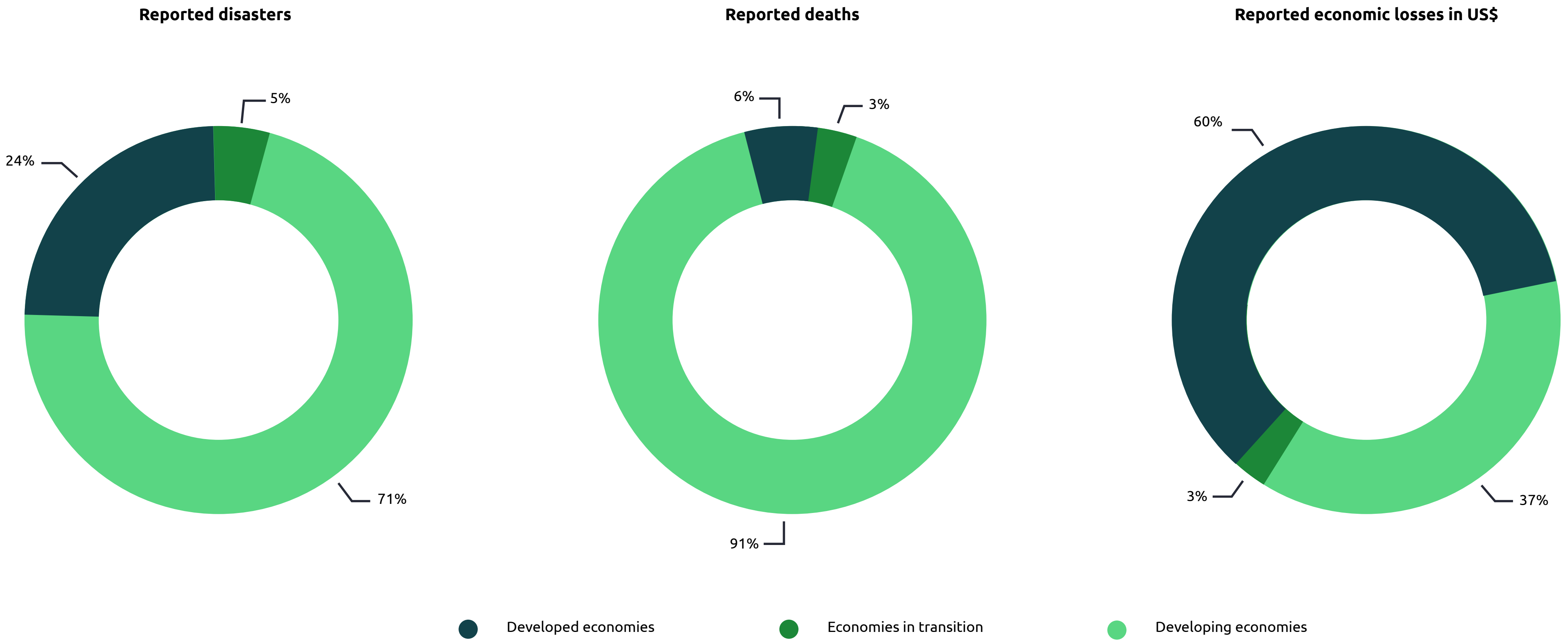


FIGURE 2

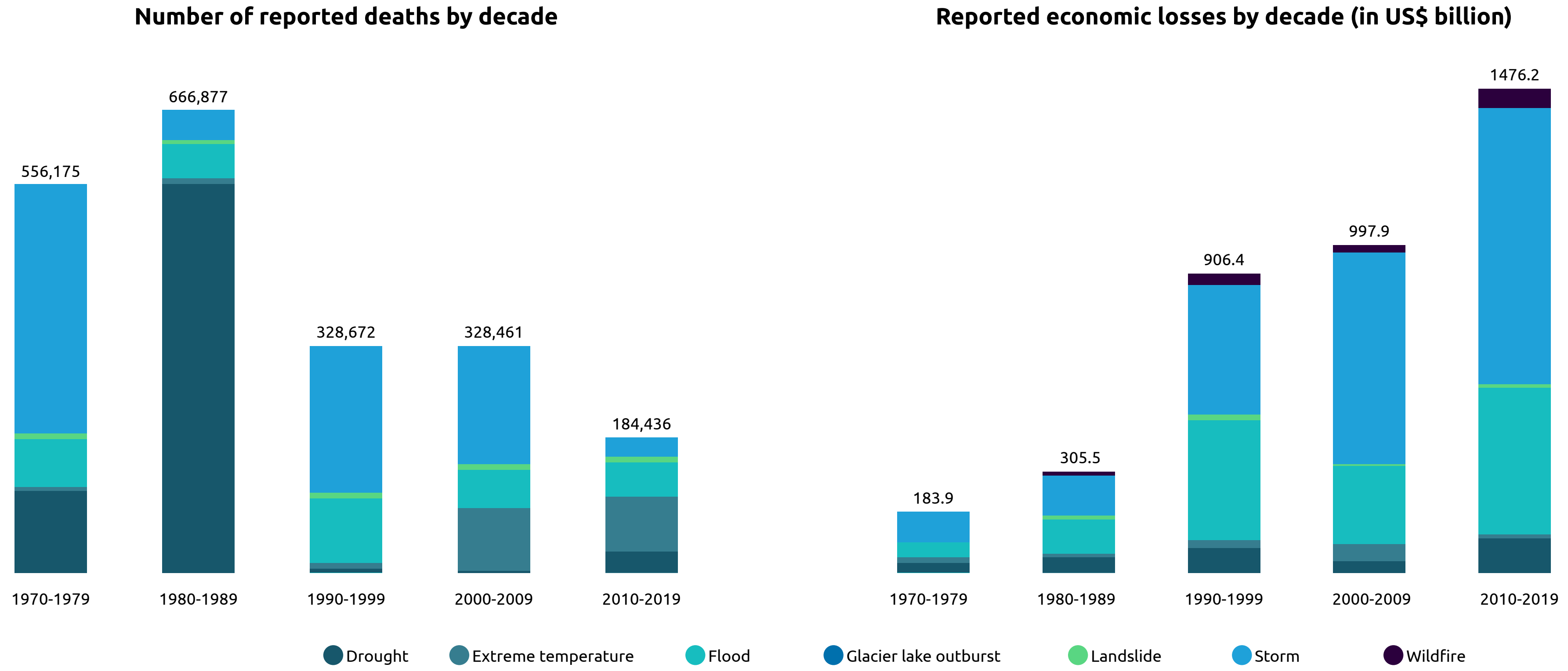
Most vulnerable communities bear the brunt of weather, climate and water-related hazards



The report highlighted decreasing mortality rates due to improvements in early warning systems and disaster management. However, increasing economic losses due to climate events:

**FIGURE 3**

Decreasing mortality rates and increasing economic losses due to climate events by decade



## Big investments are needed

Clean utility scale technologies - renewables farms, nuclear plants, hydrogen production and transportation assets, batteries gigafactories, electric networks are large assets, taking 5 to 10 years to build (even more for 3rd generation nuclear plants, 15 years), and planned to operate from 25 and up to 100 years. With the required In the TCO of these assets, CAPEX accounts for 60% to 90%. It's big money and challenging in times of relatively high interest rates (because of the TCO CAPEX share), impacting long term profitability.

On top of this big money, others need funds to be developed and scaled-up, specifically CCUS and more efficient, new storage technologies, nuclear fusion.

~$7tn per year investment for the next 30 years at least, requires regulation with stability and predictability. This investment timescale is not compatible with political and national strategic decision-making timescales which are about 5 years, the impact of Energy Transition and global warming will concern many generations.

Clear economic signals are needed to secure these big investments, made generally by private investors, and publicly owned utilities.

## Key points and challenges to stimulate the appropriate investment.

There is so much more to be done, to make massive funds available to pay for the assets and infrastructure required to clean up our global energy needs, and the increasing (huge) costs of climate events incurred from our slow progress to address climate change.

Should we prioritize the investments? Of course, every $ invested on Energy Transition must lead to results – GHG (Green House Gases) reduction. In the years 2000, the marginal abatement cost emerged as a measurement and decision-making tool. It is simply the cost of an intervention that will reduce GHG emissions by one ton[4]. But hard to abate emissions must also be considered to reduce emissions to almost zero in 2050.

So the question of prioritization is complex:

- Each measure cannot be considered individually since they interact with one another
- The question of velocity matters. But we can't wait that all electricity is decarbonized to start deploying electric vehicles. Industry and users need time to adapt
- Technology availability and associated cost that depend also on the demand…

4 Carbon emissions on the full life cycle that have to be considered.

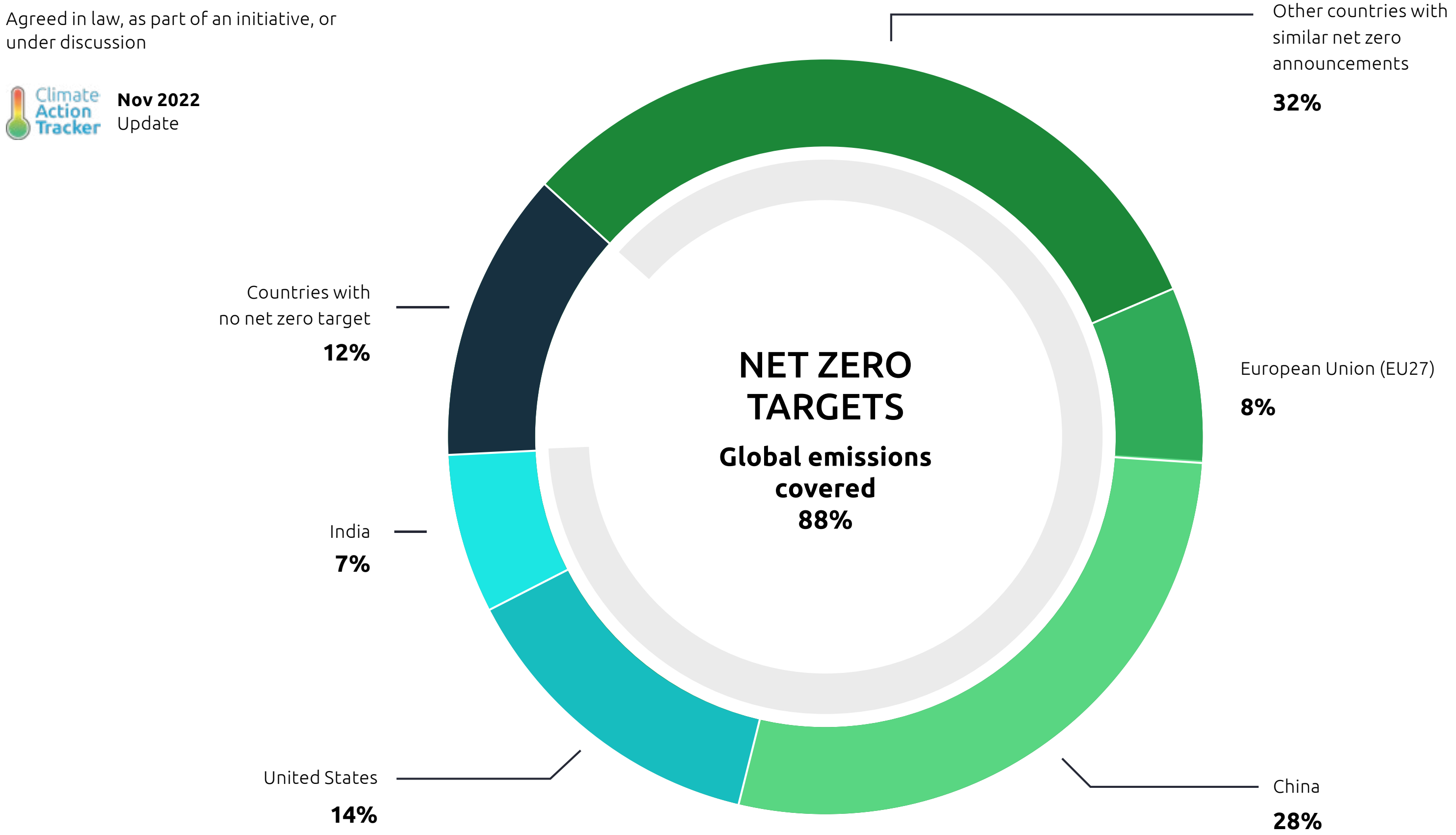
Focusing on long term objectives, thus being more complex, integrates interactions between sectors and technological changes, with an objective to minimize the cost of the transition, rather than concentrating on the marginal cost.

Certainty around real-world action for global investors is required, to enable them to come forward and co-fund massive projects with clarity of returns. This needs simplification of operating environments (regulation, access to low-cost funds, available supply chains, developed skills, etc.) through clear long-term policies for achieving Net Zero commitments. Not just from developed countries – but how to fund this transformation in developing countries.

Data tracked by the Climate Action Tracker consortium (climateactiontracker.org), suggests that 88% of the world have announced Net Zero emission targets, with detailed assessment of the policies to achieve each announcement.

**FIGURE 4**

Net zero emissions target announcements




*Note: Share of GHG emissions covered by countries that have adopted or annouced net zero emissions target (agreed in law, as part of an initiative, or under discussion). Compilation based on Net Zero Tracker (2022) and WRI (2022) as of 8 September 2022 complemented by CAT analysis. The compilation includes countries that have joined the Climate Ambition Alliance announced at COP25. Emissions data excluding LULUCF for 2019 taken from PRIMAP emissions database (Gutschow et al, 2021)*

Clarity over the business case, and commitment to the business case – why it makes sense for taxpayers, to move funds into this category of spending, needs to be accelerated. Climate taxes must be allocated to Climate actions. In WEMO 22, we demonstrated that less than half of carbon taxes were used for funding climate actions, the rest had diluted into general budgets. Value comes certainty from economic impacts, new job creation, carbon taxation, and GDP growth from scaling innovating clean technologies.

Increased taxation on profits from carbon intensive energy such as the UK Energy Profits Levy, and similar incremental taxes in other markets are additional vehicles to raise public funding. This level of taxation may help accelerate large oil and gas companies invest faster into low carbon fuels.

Funds raised from carbon markets have reached almost US$100bn according to reports published by the World Bank. Increasing additional taxation on carbon is a clear option to drive further acceleration to low carbon economies. For example – point of sale carbon taxes of carbon intensive products, would make them more expensive to buy, and therefore less competitive than low carbon alternatives. Levies and taxes to end use drives consumer demand and behaviour as seen in other end use taxation (tobacco, alcohol & sugar).

Establishing trust with taxpayers is also key – ensuring the funds raised through increased taxes are going directly to solving global climate problems must be demonstrable and transparent, as does the trust in the authenticity of carbon intensity in products. Efficient, scalable, independent testing and certification of carbon intensity would be required, along with transparent reporting of funds raised, and how they are dispersed.

Finally, the availability of funds and overall cost of money in recent times has caused some reluctance in the market to invest. Rising costs of borrowing, coupled with long permitting and approvals processes (often 4 years plus for renewables projects), has resulted in some market failures to secure bids. In September 2023 the UK Department for Energy Security and Net Zero suffered an absence of any bids for additional offshore wind generation capacity. The rising cost and complexity of supply chain, coupled with low offer price per MWh (£44) produced were among the reasons for bids not being tabled. These failed bids cause delays in progress to deploy renewable energy capacity, and lessons need to be learned about the changing market conditions, and what is required to attract a competitive – and achievable clean energy system.

## Economic rationale

Obvious question, debated many times, without clear answer as of today: in terms of economics, what will be the result of the Energy Transition unavoidable massive investment? Comparing here required investment and economic impacts.

Investment and impacts tables below result from a high level approach by categories – quite impressionist, but relevant picture and definitely not a business modeling exercise.

| Investments / Costs | Figures and comments |
|---|---|
| $7tn pa on climate tech development and deployment (for 30 years) | **~$7tn pa** (rationale: tripling climate tech efforts + adaptation measures + behavioral change programs + circular economy…)[5] |
| Adaptation measures such as… Floods, infrastructures relocation, wildfire and more generally weather events consequences protection. Covers crop changes to adapt to drought too… | **~$1tn**[6] (Derivated from a governmental evaluation in France, world representing roughly 20 times French economy) – included in the $7tn |
| Circular economy development | No real figures published on that dimension. Innovation and development required. |

5 International Energy Agency, World Energy Investment 2023 report
6 I4CE on behalf French authorities

| Contribution to the economy / payback | Figures and comments |
|---|---|
| Economy stimulation from clean energy development | **~$5.6tn** pa- Keynesian multiplicator effect ~0.8 out of climate tech development (~$7tn) |
| Jobs creation | **~50M new jobs for a decade (~5M/year)**<br>reference: Up to 10M by 2030 (Fit for 55) at European level, considering Europe weights 20% of worldwide economy |
| Capping weather events impacts | **5% to 10% GDP** in the long term (IPCC statement) |
| Circular economy benefits<br>• Economy global value creation<br><br>• Jobs creation value | **$7.7tn** pa by 2030[7]. Potential economy gains from the WBCSD. Consistent with European assumptions[8], stating $1.8tn pa savings from circular economy, with $0.6tn only for primary resources.<br><br>**$0.5tn pa**[9] (International Labour Organization assumption 2023 - $4.5tn / 2023 to 2030) |
| Energy costs contained | Not evaluated but significant |
| Insurance costs contingency | Not evaluated but significant |

7 World Business Council for Sustainable Development – 2023, previous estimates by the WEF in 2020 were standing at $4.5tn
8 https://archive.ellenmacarthurfoundation.org/assets/downloads/Note-de-Synthese_FR_Growth-Within.pdf

No choice for the planet but investing on Energy Transition. Obviously, as demonstrated above, **the impact of this huge investment will be positive** (direct impact on economy and avoided costs). No brainer and no regret (on the economical dimension). The question being, how to secure the appropriate funding?

9 International Labour Organization statement - 2023

# Conclusion

Getting the appropriate level of investment from all stakeholders is a complex equation, considering the variety of financial participants, and the level of required investment. We are dealing here with about 7% of the world GDP. It's massive. So, no final answer, but 6 key points out of the development made in this article.

- Politicians (governments) must commit their countries to mid- and long-term targets, related development objects (renewables and nuclear capacity, low carbon hydrogen, grids, carbon collection, energy efficiency…). It means public funding with money of course, but also clear and easy to manage financing mechanisms and vehicles. In a consistent overall framework with energy market design. Again, stability, predictability and easy to mobilize funding vehicles are absolute must haves.
- Public funding (countries and regions budgets) must make sacred the Energy Transition public investment. In the long term. Which is and will remain a significant challenge.
- Companies have to show the way since it becomes more and more obvious that the competition winners will be the most sustainable companies: profit, growth, image, attractiveness which applies to all business, employees, and financial markets (shareholders and banks).
- Financial institutions and markets, will naturally invest in projects and companies paving the way to a sustainable world, demonstrating balance sheet expected improvement. But without clear and immediate rules avoiding financing any fossil fuel or GHG emitting object (project or operations), no chance to get enough from the finance sector to fund the effort.
- Helping and motivating (with incentives) individuals to act upon Energy Transition, change their behaviors and consider their priorities.
- Financing enough developing countries on Energy Transition, the duty of wealthy countries. Climate change is a global thing. Being exemplary when your neighbor is not, is useless.

# OPERATIONALIZING CARBON INTENSITY TRACKING

MARK VIEHMAN, USA

Carbon intensity, the metric that captures the greenhouse gas emissions released per unit of economic output, is a crucial indicator in the fight against global warming. Monitoring energy consumption and emissions throughout a product's value chain enables the calculation of a quantitative environmental impact score. Moreover, the growing accessibility of high-frequency data now facilitates the assessment of carbon intensity down to the level of individual products at specific sites. In this article, we will explore the operationalization of carbon intensity tracking and the challenges associated with implementing comprehensive analyses that accurately capture this metric.

## The importance of carbon intensity: the power grid as an example

Carbon intensity is the measure of the environmental impact of any process in terms of direct carbon and carbon equivalent emissions, as well as associated upstream and downstream emissions. It can also be referred to as emissions intensity, probably a better descriptor, but will be referred to herein as carbon intensity (“CI”).

CI is determined through life cycle analysis (LCA), a method which evaluates the environmental impacts of a product, process, or service over its entire life cycle. There are different approaches to LCA analysis, with expressions such as “cradle to grave” which is used to capture the full environmental impact for products, “well to wheels” for transportation fuels, or, in the context of hydrogen, “well to gate” to describe the system boundaries or scope of measurement.

For example, the CI of power generation, expressed in grams of $CO_2e$ per kWh generated, is principally driven by fuel type, but will also be affected by individual plant efficiencies, operating levels and ambient conditions. In addition, how fuel is produced and transported to a point of generation, and emissions associated with its manufacturing and construction are reflected in the LCA as well. Hence, even renewable generation with no direct emissions will have some associated emissions reflected in the CI. Therefore while the CI values shown in Figure 1 reflect averages emissions, the actual CI at the point of power generation will vary significantly from the single point estimates shown.

The resulting CI of a power grid will vary depending on generation mix, as shown in Figure 2 which demonstrates the geographic variability of the power grid during a recent month. In France, for example, 61% of power was from nuclear and 25% was from wind, with a resulting CI score of 21. In contrast, Poland was 61% driven by coal and 11% by wind, with a resulting CI score of 778 for that month.

**FIGURE 1**

The Carbon Intensity of Electricity Generation (g $CO_2$e/kwh)

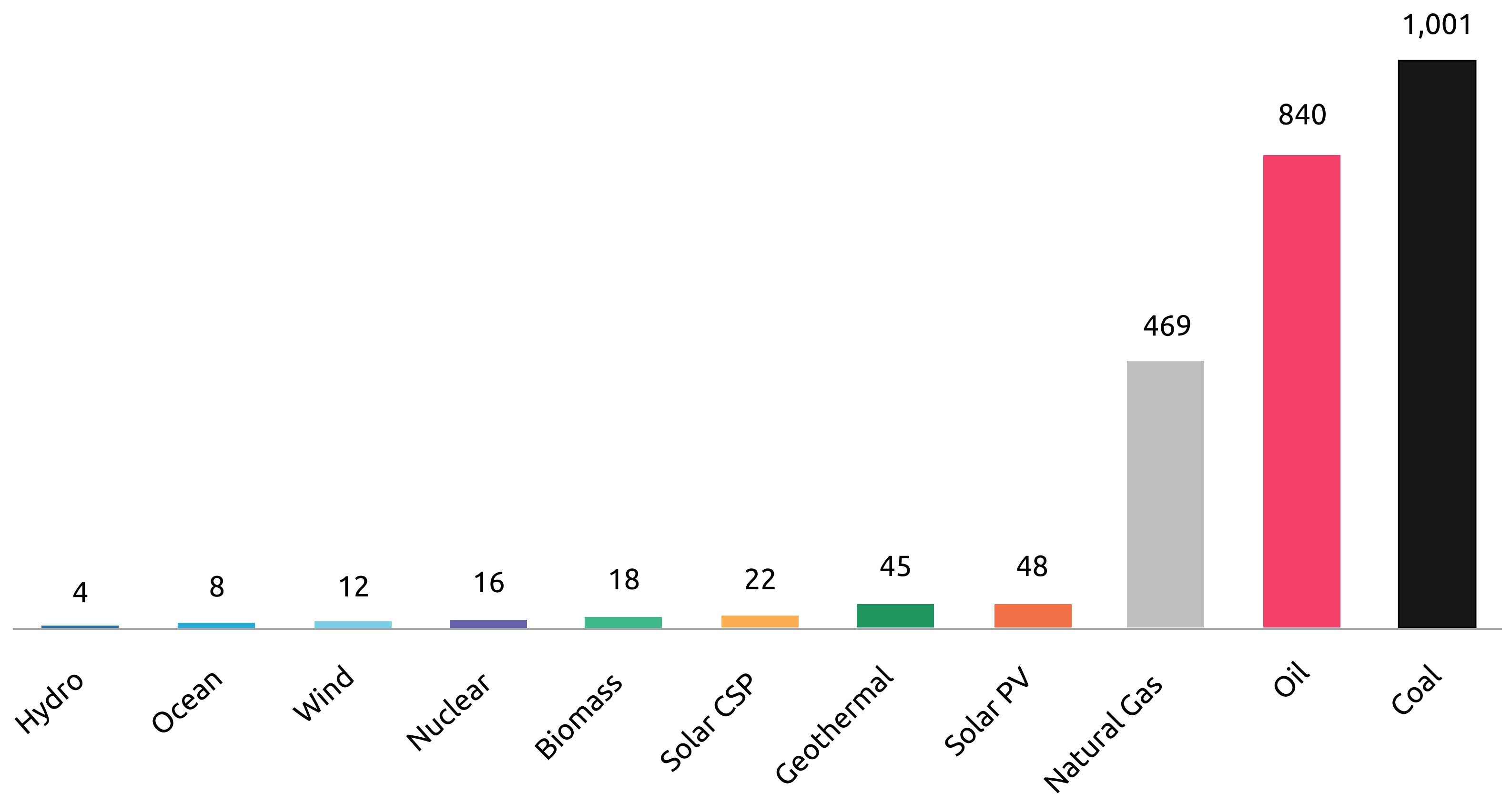
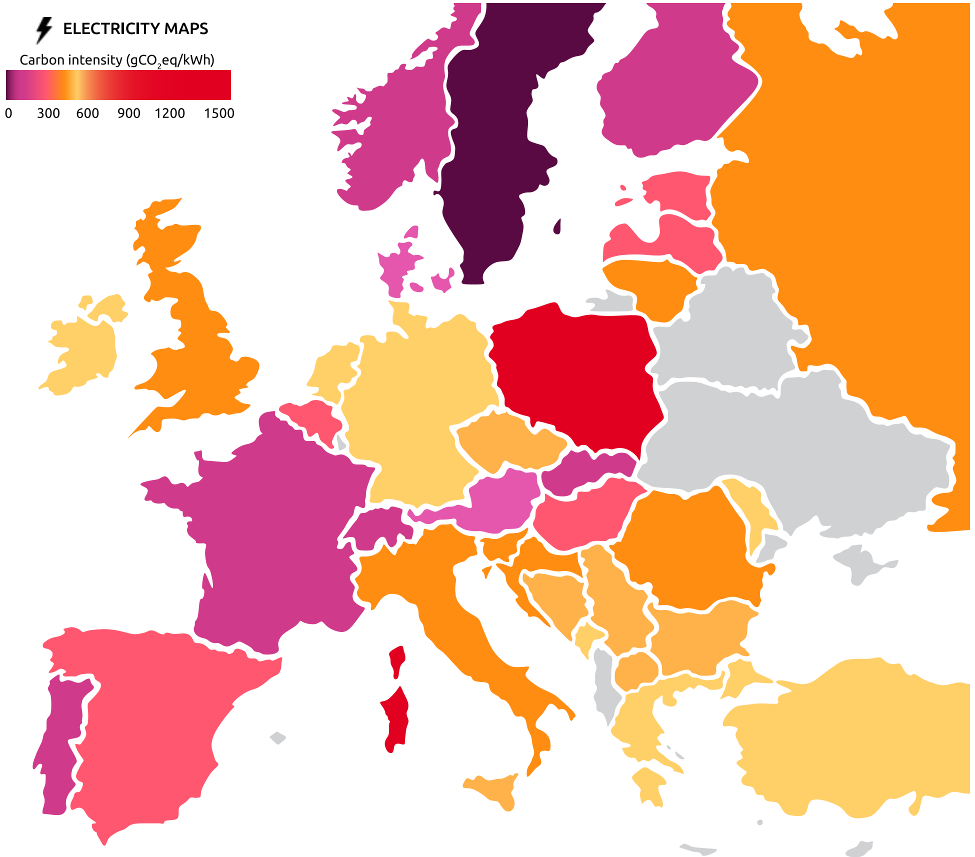


FIGURE 2

Carbon Intensity of the Power Grid in a Recent Month in the EU




Grid CI has a dramatic impact on the resulting carbon intensity of the products that require power. For example, if hydrogen was produced by electrolysis using grid power in any of the countries deep green in color, the corresponding CI of that hydrogen would be around 1.2-1.5 kg $CO_2e$ per kg H2 produced. In contrast, if the grid in Poland was relied on for H2 production, the resulting CI would be 45, which would place it is as the dirtiest hydrogen in the world. By comparison, it would be more than twice as bad as hydrogen produced from coal without carbon capture and sequestration ("black" hydrogen) and four times worse than unabated natural gas ("grey" hydrogen).

As an increasingly wide variety of products are being evaluated by their environmental attributes--including their associated CI--the management of emissions will emerge as a critical issue for commercial reasons as well as environmental considerations.

## Operationalizing carbon intensity tracking

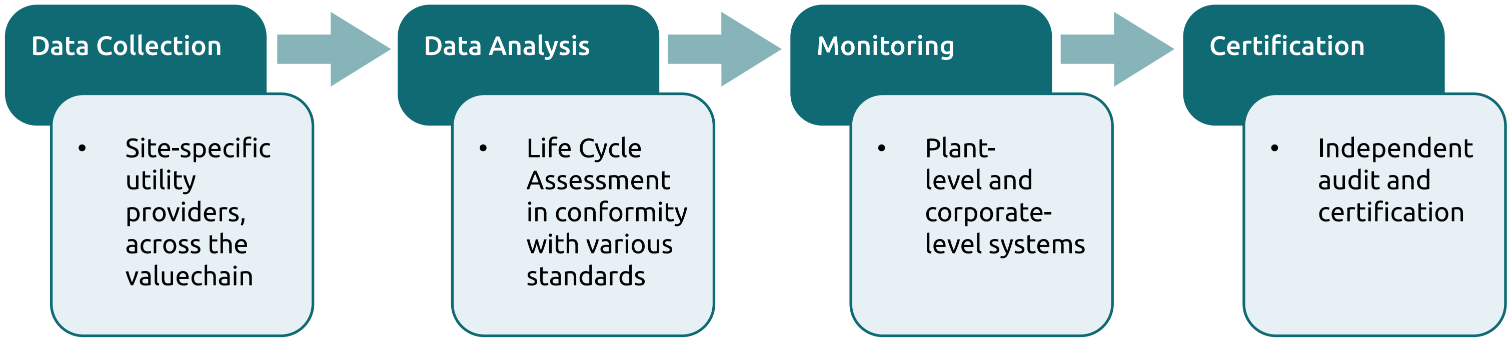
Implementing the systems to monitor energy use and emissions allows cost-savings opportunities from energy efficiency as well as emissions reductions, and typically, the value of energy savings offset much more than the cost of the systems themselves. Further, the systems to collect and share this data are no longer optional; more companies are demanding data from their suppliers on the emissions across their value chains as they have their own environmental disclosures to manage.

Carbon intensity tracking influences decision-making at both strategic and operational levels. At a strategic level, it can help shape a company's overall approach to sustainability. By highlighting areas with higher carbon intensity, companies can identify where changes need to be made to reduce their overall emissions. At the operational level, it can help determine the most cost-effective economical solutions to carbon abatement, as well as differentiate products to be independently certified as low-carbon or net-zero.

A logical starting point would be to collect all available relevant site-specific data and assess the decarbonization options available using Capgemini's Low Carbon Navigator, a benchmarking tool that helps companies develop their decarbonization strategies. It covers 25 industries and has brought together decarbonization strategies from over 400 companies. It provides a peer comparison of carbon-abatement strategies, and provides a comprehensive assessment of the transition risks and opportunities, resulting in a tailored road-map for the best-cost decarbonization solutions.

Implementing the resulting strategy requires ensuring that a comprehensive corporate data collection and reporting functionality is in place. We have observed that much of the relevant data already resides at the plant-level in local process control systems (Scope 1) but may vary in what data is being collected, the frequency of collection, and how it is being maintained. The pain-point from a corporate perspective includes these inconsistencies, as well as off-site carbon associated with utilities (Scope 2) and other suppliers or, where relevant, customers (Scope 3). Ultimately there has to be a single place where all data resides to ensure consistent reporting and support independent certification.

We have identified four steps required for successful operationalization:



## Data Collection

The first step in calculating carbon intensity is collecting the necessary data across all relevant steps of the value chain, using technologies such as infrared gas sensors, flue gas analyzers, and data from utility providers and upstream suppliers. In many cases, the bulk of the necessary data already resides in the process control systems at the production site; obtaining data from suppliers or customers may prove more challenging.

## Data Analysis

Once the relevant data has been gathered, it is analyzed using various analytical tools and software. While historically many companies have relied on data collected manually and analyzed in Excel, this has been problematic for companies with multiple products and sites, as well as those operating across multiple jurisdictions with varying standards and regulations. Industry-leading organizations have moved beyond this approach to ensure data integrity and are currently using solutions from AspenTech, AVEVA, SEEQ, Microsoft Sustainability Manager, and SAP's Industry 4.0. These solutions can be tailored to provide a consistent approach to carbon intensity measurement relevant to a single product or allocation to a collection of co-products. The method of allocating carbon across co-products can be a matter of informed judgement and debate as there are multiple valid approaches, each with their advantages and disadvantages.

## Monitoring

Once the process for calculating carbon intensity has been established, continuous monitoring and reporting can inform opportunities to adjust operations. Real-time carbon intensity monitoring can also enable a company to react more quickly to changes, thus enhancing their efficiency and reducing their carbon footprint.

## Certification

While in the past carbon intensity has been disclosed voluntarily and taken on trust, it is increasingly being used as a measure for regulatory compliance or qualification for government incentives. For example, in May 2023, as part of the Federal Buy Clean Initiative, the US General Services Administration announced a pilot program for procurement of $2.15 billion of substantially lower embodied carbon construction materials for Federal projects. As part of this program, suppliers of construction materials including asphalt, cement, glass, and steel must disclose various product environmental attributes to qualify for purchase. Figure X shows an example of a possible form of an environmental product declaration for a particular grade of steel rebar. In addition to a carbon intensity score of 0.964, other attributes are reported as well and will be driven by similar site-specific data.

**FIGURE 3**

Example: Environmental product declaration for steel rebar

| EVALUATION VARIABLE | UNIT PER METRIC TON | TOTAL |
|---|---|---|
| Primary energy non-renewable | MJ | 13,200 |
| Primary energy, renewable | MJ | 868 |
| Global warming potential | metric ton $CO_2$ eq. | 0.964 |
| Ozone depletion potential | metric ton CFC-11 eq. | 6.53E-11 |
| Acidification potential | metric ton $SO_2$ eq. | 3.74E-03 |
| Eutrophication potential | metric ton N eq. | 1.94E-04 |
| Photochemical oxidant formation potential | metric ton $O_3$ eq. | 0.0444 |
| Abiotic depletion potential, elements | metric ton Sb eq. | 1.55E-07 |
| Abiotic depletion potential, fossil | MJ | 11,800 |

Source: Sustainable Facilities Tool, U.S. General Services Administration

## Challenges in operationalizing carbon intensity tracking

Life cycle analysis is an evolving science, and the approach varies across industries. For products with complex, global supply chains, tracking every input can be especially challenging, as it can be hard to account for the environmental impacts of every component, especially when parts are sourced from different parts of the world with varying environmental standards.

We have identified seven challenges within life cycle analysis:

1. **Data availability:** One of the most significant challenges in conducting an LCA is obtaining the necessary data on materials, energy use, emissions, and waste at each life cycle stage. This data may be hard to find, particularly for complex products with supply chains spanning multiple countries. In some cases, data may be considered proprietary and therefore not publicly available.

2. **System boundary definition:** Defining the system boundaries for an LCA is a challenging task. The system boundary determines which processes and impacts are included in the analysis. However, deciding where to draw these boundaries can be complex and subjective. For example, should an LCA of a car include the impacts of building the factories where parts are made? Should it include the impact of disposing of the car at the end of its life?

3. **Assumptions and uncertainties:** LCA involves a range of assumptions, such as how a product is used or how long it lasts, which can significantly affect the results. Additionally, there are often uncertainties in the data used for LCAs, such as variation in energy use or emissions across different production sites. These assumptions and uncertainties can complicate the interpretation of LCA results.

4. **Allocation problems:** When dealing with multi-output processes it is challenging to allocate the environmental burdens across products. Various methods for allocation have been proposed, but there is no consensus on the best approach. For example, if the $CO_2$ from hydrogen production is sequestered the emissions associated with its disposal are transferred to the products from the process. This is simple when there is a single product, but what happens when the process also generates steam, power or other chemicals?

5. **Impact assessment:** There can be significant variability in the environmental impacts of a product, depending on how and where it's made and used. Additionally, the need to make assumptions and estimates can introduce uncertainty into the results. For example, methane is calculated to be approximately 80x more potent a greenhouse gas, at least in its first 20 years of release, but that value has varied over time, with significant results on reported carbon intensities.

6. **Time and resource intensity:** Performing an LCA can be time-consuming and resource-intensive, particularly for complex products with long and complicated supply chains. This can limit the feasibility of LCA, especially for smaller companies with limited resources.

7. **Lack of standardization:** While there are some general guidelines for conducting LCAs, there is a lack of standardization in the field. This can lead to inconsistencies in how LCAs are performed and how results are reported, making it difficult to compare results between different studies.

Continuous improvements in data availability, methodological approaches, and software tools are helping to overcome some of these obstacles. There is also an increasing call for harmonization of more standards globally in order to allow more direct comparison across products.

## Multiple standards and methodologies create a complex landscape

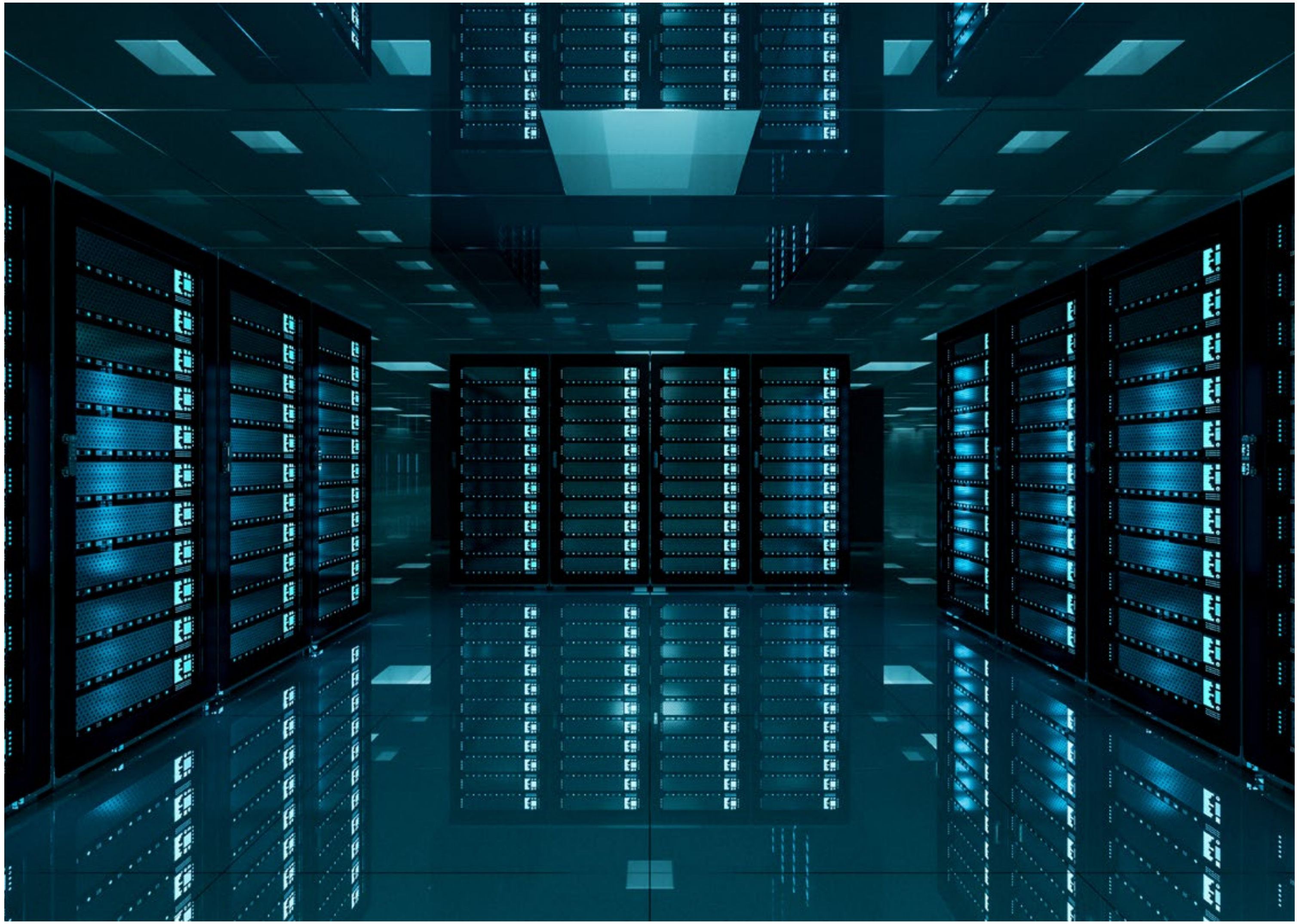
As referenced above, there are multiple standards, guidelines, and methodologies available that guide how industries measure and report carbon intensity, including but not limited to:

| | |
|---|---|
| **Greenhouse Gas Protocol (GHGP):** | Developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), the GHGP is a widely-used international standard for greenhouse gas accounting. It provides clear standards for calculating carbon intensity by defining direct and indirect emissions (Scope 1, 2, and 3 emissions) and providing guidance on emission calculation methodologies. |
| **ISO 14064 Standards** | These international standards developed by the International Organization for Standardization provide guidelines for the quantification and reporting of greenhouse gas emissions and removals at the organization level. |
| **IPCC Guidelines** | The Intergovernmental Panel on Climate Change (IPCC) has produced guidelines for national greenhouse gas inventories, which include methodologies for calculating emissions from various sectors, including energy, industrial processes, agriculture, and waste. |
| **CDP (formerly Carbon Disclosure Project):** | While not a standard in itself, the CDP sets out a comprehensive process that encourages companies to measure and disclose their environmental impact, including carbon intensity. The information CDP requests from companies is aligned with other standards like the GHGP and ISO 14064. |
| **IEA (International Energy Agency) Guidelines** | The IEA offers specific methodologies for tracking energy use and related $CO_2$ emissions in a range of industry sectors, from manufacturing to transport. These guidelines are used to help monitor progress in energy efficiency and carbon intensity. |
| **Science Based Targets initiative (SBTi)** | This initiative provides companies with a clearly defined pathway to reduce greenhouse gas emissions, in line with the Paris Agreement goals. Companies using SBTi are given access to methodologies and tools that can help measure and reduce their carbon intensity. |
| **Task Force on Climate-related Financial Disclosures (TCFD):** | TCFD provides recommendations for consistent climate-related financial risk disclosures for use by companies, which includes tracking and reporting on carbon emissions and intensity. |

While these standards and guidelines can help provide a framework for measuring and reporting carbon intensity, the precise methodologies used can vary between industries and organizations. The choice of standard often depends on the specific requirements of the industry, region, or company. There is an increasingly acknowledged need for a global harmonization of standards and approaches to life cycle analysis in order to reduce confusion and allow for more comprehensive and verifiable reporting.

# Conclusion

The need for high-integrity carbon intensity tracking systems which will inform regulators, customers, investors, and other stakeholders continues to grow. For many of our clients, we observe that much of the required data is already collected across the enterprise, but with significant variations--particularly across differing geographies--in what specifically is being collected, the frequency, and how the data is being maintained. Ultimately, there must to be a central corporate data repository and systems which will allow the calculation and certification of data, potentially across a variety of applicable standards. As the world strives to limit global warming, carbon intensity tracking will provide the data needed to help companies, industries, and economies reduce their carbon footprint and move towards a more sustainable future.



# BUSINESS PLANNING IN A FINITE WORLD

ALAIN CHARDON, FRANCE

MATTHIEU MEAUX, FRANCE

## Planetary boundaries increasingly impact the economy: Traditional business planning is no longer operational for long-term strategic investments

**$11.6 trillion investments by the global industry, $1-100 billion single corporate tickets**

To face the energy transition, the global industry will have to invest $11.6 trillion in the next ten years, representing $1-10 billion in investments for a typical international company. Regarding financial services, the risks and investment changes will be even more significant in the portfolios of equities, obligations, and loans.

Industries – including energy, manufacturing, steel, cement, aerospace, automotive, and shipping – want to make decisions about major product lines and process changes, transitions to clean energy supplies and low carbon assets, circularity of materials, and protecting physical assets from climate risks.

Banks, asset managers, and insurers want to know which future green technologies they should back, and step back from sectors and companies that contribute to climate change or whose assets, strategy, and investments are impacted by climate, planetary boundaries, and transition risks.

**Except to take major risks, business strategy and investment planning can no longer rely on traditional off-ground economic modeling**

As a strategist, can you trust the economic scenarios from economists, international financial institutions, and national governments invariably forecasting a steady 3-4% GDP growth rate for the next 30 years, as in the past 30 years? Can you trust plans such as the American Inflation Reduction Act (IRA) or the European Fit for 55 that promise clean energy and resources will be abundantly available for your industry in time?

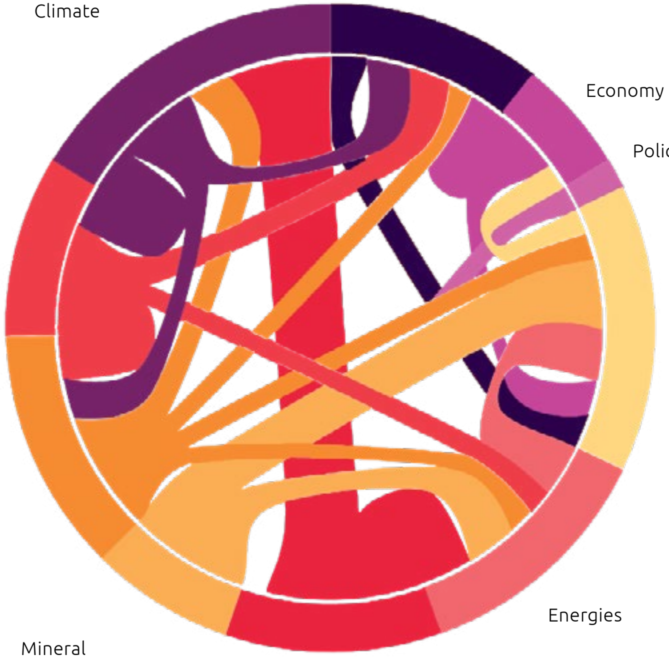
To make better decisions, strategists must understand how the changing world will impact technologies, assets, and business. Will there be a clean energy infrastructure (the blood of the economy) to power your business? Will there be sufficient materials (the skeleton) to make them in the future? Will there be enough agriculture, sea, forest, and biodiversity production (the flesh)? Will there be enough GDP (the aliment) to feed the funding of the infrastructures and techs needed by your company? How deep will climate damage GDP output and workforce productivity and affect the population's ability to consume your products? These questions are even more complex because they do not exist in isolation but are interacting and looping.

## Integrated assessment models (IAMs) are the new tool for high-stake business planning

IAMs are models that consider all or part of the interactions between climate, economy, energy, resources, and regulations. Historically, public authorities have used them to plan short- and long-term policies. In the coming years, these tools will become state-of-the-art for corporate business planning in industry, energy, and finance. In particular, Capgemini's Business for Planet Modeling (B4PM) solves some of the limitations of the existing IAMs with a broader scope and increased flexibility for business purposes.

FIGURE 1

**Can corporates plan long term investments and disconnect the impact of a finite world on GDP and business?**



# IAMs, long used by institutions, have only partial coverage of planetary boundaries, do not loop the impacts, and lack the flexibility to serve business needs

**The history and usage of IAMs:** Integrated assessment models have been developed over the past 50 years to account for intertwined economic, material, and sociologic interactions. They provide insights to international bodies, such as the United Nations, the Intergovernmental Panel on Climate Change (IPCC), World Bank, International Monetary Fund (IMF), and others, as well as national governments and financial institutions to develop strategies and policies.

**The grandfather, World3, originally meant for planetary boundaries:** World3 was the first IAM model. Developed by Denis Meadows and revealed in 1972 in the book The Limits to Growth, the model predicts the dynamic evolution of the human population depending on the level of pollution, food availability, resource availability, and economic conditions. World3 does not account for climate change, and progress in energy technologies cannot balance the overall predicted degrowth dynamics. The economic model may be considered too simplistic.

**Modern neoclassic economy IAMs are disconnected from the finite world:** Surprisingly, modern IAMs are less complete than the World3 model for the resource's limits. Often built for macroeconomic purposes, they use neoclassical considerations where the only limits are capital and workforce and cannot tackle the challenges of climate, energy, and resource transition.

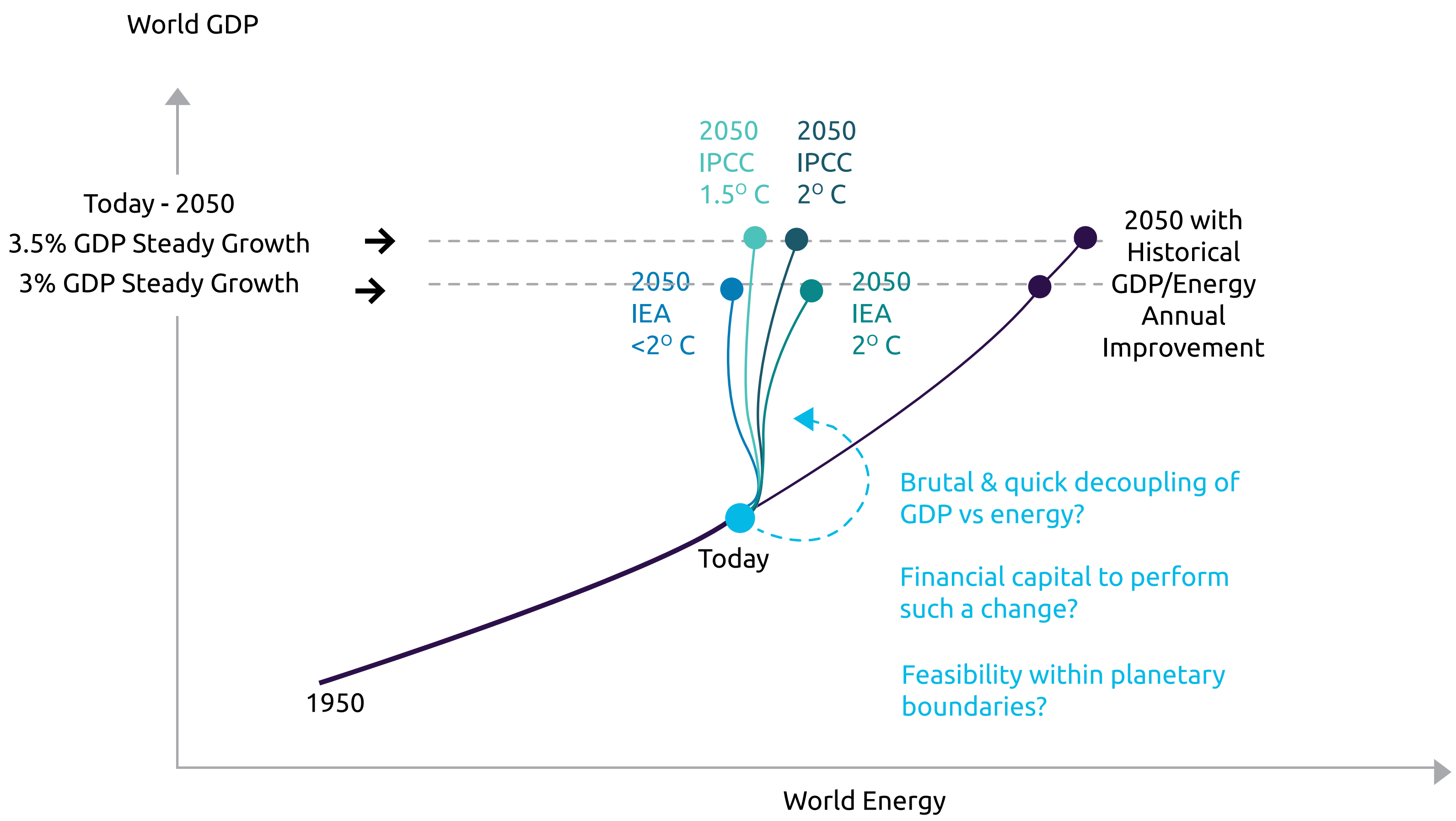
**Climate damage is underrated:** In most models, climate change does not damage GDP or population, which is a given hypothesis (it was an output in World3). William Nordhaus introduced the feedback of climate on population and GDP levels in his 1992 Dynamic, Integrated Climate and Economics (DICE) model. He received the Nobel Prize in 2018 for his work. Nevertheless, his initial damage functions are deemed underestimated today. At present, fires, droughts, and heatwaves have impacted the GDP and health in India, the U.S., Canada, Australia, Libya, Germany, and Greece.

**Resources and circular economy are forgotten:** Low-carbon technologies will dramatically multiply the need for raw resources. Few models cover raw materials, water, and land use, limiting economic development. Few models consider the circular economy, despite its potential to significantly impact the 55% of global upstream Scope 3 emissions related to converting primary resources into final products, in contrast to the 45% of emissions associated with running equipment on fossil fuels.

**Technology and platform limits:** These models are often rigid and built on outdated IT platforms, meaning they lack the transparency and flexibility to integrate additional features or adapt to existing ones. The "black-box" effect leads to a deficit of trust in the model's results. The lack of flexibility causes considerable reworking and cost to extend or tune models to explore specific scenarios. Models and languages are often proprietary, making collaboration more difficult on these highly transversal topics.

**FIGURE 2**

Transition scenarios from international institutions




Source: Michel Lepetit, Global Warning, The Shift Project, Capgemini analysis

# Capgemini's Business for Planet Modeling (B4PM): Pivot your business in a finite world thanks to WITNESS, one of the widest IAMs, and the SoSTRADES platform – both open-source

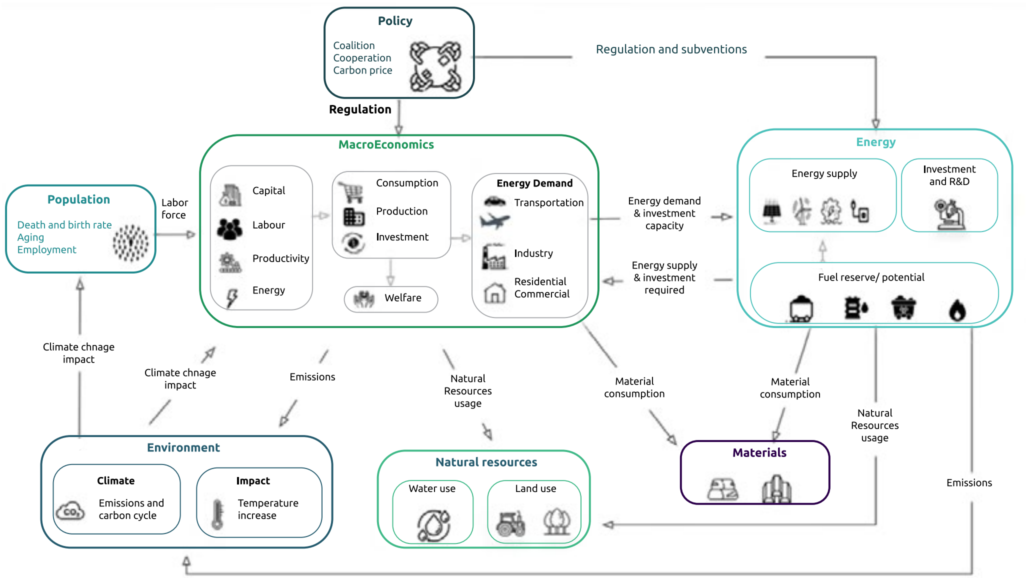
**FIGURE 3**

## B4PM IAM WITNESS

WITNESS is one of the IAMs that covers the most disciplines and interactions:

- Climate,
- Population,
- Economy,
- Policies,
- Energy,
- Resources,
- Land use…

100+ models
300,000+ variables
WITNESS is flexible and expandable thanks to the SoSTrades platform

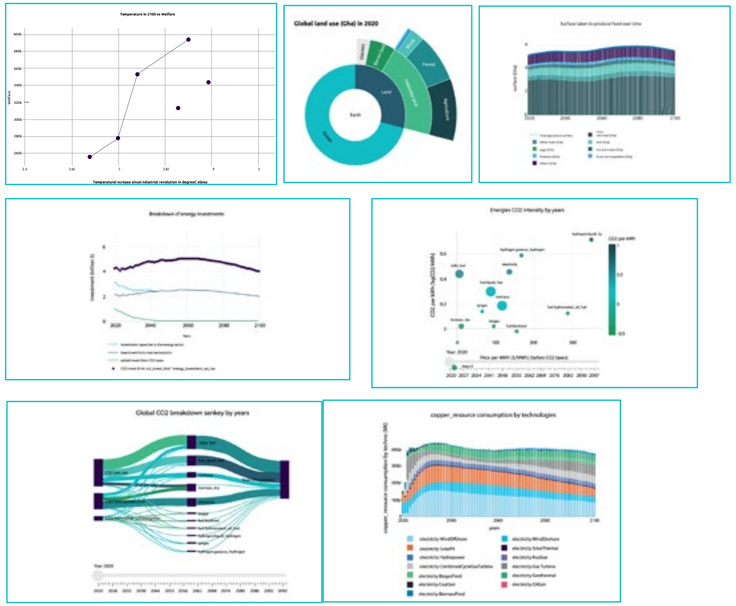



## B4PM COMPANY STRATEGIC USE CASE MODELING

Stress-test and secure the company strategy and investments.
Model your product / process / asset /services portfolio.

Plunge them in the future of the world (WITNESS scenarios or IEA, IPCC, NGFS scenarios…).

Get all the required financial, operational or emissions results.



## B4PM PLATFORM SOS TRADES

GEMSEO
Multidisciplinary Design Optimisation
Multidisciplinary Design Analysis
Design of Experiments
Sensitivity Analysis
Uncertainties Quantification

SoSTrades is a « System of Systems » cloud-based collaborative simulation platform with easy-to-use user-interface, allowing experts to work together.
SoSTrades automatically links models from various origins and runs them together without additional coding using Multi-Disciplinary Analysis (MDA).
Its advanced mathematical algorithms (MDO, DOE, UQ…) allow to solve complex optimization problems or quantify uncertainties on a large panel of models.
SoSTrades articulates WITNESS with the modeling of the strategic use case of the company and solves its business challenge optimally.

B4PM WITNESS is an open-source, transparent, and flexible IAM designed to allow companies to develop models that explore how their plans, assets, and investments play out under different future scenarios. This helps them understand the associated risks without compromising the confidentiality of their business assumptions and data.

WITNESS combines all best-of-breed climate-relevant models in one place, including models on climate change, climate impacts (people, assets, etc.), the global economy, capital flows, demographic change, energy tech, infrastructure (availability, aging, etc.), and resources.

**B4PM SOSTRADES is the potent open-source platform** that runs and provides all the flexibility and power to B4PM WITNESS. This advanced climate data and IT platform, with libraries and calculation tools, allows all models to operate together and for new models to be added. They can be switched on or off at will. With minimal data naming, the platform makes links between models automatically. Its advanced MDA features solve the looping interactions between population, economy, regulations, energy, resources, and climate. Its MDO tools help to fix constraints, find the optimal path within high uncertainties, and to derisk the company's transition choices.

**Companies can build a strategic twin model of their business issues.** They can generate infinite options. Users build their scenarios by combining models from the database, which can be clicked together like building blocks to simulate the world. They plug them into WITNESS, the B4PM model of the world. The underlying platform, SoStrades, loops the interactions between the company's business and the global model. The users can stress-test the choices they are considering in a wide range of possible future scenarios.

**They can tweak inputs and visualize** how future decisions (their own, competitors, or governments) would affect economic flows, climate impacts, resource availability, and therefore, risk levels. This enables the company to derisk its transition decisions and roll out a profitable business plan in a finite world farther and better than the competition. This helps strategists make informed decisions about the least risky path to success, including where to invest, how quickly to progress new technologies, how to evolve supply chains, where to build or move factories and assets, and what insurance and risk-mitigation policies to pursue. All of these help derisk decisions, build resilience, and chart a profitable course through the energy transition.

**Mixing a private and open-source approach for WITNESS and SoStrades carries many benefits**

One benefit of WITNESS and SoStrades being at least partly open-source is increasing the transparency and, therefore, the trust from third parties in the model's results and transition paths proposed by the company. A second is that joining a community facing the same climate and data challenges creates a shared experience. This approach prevents duplicating research and data capture, establishes common data standards for processing the climate and economy data, and enhances the model's integrity and evolvability.

Once the first results are reached and momentum builds for the company's transition models, the question of maintaining the data and codes will arise. The third benefit of open source is the ability to collaborate with other companies to maintain, share, validate, and update data of common interest.

This would give the companies valuable data to steer their strategy, which would be costly or impossible to maintain alone.

**Capgemini is a member of Open-Source Climate (OS Climate) - Why not join us?** We facilitate the transition scenarios working group with WITNESS and SoStrades. The purpose of OS-Climate – part of the Linux Foundation – is to gather a community around these topics, with several high-profile members, including banks, tech giants and industries. Capgemini joined OS-Climate as one of three premium members (alongside Goldman Sachs and BNP Paribas). Why not join us?

# Capgemini's Business for Planet Modeling (B4PM): Pivot your business in a finite world and solve a wide variety of practical use cases (potential non-exhaustive list)

**FIGURE 4**

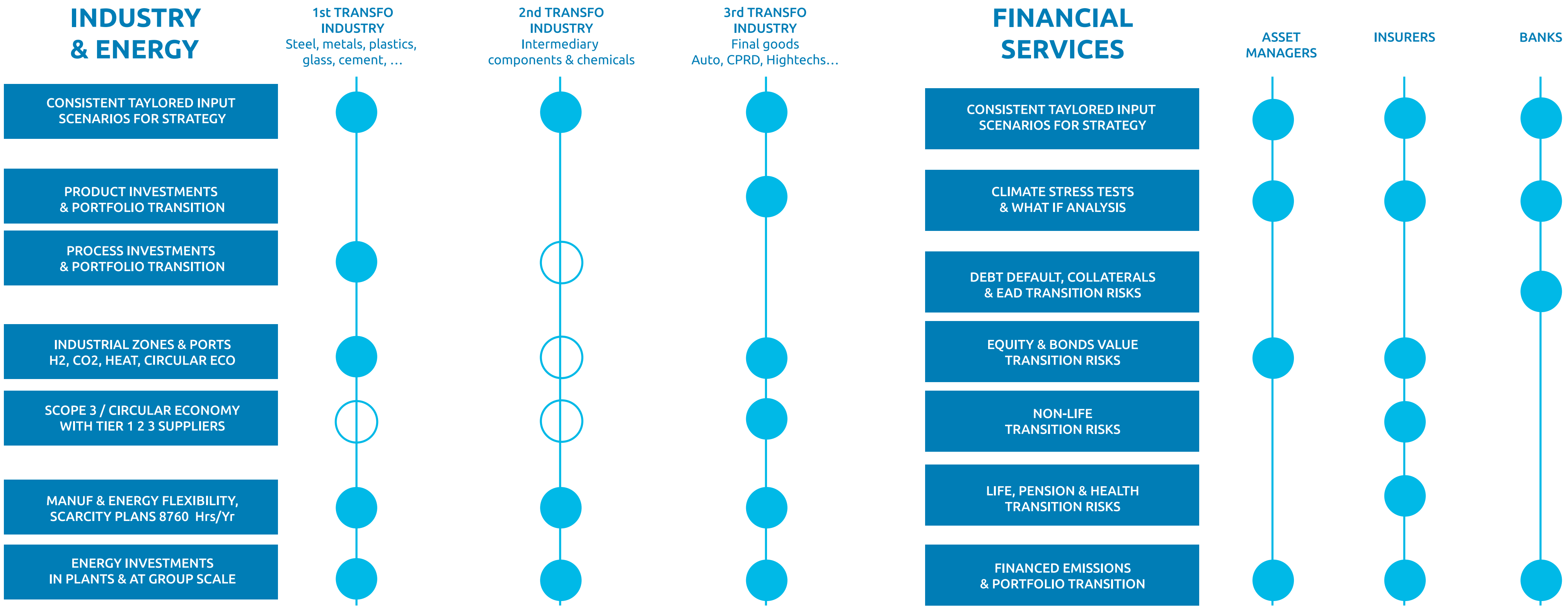
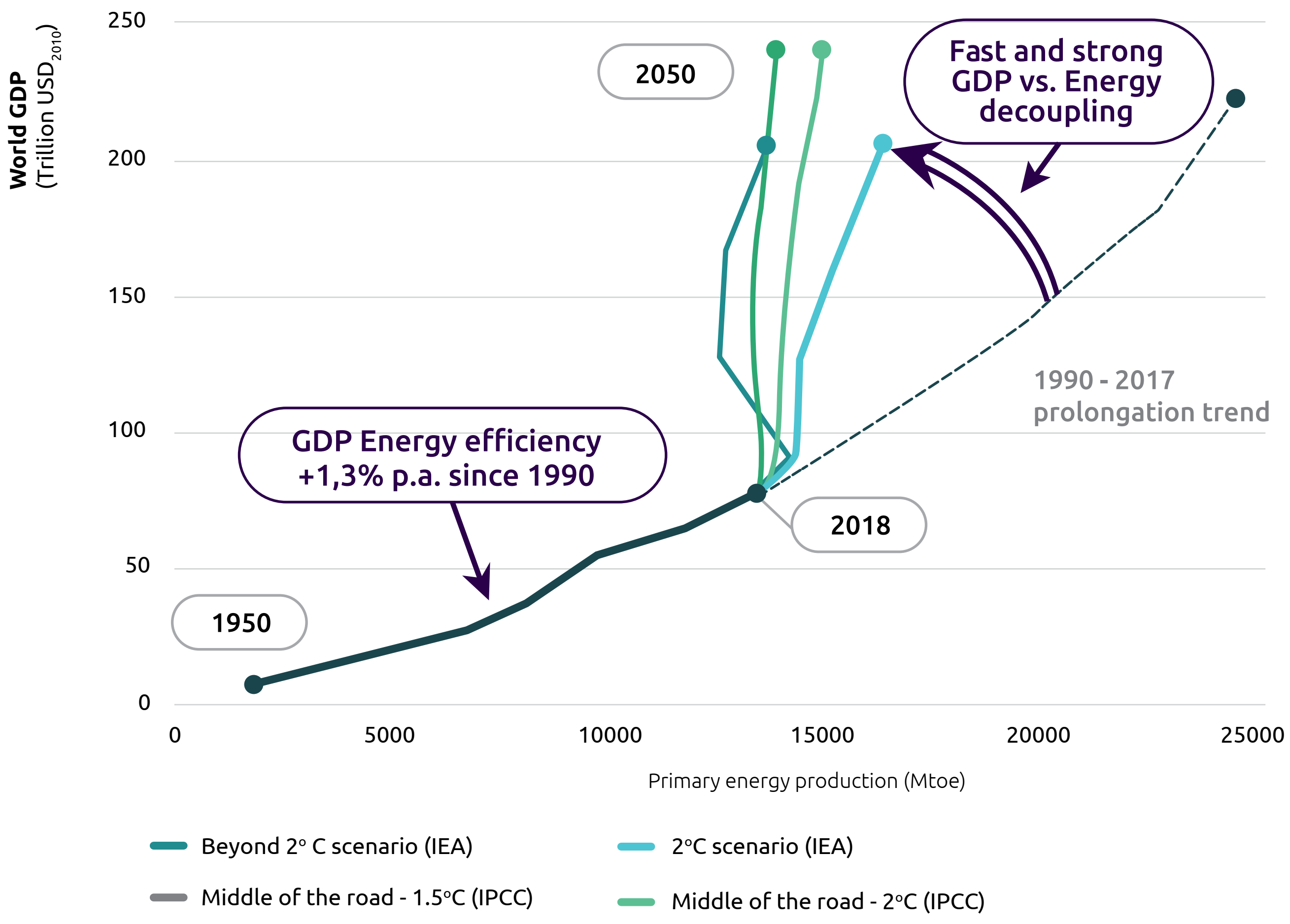


FIGURE 5

GDP versus energy production evolution | 1950 - 2050



# DECARBONISING ENERGY. ARE WE MOVING FAST ENOUGH? LIGHTS AND SHADOWS

DAVID PEREZ-LOPEZ, SPAIN

**Current decarbonization path is the under 2.5°C average temperature increases but far from 1.5°C Paris Agreement goal. The arctic will be ice-free in a time between 2030 and 2050.**

Energy transition is off-track. According to international institutions under current decarbonization path will rise of 2.5 °C in global average temperature far from 1.5°C Paris Agreement goal. Current pledges and plans fall well short of 1.5°C pathway and will result in an emissions gap of 16 gigatonnes (Gt) in 2050 representing more than 40% of total current emissions to be abated.

$CO_2$ emissions path to 2050 under STEPS and even APS scenarios are far from Paris Agreement temperature rise goal, encourage policies and pledges are key to reach a NZE path.

**2023 will surely be the hottest year ever recorded,** last July 6 was the hottest day in recorded history reaching 17.2°C global average.

Every fraction of a degree in global temperature change will trigger significant and irreversible effects in biodiversity losses, droughts, food security, fires, extreme heat and weather events, floods sea level rise, or coral reefs disappearance.

A recent study based on NASA and ESA latest satellite observations and IPPC climate model predicts that between 2030 and 2050 will arrive an ice-free Arctic even under a low emission scenario path, and by 2100 the Arctic region will be ice-free for almost half a year. Nature Observationally-constrained projections of an ice-free Arctic even under a low emission scenario.

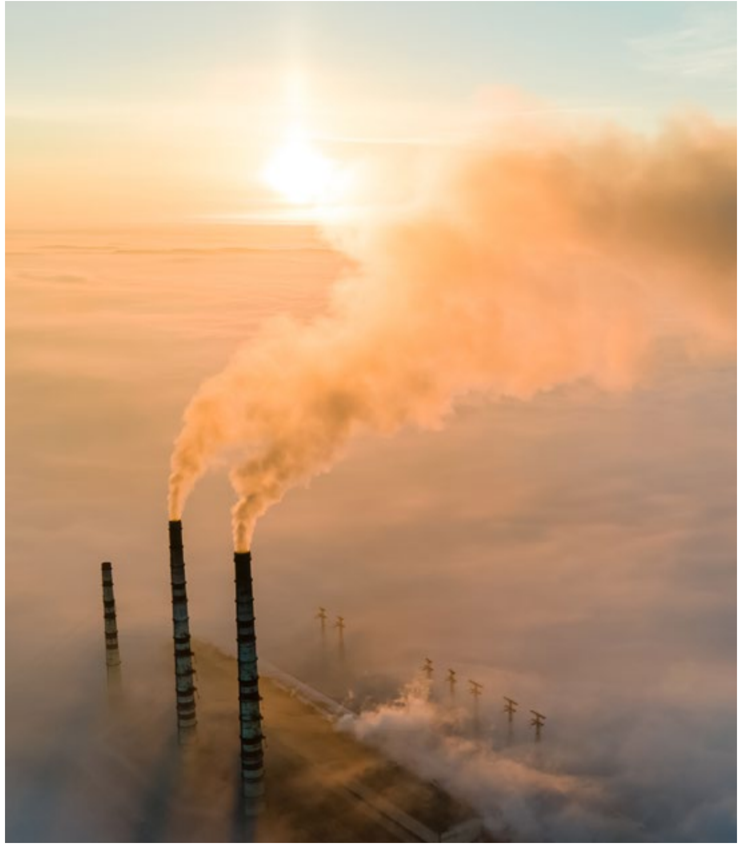
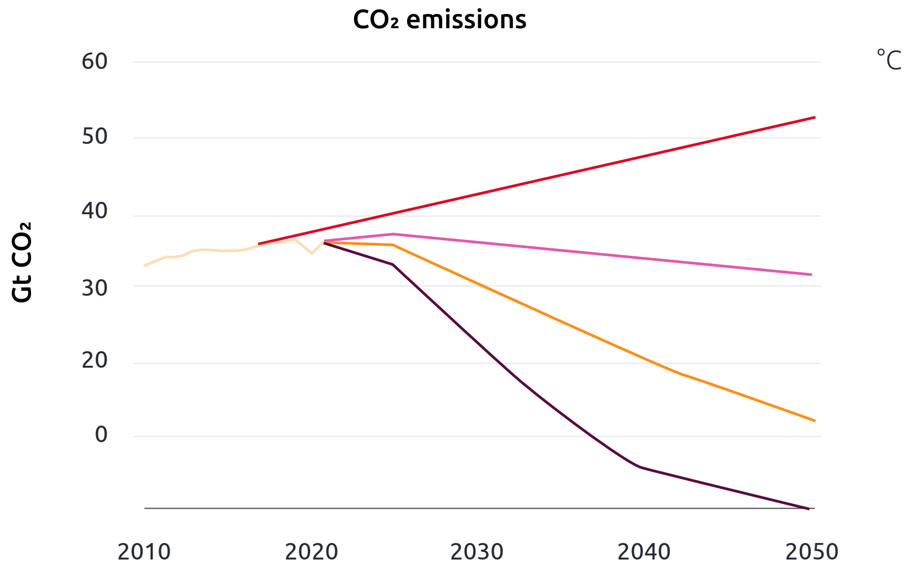
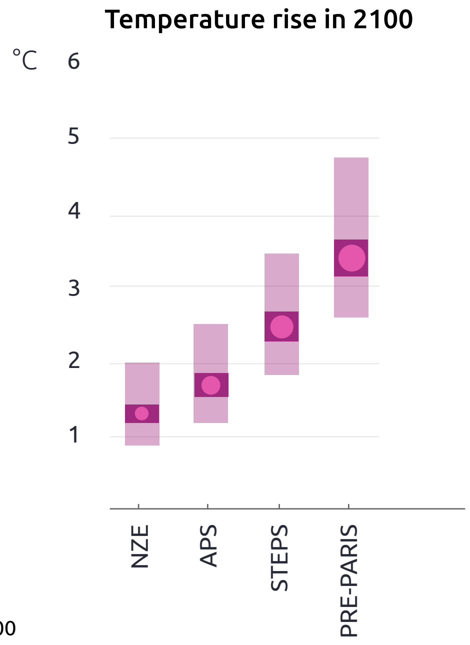


**FIGURE 1**




$CO_2$ emissions paths to 2050 under STEPS, APS and NZE and temperature rise in 2100

— Pre-Paris baseline — STEPS — APS — APS — NZE

5th - 95th percentile

33rd - 67th percentile

Median

## Climate change is the largest humanity risk.

The world is experiencing multiple crises but climate change in the long-term are the largest global risks , and extreme damages were caused by climate change over for 2022 with thousands of deaths, environmental disasters, and billions of economic losses.

The need for the energy transition has become even more urgent. The recovery from the Covid-19 pandemic and the global energy crisis have provided a major boost to global clean energy investment.

In the next 5 years solar and wind will be installed as much as to date and by 2030 will double or triple the current annual capacity installed. This is not enough.

Renewable energy growth is accelerating due to the energy and gas crisis context where countries seek to strengthen energy security as main part of the solutions to be addressed accelerating its hypergrowth. Wind and solar avoided €11bn to EU in gas costs for 2022 lowering the inflation.

Several progresses are being made, especially in the electricity sector, where renewables is representing 83% of the new capacity additions globally by 2022 and expected to be more than 90% of global new additions in the next 5 years. By 2027 solar energy will account becoming the largest source of electricity.

Although global investment across all energy transition technologies reached a record high of USD 1.3 trillion in 2022, annual investment must more than quadruple to remain on the 1.5°C pathway . By 2023 an increasing push anticipated spending up to a record USD 2.8 trillion, with renewables, and EVs leading the expected investment. This momentum behind clean energy investment stems from a powerful alignment of costs, climate and energy security goals, and industrial strategies, but remains heavily concentrated in advanced economies.

There are positive signs they are still not enough, even during 2022 worrying signs occurred: gas use has declined, but not enough, we have gone from the golden age of gas to the golden age of LNG., coal investment is higher than pre-pandemic levels, low carbon fuels are only a small portion, energy efficiency is not under expected pace specially in a period of high energy prices, critical minerals could be a constraint for energy transition goals, slow permitting and bureaucratic processes that projects cannot be developed at the speed expected, NIMBY social position movements.

**Renewables alone isn't enough. Energy transition is also about storage, heat pumps, hydrogen, grids, CCUS, energy efficiency, flexibility.**

Storage strategies and business models for front-of-the-meter and after-the-meter in short, mid and long duration storage are moving slowly by specific regulations and the difficulty to monetize getting clear returns, usually together renewables plants and stand-alone grid-scale uses are being a promising growing year to year.

About 50% of all energy consumed in OCDE countries is used for heating and cooling and more than 70% still comes from fossil fuels. Heat pumps are a mature technology that is much more energy efficient than boilers would nearly double their share of heating in buildings by 2030 at current growth rates. New applications of electric water heaters could also work as household batteries, storing energy and saving billions in full-electric homes powered by renewable energy.

Grid infrastructure, especially in weak grids, is being a limiting factor for renewable deployment constraining the grid access capacity and starting to see the first global awareness about curtailments situations due to this grid issue.

Carbon capture, utilization and storage (CCUS) technologies have entered into a new era offering a strategic value tackling emissions in sectors where other technology options are limited expecting to abate 20% of total current $CO_2$ emissions in 2050.

***Time matters and carbon budget is running out.***

## Hydrogen. Hype or hope?

Hydrogen is still in the early stages but has the potential to be one of the most technologies capable of accelerating the energy transition in heavy industry and long-distance transport uses, living an undisputable momentum strengthened by energy crisis and expecting to be the next 1trn business.

**1.5°C energy transition pathway will require the use of all technologies and a massive change in how produce and consume energy.** Many of technologies are currently fully available as renewables, heat pumps or energy efficiency, and another will need to be developed, improved or optimized as storage, EV, carbon capture or hydrogen. Despite some progress we are far from being on energy transition track and multiple actions are needed to be on the right track.

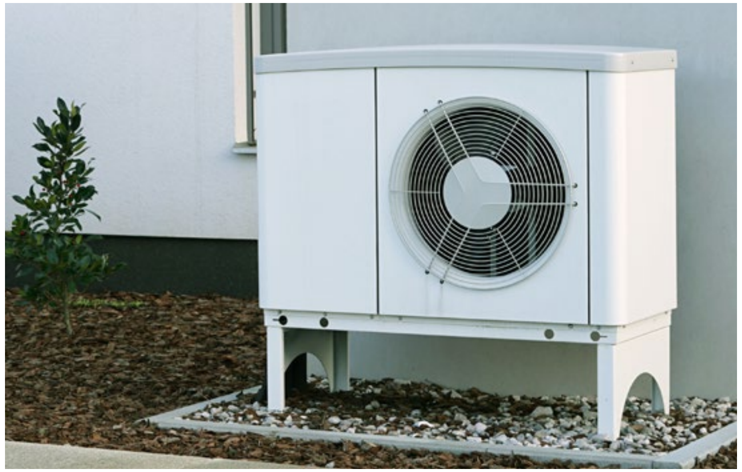


**FIGURE 2**

IRENA Tracking progress of key energy system components to achieve the 1.5°C scenario

| | Indicators | Recent Years | 2023 | 2050 | Progress off/on Track |
|---|---|---|---|---|---|
| RENEWABLES | **ELECTRIFICATION WITH RENEWABLES** | | | | |
| | Share of renewables in electricity generation | 28% | 67% | 91% | |
| | Renewables power capacity additions | 295GW/yr | 975GW/yr | 1066GW/yr | |
| | Annual solar PV additions | 191 GW/yr | 551 GW/yr | 615 GW/yr | |
| | Annual wind PV additions | 75 GW/yr | 329 GW/yr | 335 GW/yr | |
| | Investment needs for RE generation | 468 USD billion/yr | 1300 USD billion/yr | 1382USD billion/yr | |
| | Investment needs for RE generation | 274 USD billion/yr | 548 USD billion/yr | 790 USD billion/yr | |
| | **DIRECT RENEWABLES IN END-USES AND DIRECT** | | | | |
| | Share of renewables in final energy consumption | 19% | 34% | 83% | |
| | Solar thermal collector area | 746 USD million m²/yr | 1700 USD million m²/yr | 3700 USD million m²/yr | |
| | Modern use of bioenergy (direct use) | 1.5EJ | 44EJ | 56EJ | |
| | Geothermal consumption (direct use) | 0.4EJ | 1.3EJ | 2.2EJ | |
| | Renewables based district heat generation | 0.9EJ | 4.3EJ | 12EJ | |
| | Investment needs for renewables end uses and district heat | 13 USD billion/yr | 269 USD billion/yr | 216 USD billion/yr | |

2

| | Indicators | Recent Years | 2023 | 2050 | Progress off/on Track |
|---|---|---|---|---|---|
| ENERGY EFFICIENCY | Energy intensity improvement rate | 0.6%/yr | 3.5%/yr | 2.9%/yr | |
| | Investment needs for energy conservation and energy | 295 USD billion/yr | 1772 USD billion/yr | 1493 USD billion/yr | |
| ELECTRIFICATION | Share of direct electricity in final energy consumption | 22% | 29% | 51% | |
| | Passenger electric cars on the road | 10.5 million | 355 million | 355 million | |
| | Investment needs for charging infrastructure of EV's and EV addoption support | 30 USD billion/yr | 141 USD billion/yr | 364 USD billion/yr | |
| | Investment needs for heat pumps | 64 USD billion/yr | 266 USD billion/yr | 258 USD billion/yr | |
| HYDROGEN | Clean hydrogen production | 0.7 Mt/yr | 21.4 Mt/yr | 518 Mt/yr | |
| | Electrolyser capacity | 0.5 GW | 233 GW | 5722 GW | |
| | Investment needs for clean hydrogen and derivatives infrastructure | 1.1 USD billion/yr | 80 USD billion/yr | 170 USD billion/yr | |
| | Clean hydrogen consumption industry | 0.04 EJ | 2.4 EJ | 40 EJ | |
| CCS AND BECCS | CSS/CCU to abate emission in industry | 0.01 $GtCO_2$ Captured/yr | 1.0 $GtCO_2$ Captured/yr | 3.0 $GtCO_2$ Captured/yr | |
| | BECCS and other to abate emissions in the industry | 0.002 $GtCO_2$ Captured/yr | 0.7 $GtCO_2$ Captured/yr | 1.0 $GtCO_2$ Captured/yr | |
| | Investment needs for carbon removal and infrastructure | 6.4 USD billion/yr | 18 USD billion/yr | 107 USD billion/yr | |

# EMPOWERING YOUR SPACE: EFFECTIVELY LEVERAGING BUILDING EFFICIENCY TECHNOLOGIES


JOANNE SIU, UK


CHARLOTTE WARD, UK

## Accelerating zero-carbon buildings

**Buildings account for almost 40% of global energy-related carbon dioxide emissions – more than the global transportation sector. To achieve net zero emissions by 2050, all new buildings, as well as 20% of the existing building stock, must be zero-carbon ready by 2030.**

Innovative technology makes it possible to achieve a 60% energy efficiency improvement at present. But to be on track for zero-carbon buildings by 2050, an 80% efficiency savings by 2030 is needed. This is possible only with significant investment in R&D and vast electrification implementation.

Upgrading buildings will unlock a huge sustainability benefit, as well as long-term cost savings. Those using the buildings will also experience improved comfort and productivity. People can make a significant impact on old and new builds through passive strategies, active technologies, data and analytics, and renewable energy solutions (RES).

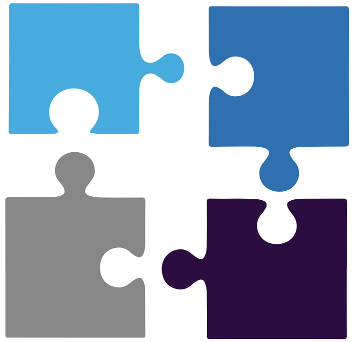
26% of energy-related emissions are directly or indirectly caused by building stock. About 20% of these emissions are accounted for in the construction process and the embodied carbon in building materials. However, 80% of these emissions are caused by the direct and indirect emissions produced throughout the building's lifecycle, which will be the focus of this article.

Emissions are only growing year on year. Population growth, combined with an expectation for more space per individual through declined household sizes around the world, is intensifying pressure on the energy system. In fact, total building footprint has increased by approximately 70% since 2000 (80% of which is residential), while the energy use per square meter has declined by only 20%. Combine this trend with improved access to energy, especially in developing nations, increased heating and cooling appliances due to more extreme weather, and higher ownership of energy-consuming appliances, and the average energy used in buildings could increase by 70% by 2050 without targeted energy efficiency improvements.

More stringent policies, supportive financing, improved consistency in design standards and tools, upskilling programs across construction, and better use of data and analytics technology is needed globally. In addition, without an improvement in collaboration at a local, regional, and global level, zero-carbon buildings will remain a pipe dream.

**FIGURE 1**

Strategies for energy transition



## Who's winning in the race for energy efficiency?

Despite the significant carbon impact figures we face today, there is optimism for the future in Europe, parts of the U.S., and China, where the goal of achieving zero-carbon, energy-efficient buildings by 2050 is promising.

The American Council for an Energy-Efficient Economy's (ACEEE) 2022 building energy efficiency ranking provides insight into how close the countries' building stock, on average, is to achieving zero carbon for both retrofits and new builds.

The Netherlands is leading the way with strong building regulation across both residential and commercial, closely followed by France, Spain, and Germany. China comes in fifth, having comprehensive energy use reduction, building code regulation, and appliance labelling despite an overreliance on coal.

The most energy efficient countries act as pathfinders globally. Similarly, individual projects can showcase and inspire scalable solutions.

**Country case study: Iceland's 85% renewable power mix.** In the 1970s, the United Nations Development Programme (UNDP) classified Iceland as a developing country with no integrated grid system, inexperienced institutions, and a sparse population. By fostering cooperation among municipalities, government entities, and actively engaging the public, local communities gained a sense of empowerment. This enabled the country to transition to geothermal and hydroelectric power sources, harnessing the potential of its natural environment.

**City case study: Milan MIND Project.** A €4 billion project transformed the 2015 World Expo grounds into Europe's largest testbed for innovation, exploring green architecture and urban living. Milan Innovation District (MIND) aims to become a sustainable smart city tying together housing, offices, and municipal buildings. E.ON ectogrid™ supplies the heating and cooling requirements for all 32 buildings in one system. This results in a circular energy system that intelligently distributes energy for heating and cooling.

**Building case study:** Energy Command Center (ECC). Next-generation technology plays a critical role in increasing building energy efficiency. Capgemini has introduced the Energy Control Center (ECC). Established in India at its facilities and structured around an IoT-based architecture, this framework enhances resource management and facilitates the efficient monitoring of energy assets within the designated location.

Since the launch of ECC, energy efficiency has increased by 25% and maintenance costs have been reduced by 20%. This solution is available to customers for similar site needs.

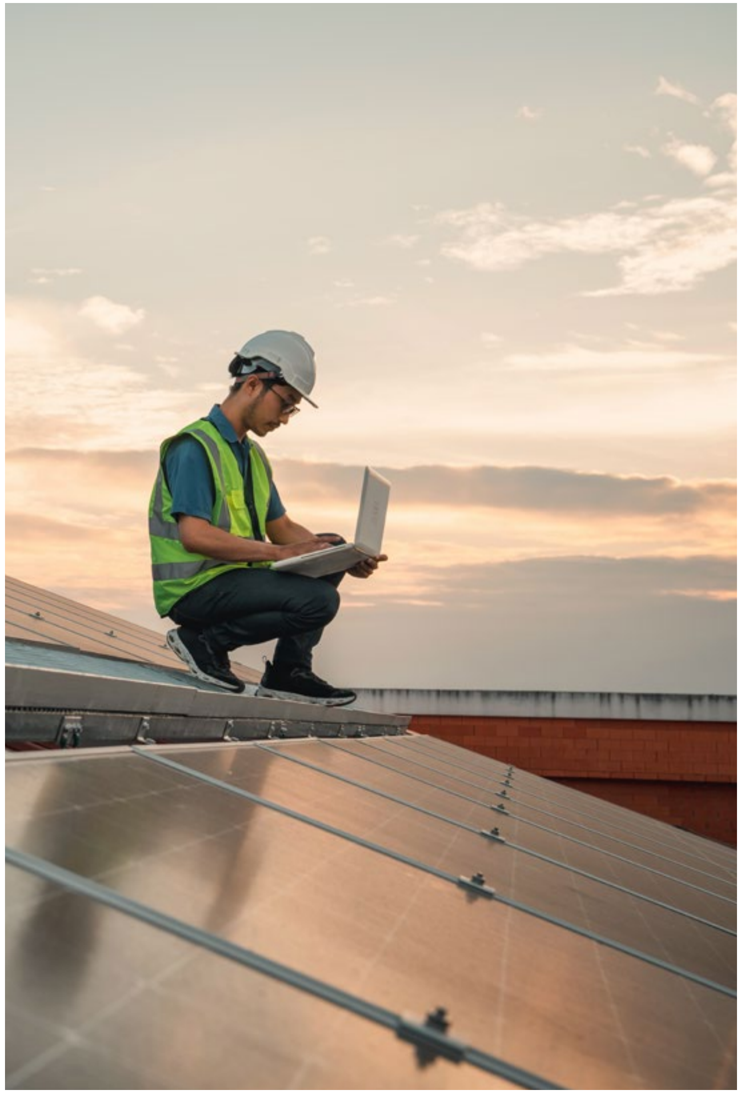
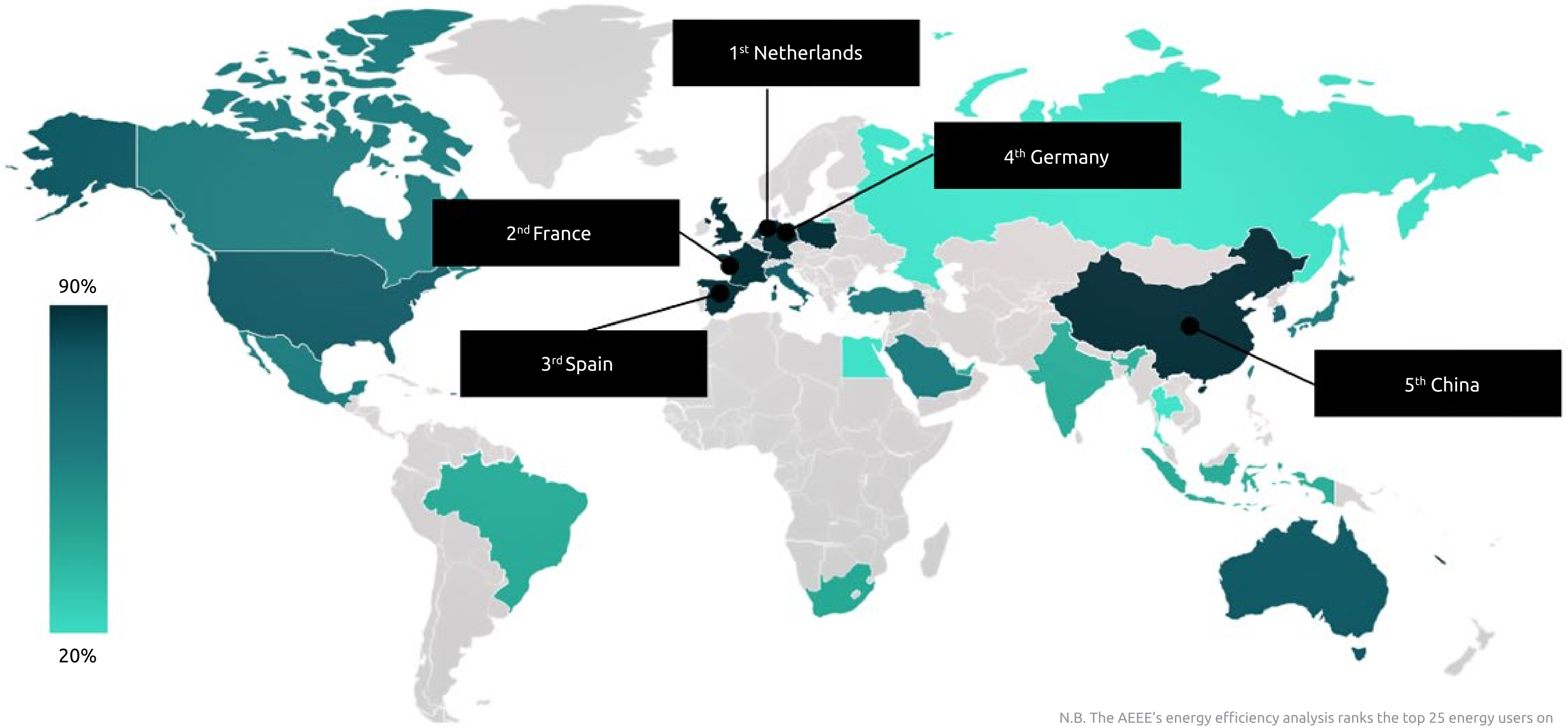


**FIGURE 2**

Energy Efficiency rankings (including policy measures and performance metrics)




N.B. The AEEE's energy efficiency analysis ranks the top 25 energy users on 36 efficiency metrics including policy measures and performance metrics

# Zero-carbon buildings: Capitalizing on energy efficiency across the building spectrum

> *When people move house they are more likely to make improvements to their bathrooms and kitchens, but why not the efficiency of their houses, which can save them money - as well as emissions?"*
>
> **Baroness Neville-Rolfe,**
> Former Minister of State (U.K. Cabinet Office), 2016

Zero-carbon homes produce 75-80% fewer carbon emissions. This figure is based on improvements to energy intensity and renewable electricity provision, as well as minimized active emissions produced by the building and embodied carbon in the materials. This is achieved primarily by improving the building envelope's effectiveness and the heating and cooling systems.

To achieve the full potential, integrated building energy management systems must be implemented and utilized to manage all appliances, equipment, and technological innovations across the building ecosystem.

**The opportunity is clear, but the realization of such a task is daunting for every economy. Both new builds and retrofitting need sizeable amounts of work done so that they can reach zero-carbon ready buildings standards.**

This is especially true of retrofitting since each historic building has unique needs. One of the benefits of a deep energy retrofit (DER) over a conventional energy retrofit is that, instead of viewing items in isolation, the building is flexibly upgraded as an entire system. **This marks a transformative shift, elevating the standard 20% isolated energy savings to a significant enhancement in energy efficiency, reaching up to 60% or even more – a substantial leap forward.**

On top of retrofitting existing buildings, governments and individuals should ensure all new-build homes are net-zero emissions ready. Architects and construction firms must analyze the full process from start to occupancy to deliver a low-carbon home fit for the future as well as today. Energy-efficient designs consider factors from embodied carbon in materials to current and future energy consumption, a principle equally crucial in comprehensive renovation initiatives.

To attain the crucial goal of retrofitting 20% of existing buildings by 2030, every market must sustain an annual deep renovation rate exceeding 2% from the present day through 2030 and onwards. Furthermore, all newly constructed homes should be zero carbon-ready by 2030.

Europe is leading the way with multiple retrofitting projects since 2021. However the rate is around 1%, well below what is needed. This started with the least efficient buildings, followed by promotion of large-scale renovation programs and future targets of passive hospitals and passive schools by 2025.

The market value potential for retrofitting in Europe, totaling €245 billion (comprising turnover and investments) annually by 2030, along with its substantial carbon impact, is significant.

A study published by the Buildings Performance Institute Europe (BPIE) also states that for every €1 million invested in the energy renovation of buildings, an average of 18 jobs are created in the EU economy.

However, this market value will only be realized through creative new financing schemes. Government tax credits and rebates can help catalyze short-term uptake, but financial institutions need to continue to support energy companies' as-a-service propositions, which spread the cost and capitalize on the long-term savings, despite current high interest rate conditions.

***With the investment in deep renovations, there are millions of job opportunities possible.***

## The power of proactive change

Effective policy positions were a key enabler to change throughout Iceland's successful renewable electrification journey. In fact, the AEEE's energy efficiency analysis places government policy positions as the principal factor in comparing the country's energy efficiency levels.

Despite some countries having similarities in their building stock footprints, each has taken a different route in their policy. When comparing five well-known countries in their advancements in energy transition and construction, the outcomes are surprising.

Japan, despite being one of the most innovative construction markets in the world in earthquake technology, falls short across the board for energy efficiency policy, as does the U.S. for whole building energy intensity. The Netherlands performs well in most of the areas, setting a benchmark. This country has set thorough policies, ambitious standards, and requirements, but still relies on fossil fuels for too much of their energy mix. Across the board, these countries are struggling to apply fully-integrated electrification systems (Figure 3).

**FIGURE 3**

> *We've discovered that the cost of 'deep retrofit' [on a Nottingham council house] …is at least double the expected amount – averaging around £69,000."*
>
> **Professor Lucelia Rodriguez**
> Professor of Sustainable and Resilient Cities
> University of Nottingham

Financial support is the key – especially for the lowest-income communities. These communities inadvertently exhibit lower indirect emissions because of their limited financial resources. However, they still face substantial direct emissions since they lack the necessary support to invest in energy-efficient technologies and home upgrades.

Situation highlights the importance of finding inclusive solutions to alleviate the economic burden on communities.

Governments need to work with financial institutions, as well as commercial and residential stakeholders, to balance the financial costs in the short-term and achieve long-term carbon and cost savings. Examples include Weatherization Assistance Program (WAP) in the U.S. and Affordable Warmth Grants in the U.K.

Financially supported policies are not the sole drivers of change. Figure 4 outlines additional key factors for facilitating change.

| **Upskilling** | **Demand response (DR) programs** |
|---|---|
| The European Commission and the construction industry successfully joined forces to upskill and reskill three million workers (25% of the workforce) in the next five years through an initiative called the Pact for Skills. Other markets must follow suit. | Demand response programs are important to attaining decarbonization within the construction industry and beyond. These efforts have yielded notable electricity savings in Australia, the EU, and South Korea. In the case of the Auto DR pilot program in South Korea, there was a remarkable 24% increase in electricity savings. |
| **Cross-party collaboration** | **Energy efficiency standards and labelling programs (EES&L)** |
| Policy makers, financial mechanisms, the construction sector, and consumers all need to work together to achieve this goal. | Appliances and equipment are critical to achieving decarbonization and can result in energy reductions of 10-30% over 15-20 years in most regulated products across all countries. |

# Passive strategies enabled by active technologies and renewables are the key to acceleration

**FIGURE 4**

- Governments must make urgent reforms to the planning process for all types of renewable generation.
- Innovation to improve the energy generation potential of each asset ( e.g. solar PV or wind turbines) must continue, with existing assets upgraded strategically to maximize energy output.
- Trade of renewable energy reserves is key to balancing the enrgy mix, just as it is with fossil fuels.


- More effective collaboration is needed through universal labels across Building Information Modelling (BIN) and related tools for embodied carbon and energy modelling. This will enable immidiate insight n the effect of their design choices.
- Upskilling of the existing workforce in the cnstruction industry is needed to embed zero-carbon building ready practices by default into new building designs.

- Traditional electricity grids are not robust enough to support the needed electrification. data-driven prioritization is needed to strategically upgrade the physical infrastructure.

**The management of renewable power generation differs significantly from that of fossil fuel power stations. To effectively handle grid outages and surges, it's essential to make smart grids and virtual power plants the standard approach.**

- Data monitoring and management systems should be mandatory across all buildings, rather than being left t the discretion of private landlords.

**Just as phone app management optimizes energy demand and supply, building energy management systems should automatically adjust energy use, activate energy-saving mode for underutilized appliances, and offer proactive guidance on energy-saving opportunities.**

# Conclusion

## Zero-carbon buildings are the key to building energy efficiency

Accelerating the deployment of zero-carbon technology across the construction sector is crucial. Deep-retrofitting of the hardest-to-abate buildings must be prioritized today to create the step-change needed. Further, zero-carbon building methods must become the norm in both developed and developing countries.

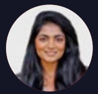
- **Governments:** Governments should follow the lead of the most energy efficient markets, which have set aggressive targets to boost deployment. In the Netherlands, all office buildings will be required by law to have an energy rate of C or higher by 2023; there is also a target to achieve an energy rate of A by 2030. The U.K. is on a similar path, targeting an EPC rating of C or above for all rented properties by 2028. With more support from governments in terms of policy setting and financial backing, there is a chance to set a more aggressive target, aiming for an EPC rating of B or above for all buildings by 2030.

**Consumers:** It is crucial to invest in preparing your residential or commercial property for zero-carbon standards today. Adopting a comprehensive deep renovation approach is essentia

- **Renewables developers, grid operators, and energy suppliers:** Focus less on 'quick wins' and accelerate where the largest opportunities lie. Ensure that upgrades today are future-facing as technology improves.
- **Financiers:** To achieve this, government, energy companies, and financial institutions must support business models which capitalize on the new market opportunity. Spreading the high upfront costs over time will accelerate uptake while providing long-term stable interest opportunities like mortgages today. This will ensure that the poorest in society are not left behind.

# DO WE HAVE MINERALS AVAILABLE TO REDUCE THE IMPACT OF CLIMATE CHANGE?


JEAN-MICHEL CHARETTE, AUSTRALIA


NEELAM YADAV, AUSTRALIA


JOHN WAREING, AUSTRALIA

## Turning our net-zero ambitions into reality

**It has become a necessity for the world to move towards renewable and clean energy sources sooner rather than later.**

**Are we on track to decarbonize our society in time to mitigate the severe impacts of climate change?**

**Decarbonization can be achieved through operational efficiencies, use of renewable energy, electrification and adoption of new technologies. To build the new technologies, raw materials must be provided by the mining industry.**

**Do we have enough minerals to achieve this?**

**What role will geo-political forces play?**

**How can we come together to make the required minerals available to bring the energy transition to life?**

The solutions coming to the energy market to enable and support decarbonization efforts continue to grow. Whilst we have seen increased adoption of corporate power purchase agreements (PPAs), we have observed growth in technology solutions becoming available, including wind turbines, advanced batteries, electric vehicles, metal recycling, carbon capture and storage, solar photovoltaics, hydrogen related fuels, artificial intelligence, etc.

There will continue to be a range of factors that will influence decarbonization efforts, such as customers, regulators and investors, and the impact of differing geographies.

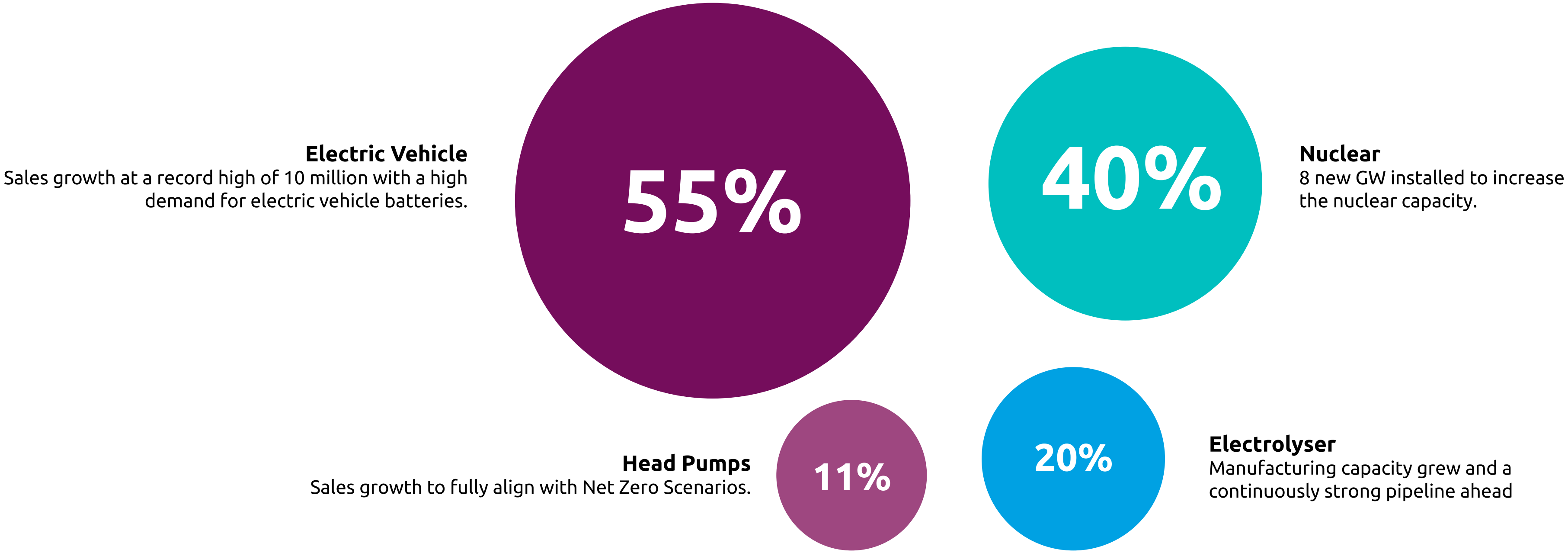
The availability of these technologies has improved over recent years, however, there is still a requirement to utilise a vast amount of minerals to create and scale the new technologies. For example, electric vehicles are dependent on lithium, meaning greater amounts of lithium will need to be mined and / or extracted.

### We can realise our net-zero ambitions. It will require everyone to work together, to re-invent our future.

The fight against climate change continues, however the world must work together to refresh the way we use energy, make resources available, and review our policies, economics and behaviors. Let's deep dive into understanding how the availability and location of minerals will play a vital role in the energy transition.

**FIGURE 1**

The progress on clean energy technology deployment in 2022 has grown
Clean Energy Economy in 2022




Source: IEA (2023), Tracking Clean Energy Progress 2023, IEA, Paris https://www.iea.org/reports/tracking-clean-energy-progress-2023, License: CC BY 4.0

## The race against time for clean energy technology deployment and rapid growth in 2022

The progress across the globe for clean technologies has been quick in some countries, however in others it's off track. Several steps have been taken towards Net Zero Scenarios which has led to the deployment of low emission technologies in the four areas over the years.

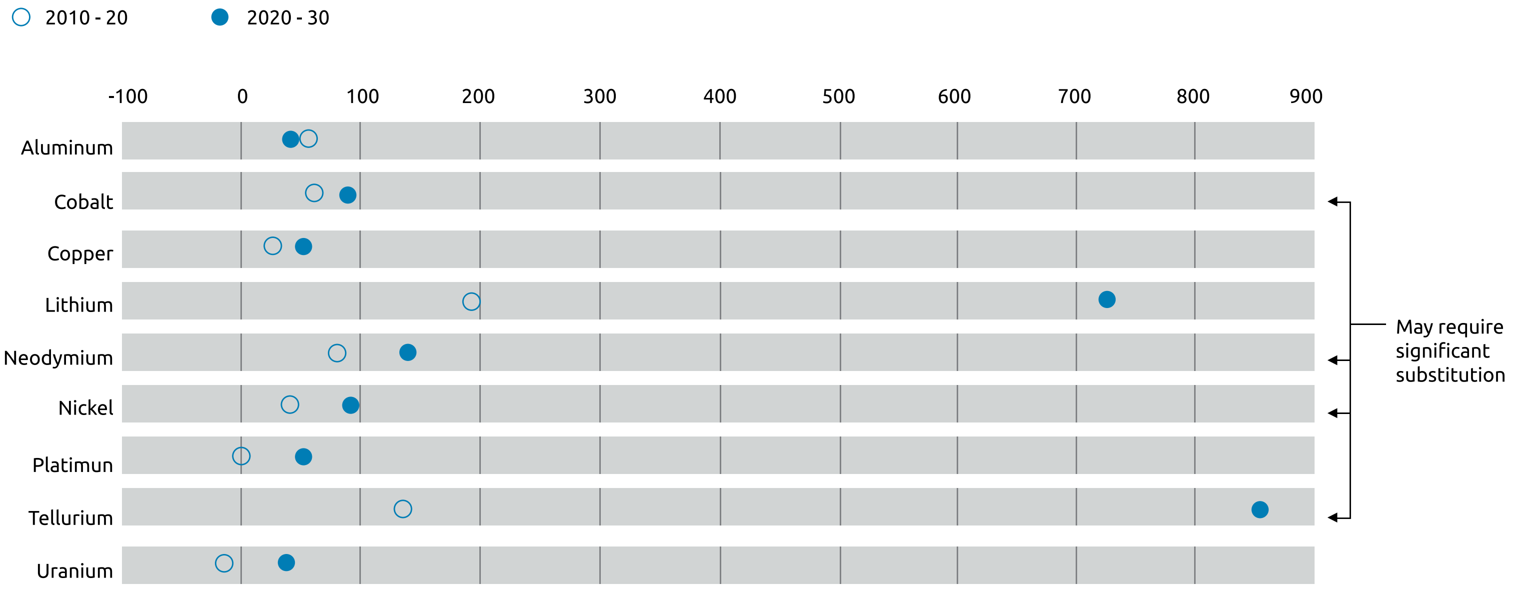
## Mineral and raw materials will be at the centre of decarbonization initiatives and electrification of the economy as we transition into a low-carbon economy.

Mineral and raw materials are poised to play a pivotal role in the ongoing efforts to decarbonize our industries and drive the electrification of our economy, particularly as we steer towards a low-carbon future. As the world seeks to reduce its carbon footprint and transition away from fossil fuels, these essential resources are at the heart of the transformation. They are the building blocks for the renewable energy infrastructure, electric vehicles, and various sustainable technologies that will underpin the eco-friendly economy we are striving to achieve.

For the technology transition to occur as forecasted, the raw-materials growth will need to advance at a rapid pace, as compared to earlier calculated rates. The demand for minerals has exceeded the calculated historical rates and will continue to grow in the coming years. As shown in the visual above, the forecast for minerals like cobalt, copper, lithium, neodymium, nickel, platinum and tellurium has exceeded the historic usage in the last decade.

**FIGURE 2**

Forecast of consumption of rare minerals and a comparison from last decade




Source: McKinsey and Company, January 2022, https://www.mckinsey.com

## How quickly can the mining industry meet the demands?

Steel is a crucial metal and infrastructure enabler across all elements of the low-carbon economy, however specific elements will be playing a vital role in technology transitions. Below is a view of essential materials required for the shift toward a sustainable, low-carbon economy, categorized by their respective technology types.

### Consideration #1: Location

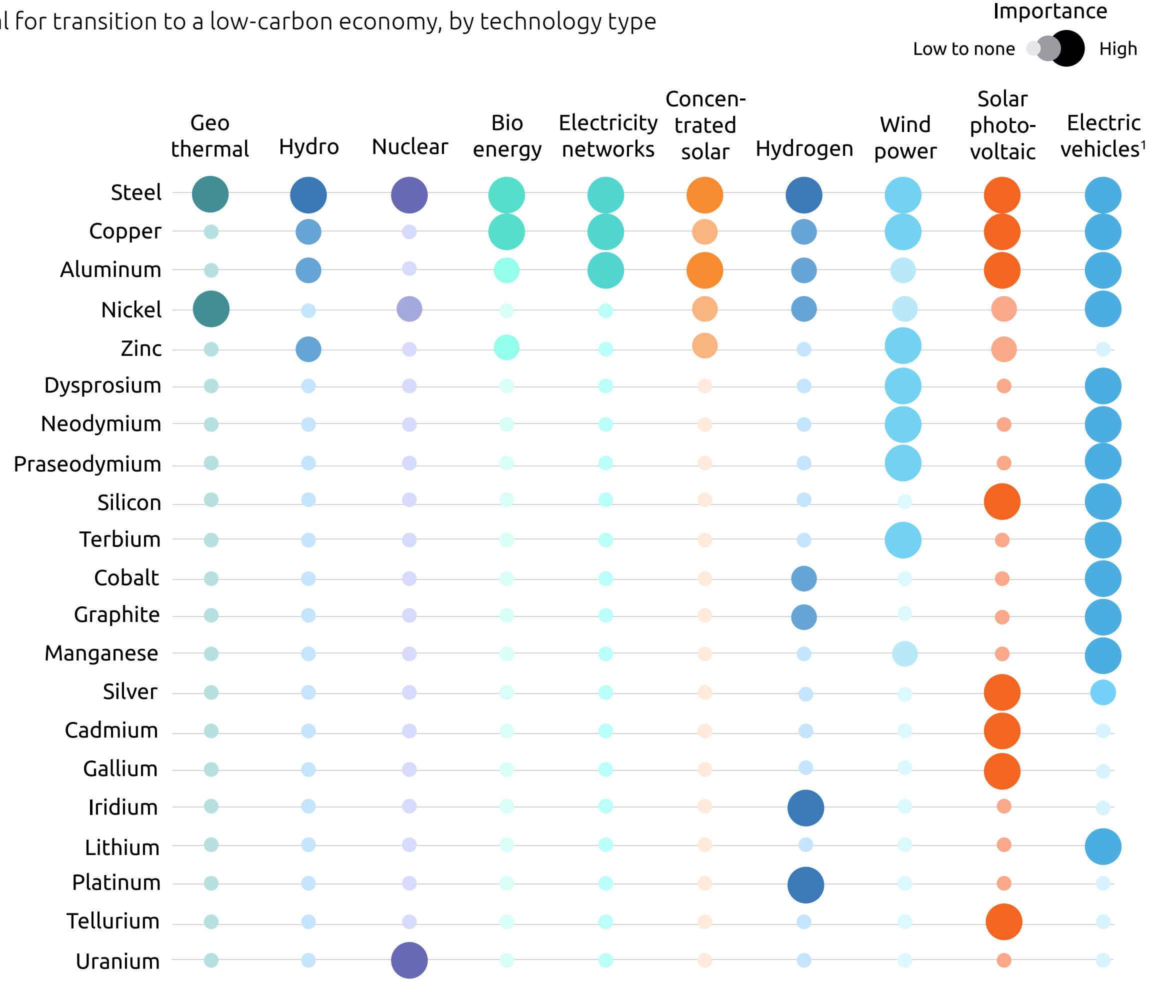
The world's mineral raw materials are known to be of great economical value and are vital in our modern and emerging society. For example, minerals are crucial to battery performance, longevity and energy density, as well as for wind turbines and electric vehicle (EV) motors, as stated by the International Energy Agency.

Mineral reserves, such as iron, copper, nickel, cobalt, graphite, rare earths and lithium, are spread across the globe. The top producing countries in extraction vary by mineral type, however China is one of the largest producers of many of the world's critical minerals. Following China, the United States, Australia, Russia, India, Brazil and Canada are recognised as key producers. Other countries such as Chile and the Democratic Republic of the Congo are large producers of specific minerals, lithium and cobalt respectively.

Location of minerals plays a key role in solving for decarbonization, as it can present a different set of challenges per geography, such as physical change to climate increasing the risk of assets.

**FIGURE 3**

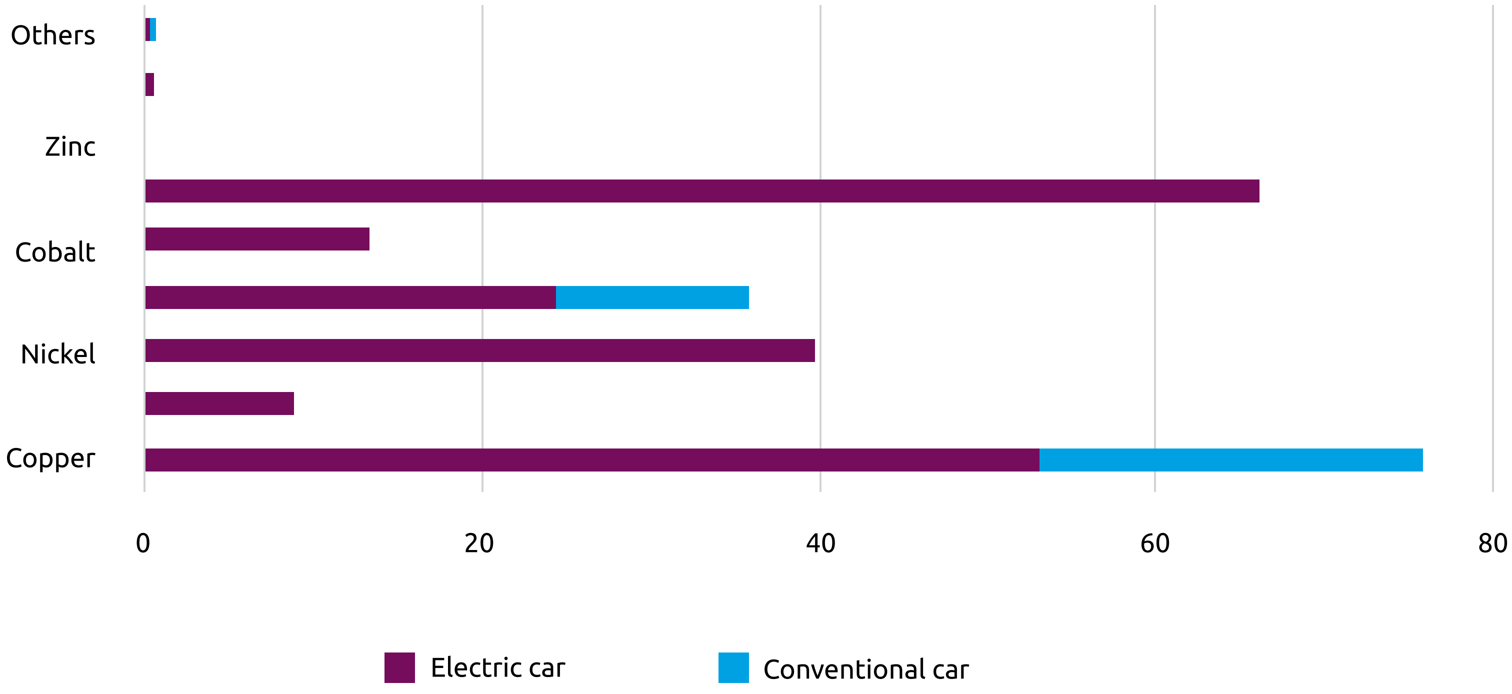
Materials critical for transition to a low-carbon economy, by technology type




Source: McKinsey and Company, January 2022, https://www.mckinsey.com

FIGURE 4

Minerals used in electric cars compared to conventional cars (kg/ vehicle)




Source: IEA

**Consideration #2: Geo-political factors**

The last 18 months has shown us the impact that conflict between two or more countries can have on the world, the flow-on effect to global businesses and the influence on our societies and practices.

The ongoing conflict between Ukraine and Russia, the increasing tensions between USA and China, and rise in resource nationalism are felt by miners as they continue to be under pressure to resolve supply-chain challenges and transform rapidly.

Geo-political influences can have further implications for countries with emerging policies. For example, countries looking to nearshore critical minerals under new policies or legislation may result in inclusion of some but not all countries. Where countries are not aligned on new policies, this opens the door for other players, introducing increased competition.

Periods of geo-political instability increase the risk of disrupting or reducing interdependencies between countries, particularly those that have standing agreements in place.

Amidst these rising challenges, how can we work together to make the required minerals available for decarbonization technologies?

With challenges, comes opportunity. There is a large focus on energy transition, and 'going green', meaning there is an increase in scope for investment in geographies that are rich with critical minerals. Further, countries can take advantage of changing geo-political environments to advance trade agreements and increase collaboration across mining extraction and production. Governments also have a key role to play here, by building stronger ties with other countries and industry / sector groups, and in turn developing shared policies, behaviours, and methods to safely transition.

G20 Nations Summit are the driving force for leading the brighter path for humanity and the 2023 summit focussed on three themes:

**1. Climate Change**

**2. The Blue Economy**

**3. Resource efficiency and circular economy**

**Consideration #3: Nationalization/sovereignty of resources**

In late April 2023, Chile's government announced a major policy change to its lithium mining industry. The new policy will require private organisations to partner with the Chilean government for the development of all future lithium mines. Some have termed this as a 'nationalization' effort, others see this as a balancing act retaining involvement from the private sector.

The Chilean government has proposed to create a new state company, National Lithium Company, and will follow the existing model of Chile's state-owned copper company, Codelco.

The policy change will set a precedence for the rest of the world, particularly as critical minerals become a key focus for many, such as lithium. Whilst Chile falls behind Australia as the leading producer of Lithium, they are still a significant contributor to the global lithium supply chain.

The national approach will likely require private companies to agree to new terms, focusing on reducing or eliminating environmental damage, providing improved conditions for workers, increasing consultation and engagement with Indigenous and local communities, and utilising new technologies. Regarding the concept of exporting raw materials versus producing the finished product within a country, it's important to recognize that the worth of the end product, such as a battery, can significantly surpass the value of the initial raw material, like lithium, often by a factor of 100 or more.

With the shift, there is an inherit risk for Chile and other countries that follow this pathway – Foreign investors and mining companies may look to other countries for lithium opportunities, if Chile is regarded as less attractive. This may open the door for Argentina and Bolivia, who make up the 'lithium triangle' together with Chile. On the other hand, opportunities exist for countries to enter into treaties and agreements. For example, the US-Chile tax treaty that has been recently approved by the US Senate, in turn resulting in tax rate reductions and other benefits, enabling greater US involvement in Chile's lithium industry.

## Consideration #4: Recyling

With the need for critical metals accelerating, there is a need for recycling and sustainable practices across the value chain. Recycling will also support the need to reduce carbon emissions. The carbon footprint of recycled material is much lower than the original material.

New legislation, such as the **European battery passport**, are making recycling compulsory. The industry needs to come together to ensure recycling is standardised across the value chain.

**"Black mass"** is obtained when dismantling batteries and it is made up of many recoverable rare metals and separated into ferrous and non-ferrous materials. The S&P Global launched regular pricing of this material in 2023 and the carbon footprint of recycled materials has a much lower carbon footprint than the original material itself.

The graph below shows the Ni and Co Black Mass calculated prices in $ per metric ton for Europe and US, and Yuan per metric ton for China.

***Technology progress and the mineral recycling process can bridge the gap and create a balance between rare mineral consumption and the high cost of such materials.***

**FIGURE 5**

Recycling process for Li-Ion batteries

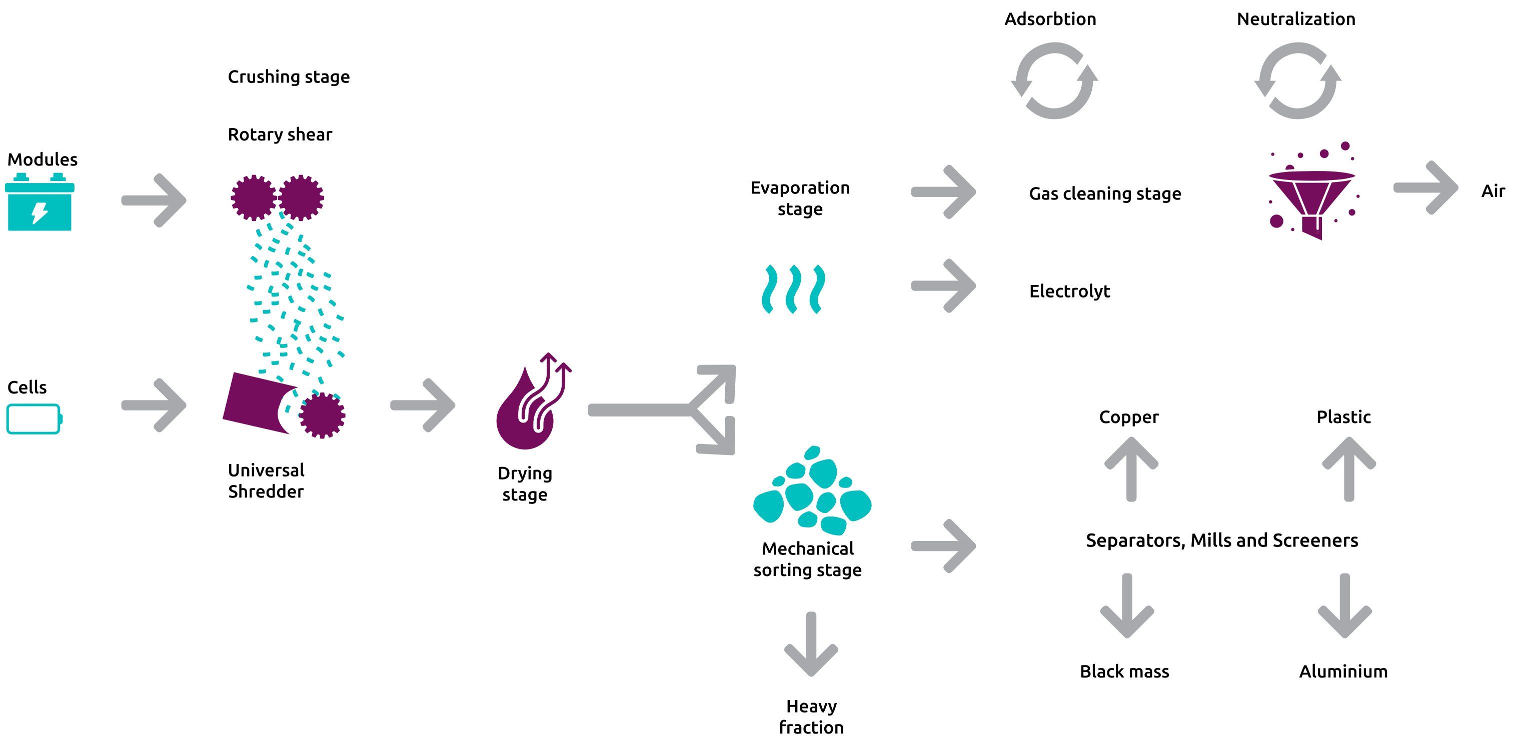
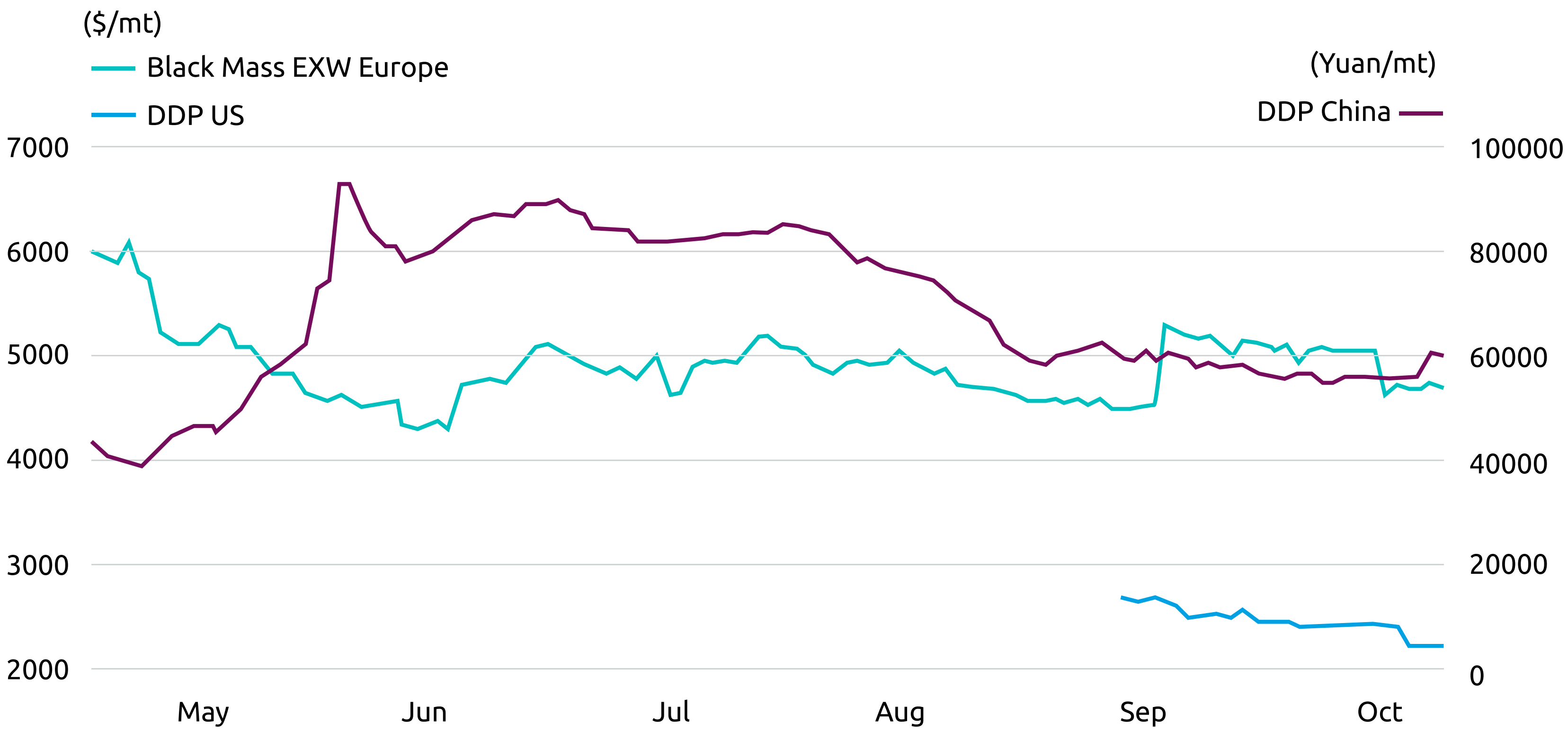


FIGURE 6

Platts global Ni-Co Black Mass calculated prices



# Conclusion

**These considerations must be explored to increase availability of critical minerals to reduce the impact of climate change around the world. We should acknowledge the complexity and scale of the challenge at hand, noting this cannot be solved for in isolation.**

It is understood that we must mine additional minerals to create the technologies we need to decarbonize. We have started to see examples of increased collaboration between countries to support this, however further work is required to establish practical consortiums and working groups.

We've gone past the stage of simply setting and forgetting goals, we must re-visit and bring them to life through action. We must also remember that whilst this is a global effort, we must continue to engage with local communities to minimise impact from a people, and biodiversity perspective.

***We can only ascertain the minerals we have available on earth if we work together, to build the future we want for ourselves and those that come after us.***

We recommend starting the conversation now.

## Call to action

- **Government and policymakers –** Designing the policies and processes from the nation's ability to maximise the resources for the change we are experiencing around energy transition, to add the most impactful value. Invest in value creation for the respective country.
- **Miners and refiners –** Collaborate and engage across industries to drive meaningful change and ensure that the critical mineral resources we need are available to produce the technologies to reduce the impact of climate change. Moving away from the traditional approach and harnessing the technology for the benefit of future generations.
- **Industrial consumers -** Manufacturers in the clean energy and automotive sectors have a range of choices within their supply chain when it comes to sourcing minerals. They have the capacity to strike a harmonious balance between ethical considerations and economic value, thereby ensuring both the sustainability of their industry and the well-being of their organization.

# FINDING OPPORTUNITY IN THE HEAT TRANSITION

SIMON BROD, NETHERLANDS

Energy use in buildings is a major source of $CO_2$ emissions worldwide, representing 27% of global energy and process-related emissions. Buildings used 135 EJ of energy in 2021. Space and water heating is responsible for a little under half of this (62 EJ), producing around 2.5Gt of $CO_2$ as direct emissions from burning natural gas, oil, or coal consumed on site. A further 1.5 Gt was emitted from district heating plants and power stations serving buildings with heat and electricity for heating. The amount of energy used in space and water heating is equivalent to roughly 60% of the electrical energy consumed worldwide.[1]

Some 40% of the world's human population lives in areas where some kind of space heating is needed. Residential heat load is expected to remain stable in coming decades, while the number of large buildings needing heating is expected to increase. Of the world's energy consumption for space and water heating, some 50 to 60% is in advanced economies. Around half the heat load is represented by households.[2]

This article focuses on heating rather than heating and cooling. While cooling load is expected to increase, and will bring its own challenges, most cooling systems are electrical, with no $CO_2$ emissions at the point of use. In contrast, a large share of heating systems burns fossil fuels directly. This is where decarbonisation efforts are urgently needed.

## Electrification is essential

Many approaches have been proposed for the heat transition. There are overwhelming advantages to tackling it through electrification:

- **Most countries already have a goal of increasing the penetration of renewable energy sources (RES) in their energy mix.** By making heat load electric, decarbonisation will take place along with the rest of the electricity system. A desirable side-effect is reduced dependence on imported energy. Countries with a high penetration of zero-carbon energy (such as Norway and France) already use electricity for space heating, as this was historically their cheapest option. This situation will become widespread around the world over the next few years, as almost all countries increase the share of renewables in their electricity mix.
- **Efficiency will increase.** Electrification enables deployment of heat pumps which are much more efficient than direct heating, thus reducing load on the energy system as a whole. Heat pumps can provide as heat two to five times what they consume as electricity, enabling significant amounts of heat load to be electrified without a corresponding increase in electricity generation and transmission capacity. Currently, heat pumps provide around 8% of heating worldwide. This will rise to over 50% by 2050, according to the IEA's 'net zero' scenario[3]. Each year, more than 1% of heating systems worldwide will need replacing, representing tens of millions of installations per year.

1 All based on IEA, 2021 data and https://www.iea.org/reports/the-future-of-heat-pumps
2 https://www.iea.org/reports/the-future-of-heat-pumps
3 https://www.iea.org/reports/the-future-of-heat-pumps

- **Demand flexibility from heating will be available to the electricity system.** Deploying millions of electrical heating devices offers the potential to modulate electricity demand (for example, by allowing indoor temperature to vary within certain limits, or by storing energy in the form of hot water), helping the grid manage large amounts of variable RES generation cost-effectively. Such smart technology can be used to reduce the need for capital-intensive grid strengthening.

There are technologies which can help decarbonise heat supply without electrifying – such as green or blue hydrogen, biomass, biogas or geothermal. These can be attractive if they reduce the need to invest in new infrastructure (for example, some countries such as the UK and The Netherlands are considering repurposing existing gas networks for hydrogen). None of these technologies is suitable beyond niche applications. For example, using biomass as a fuel can make sense in areas which already have a heat distribution network and access to properly sustainable biomass. Using green hydrogen as a fuel can make sense in areas that already have a large surplus of renewable electricity at all times which can be used to generate hydrogen. Producing biogas at scale competes with food production, which limits its availability. Geothermal heat can only be safely accessed in certain places. Blue hydrogen might provide a temporary step towards decarbonisation but is only a partial, costly solution, and its use will delay measures which can fully decarbonise our energy system.

Waste heat from industry, water treatment, data centres, and the like, is a large, potentially cheap resource. In Europe, some 2.5 to 9.8 EJ/year of such excess heat may be recoverable[4], while space and water heating demand is 13.1 EJ/year[5]. In areas where a district heating grid already exists, such heat sources should be used where possible. Areas without a heat distribution network will need to carefully consider the costs, risks, and benefits of investing in one. District heating currently supplies some 10-15% of Europe's heat load.

The heat transition will be accomplished largely through electrification. In certain places, local conditions will make it cost-effective for electrification to be combined with other technologies.

4 https://heatroadmap.eu/wp-content/uploads/2019/04/Urban-Persson_Halmstad-University.pdf
5 https://heatroadmap.eu/wp-content/uploads/2018/09/STRATEGO-WP2-Background-Report-4-Heat-Cold-Demands.pdf

## Multiple challenges and opportunities must be addressed

At the level of the individual house or building, the optimal solution varies widely, even within the same neighbourhood. For example, in the Netherlands city of The Hague, only 50% of housing units are suitable for a heat pump without other modifications[6]. Those that are not suitable may need insulating first or may need to modify their heating system in other ways. Innovations such as high-temperature heat pumps extend the range of homes which can easily be upgraded. But many homes face the cost and disruption of a major refurbishment. A typical ground source heat pump retrofit for a house costs US$10,000 or more. Costs can be far higher when combined with other modifications to the heating system or the building. The wealthiest households can afford this, but for a mass roll-out to take place, financing needs to be provided. Large buildings will see lower specific costs than individual households, thanks to economies of scale.

If large numbers of houses are to convert to electrical heating the electric grid will need strengthening. This can partly be mitigated through local energy storage in batteries or as hot water, enabling the neighbourhood to smooth its demand over time and even absorb surplus energy at times of high wind and solar electricity production. Coordination at a neighbourhood or city level also opens new possibilities to reduce system costs - for example, making the complex trade-off between running larger, central, heat pumps combined with a heat distribution network, and having a separate heat pump for each building.

In tandem with electrification, in some neighbourhoods it will be possible to use other sources of zero-carbon heat. Geothermal sources are accessible in some areas. And certain waste heat streams from industry can be recovered. For example, Meta's hyperscale Tietgenbyen data centre in Odense, Denmark is donating waste heat into the local district heating grid, providing energy to warm more than 11.000 homes[7]. Such use of waste heat is a good way to decarbonise but requires homes to be connected to a (local) heat grid. In specific situations building such a grid can make economic sense.

## The economics today are marginal

Subsidies are needed. The US government has earmarked USD 8.8 billion for home energy efficiency and electrification projects, aimed at low- and mid-income homes[8]. In Europe, subsidies vary per country, and are typically in the range of Eur 3.000 – 10.000 per heat pump installation[9]. Subsidies come mostly in the form of one-off grants, and are not explicitly linked to $CO_2$ emissions reductions. Estimates of payback times for a typical single-household heat-pump project in The Netherlands[10] are:

| | |
|---|---|
| Without subsidy | 12 to 18 years |
| With current level of subsidy | 8 to 13 years |
| With current level of subsidy and with $CO_2$ emissions reductions priced at 100 Eur/tonne | 7 to 10 years |

Experience with rooftop solar panel deployment in Western European markets indicates that, where financing is available, a 5-to-7-year payback time is sufficient for households. Large buildings will see better returns as the specific capital costs are lower for large systems, but business owners will have more stringent return requirements for making an investment.

6 Capgemini analysis, 2022

7 https://datacenters.atmeta.com/wp-content/uploads/2023/05/Denmark-Odense.pdf
8 https://www.energy.gov/scep/home-energy-rebate-programs
9 https://www.ehpa.org/wp-content/uploads/2023/03/EHPA_Subsidies-for-residential-heat-pumps-in-Europe_FINAL_March-2023.pdf
10 Based on: https://www.verbeterjehuis.nl/verbeteropties/volledig-elektrische-warmtepomp/

## What can be done?

Given the marginal economics, it makes sense to seek to reduce costs. There are many opportunities to capture economies of scale in carrying out the heat transition:

- **Standardisation:** if a whole city settles on a limited number of equipment choices, it will be able to negotiate better with equipment makers. There will also be savings in training installation and maintenance staff, in the time taken to install, and in the quality of the work.
- **Labour efficiency:** if building upgrades can be coordinated, then installation programs can move from district to district, carrying out upgrades as a well-structured industrial process.
- **Lower specific costs:** whatever technology is chosen, a general rule is 'the larger the equipment, the lower the capital and operating costs per unit of heat supply'. Pooling heat demand can make the difference between a marginal project and an attractive one.
- **Financing:** if large numbers of upgrades can be packaged together as one program, run by a reputable entity, it will be easier to attract debt finance.
- **System-wide cost-effectiveness:** if the energy system of a whole neighbourhood or city can be considered, rather than each building making an independent decision, optimal choices can be reached with respect to how central or distributed heat production should be, how much energy storage to include, whether to build electricity or heat microgrids and at what scale, and any additional energy sources to use.

To roll out new heating systems on a large scale, it will be necessary to mobilise households. What can be done to increase people's willingness to invest and to endure disruption? The most important driver is the extent to which homeowners perceive tangible benefits. For example, a study in rural India found that owners of homes that were not connected to a water supply were willing to pay a higher price than expected to get access to piped water. Willingness to pay was above the regulated price of water and was sufficient to justify the necessary investments in infrastructure[11]. When the benefits are as obvious as those of having clean water on tap, people want to pay. Conversely, a study in France of homes at risk of flooding found that most homeowners were reluctant to invest in even modest flood protection measures (such as installing non-return valves in sewage pipes), or to rearrange their home to reduce risk (for example, moving a kitchen from the ground floor to an upper floor). By far the most important determinant was the homeowner's perception of risk. Many felt the risk was remote or non-existent. Those that did feel at risk were willing to make the necessary changes.[12] Against this background, climate change emerges as a weak driver for most people. The risks seem remote and uncertain, and the benefits of decarbonising will be felt in the relatively distant future. Perhaps, with growing evidence of climate change making news headlines, more people will take the risks seriously.

Experience in the energy retail market suggests only a limited section of the population is prepared to pay more for renewable energy – perhaps 5% to 10% of households. This group can be increased by creating a sense of belonging and by giving people something to be proud of – being seen to be doing the 'right thing'. For example, Powerpeers created an energy sharing community with tens of thousands of members in The Netherlands. An important success factor was to find and mobilise local 'champions' to spread the message and act as trusted ambassadors. Such enthusiastic, intrinsically motivated community leaders can help create a feeling of belonging and re-set people's ideas of what is normal, boosting participation even when there is no financial return.

11 https://documents1.worldbank.org/curated/en/439161468034759169/pdf/447900PP0P09411413B01PUBLIC10PAPER1.pdf

12 https://onlinelibrary.wiley.com/doi/10.1111/jfr3.12696

## What might change the game for the better?

Certain events will help the heat transition, if they take place:

- **Technical innovation** around equipment such as heat pumps, and around smart system controls, could bring costs down and performance up. The world will more than double its fleet of heat pumps in the next 10 years[13]. Such large-scale deployment is likely to stimulate innovations that yield significant improvements.
- **Dramatically higher fossil fuel prices,** relative to electricity prices, will give project returns a boost. Barring geopolitical shocks, there is little prospect of this in the short-to-medium term. Long-term electricity prices are expected to fall, as the share of low-marginal-cost generation (such as wind, solar, or nuclear) increases.
- **A turning point in public sentiment,** caused by increasing climate-related disruption, would signal a step change in willingness to invest.
- **More decisive government action,** such as mandating the deployment timetable rather than relying on the market, could increase progress dramatically. While some western governments are starting to ban fossil-fuel technologies for home heating (for example, The Netherlands[14]), it is inconceivable that they would impose on citizens a centrally planned program of building upgrades. Autocratic regimes such as in China may make this possible.

Any of the above could significantly accelerate the heat transition.

## What steps should local communities and governments take?

Collective action is essential, otherwise heating system upgrades will be deployed piecemeal. By orchestrating the roll-out of upgrades and carrying them out at scale, the transition can happen faster and more cheaply. What does that require?

1. **Form a broad group** to evaluate and come up with a plan. Include citizen representatives, and local government, real estate, construction/refurbishment/installation industry, energy grid, energy supply, and finance sectors.
2. **Run educational campaigns** to inform people about climate change and about the benefits of decarbonising their homes. Find community leaders eager to champion the cause.
3. **Map the building stock** and evaluate solutions appropriate at neighbourhood level. Ask the following questions: How well insulated are buildings? What kind of heating system do they have? Are they suitable for a heat pump, and if so what kind? How much local RES is there? What are the constraints of the electricity grid? How much disruption will citizens accept for what reward? What opportunities are enabled for job creation and re-skilling? Consider different possibilities systematically, taking into account the costs and benefits for the whole system. Seek optimal solutions at a neighbourhood or city level.
4. **Standardise solutions** where possible for economies of scale, but make sure solutions work for all. Some buildings may simply be uneconomic to upgrade; focus on what can be easily achieved.
5. **Create a plan which addresses citizens' needs.** Ask the following: how will disruption be kept to a minimum? What benefits will they get?
6. **Take the time to publicise the plan and engage citizens.** Slow and thorough at this stage saves effort and delay later.
7. **Set up a competent body to oversee the program,** once you decide to go ahead and execute.

13 https://www.iea.org/reports/the-future-of-heat-pumps
14 https://www.rijksoverheid.nl/actueel/nieuws/2022/05/17/hybride-warmtepomp-de-nieuwe-standaard-vanaf-2026

Around the world, examples are multiplying where local communities have gone through some version of this process. Here are two examples which illustrate different approaches:

- **Republica microgrid, Amsterdam, The Netherlands –** The community consists of 74 apartments, office space, a large hotel, leisure facilities, a parking structure, and a restaurant space. Republica has become its own private grid operator, with both heat and electrical microgrids. Heating is provided by central heat pumps. A central battery enables the community to minimise its demand on the regional electricity grid while maintaining comfort for community members. The community benefits from consuming locally generated energy, lower tariffs, and lower energy costs.[15]

- **Heat the Streets scheme, Stithians, England –** hundreds of homes are being connected to a shared network of underground pipes which provide ground source heat. Individual households are spared the cost of this element, reducing the cost of their home heat pump installation by nearly two-thirds, and eliminating the need to modify their home heating system. In return, participants pay a fixed monthly fee for being connected to the network. This concept was initially championed by local residents and was awarded a GBP 6.2 million grant by the European Regional Development Fund (ERDF).[16 17 18]

15 https://spectral.energy/project/republica-microgrid/
16 https://www.kensautilities.com/
17 https://heatthestreets.co.uk/
18 https://www.theguardian.com/uk-news/2022/jun/22/cornish-village-to-pilot-communal-grid-to-source-low-carbon-energy

## What is likely to happen in practice?

In the advanced economies, political will is growing (not least because electrification of heating also increases energy independence). It is expected those economies will reach perhaps 30-40% of what's needed for net-zero in 2050. For this group of countries, the task is largely one of retrofitting existing buildings with new technology. The heat transition will progress fastest:

- **In places with environmentally minded populations and wealthy governments** (think Austria or Denmark). Here it will be easier to align all stakeholders and provide sufficient subsidies.

- **In places with large amounts of government-controlled social housing** (for example, Denmark or The Netherlands). This is often owned and managed at scale already, removing a big hurdle to systematic roll-out of new heating systems.

- **Among wealthy households.** This segment can afford the necessary investment and is more susceptible to wanting to be seen to 'do the right thing'.

- **Among commercial buildings.** Professionally managed buildings will upgrade whenever there is a competitive return on investment. They will act quickly to take advantage of (perhaps temporary) fluctuations in energy prices, or advantageous subsidies.

- **Among communities of residents.** Community schemes will proliferate wherever citizens feel motivated. Gradually citizens' groups and local governments will acquire the skills needed to execute the transition.

Developing countries will likely not have much appetite to invest in retrofits. But as growing economies, their building stock is increasing. If new buildings are fitted with zero-carbon systems, this group of countries will succeed in gradually reducing the carbon intensity of heating.

Opportunities will fall to those who combine a careful choice of which countries to do business in, with know-how in community leadership and in operations. Systematic deployment of heating upgrades is a challenge, but the potential scale makes it worthwhile to become expert at it, bringing together the interests of residents, building owners, equipment makers, energy suppliers, energy grids, financiers, and government. This is the biggest value add.

In conclusion, while it is unlikely the world will progress as fast as required to reach 'net-zero' in 2050, some optimism is justified. Technology to decarbonise exists and will improve. Electricity will be cheaper in the long term, making electrical heating more attractive. And, with luck, early success of some large roll-out programs will help shift public sentiment, boosting demand and creating a virtuous circle.

*Get in touch with the author at simon@circulusworks.com. Circulus Works brings a commercial mindset to sustainability and the energy transition. We support leadership teams in*
– *creating sustainability strategies that impact the real world; and*
– *executing those strategies through fit-for-purpose change, innovation, and go-to-market processes.*

# TRANSITION TO RENEWABLE ENERGY: PROGRESS AND CHALLENGES

NATASHA DOWLING, USA

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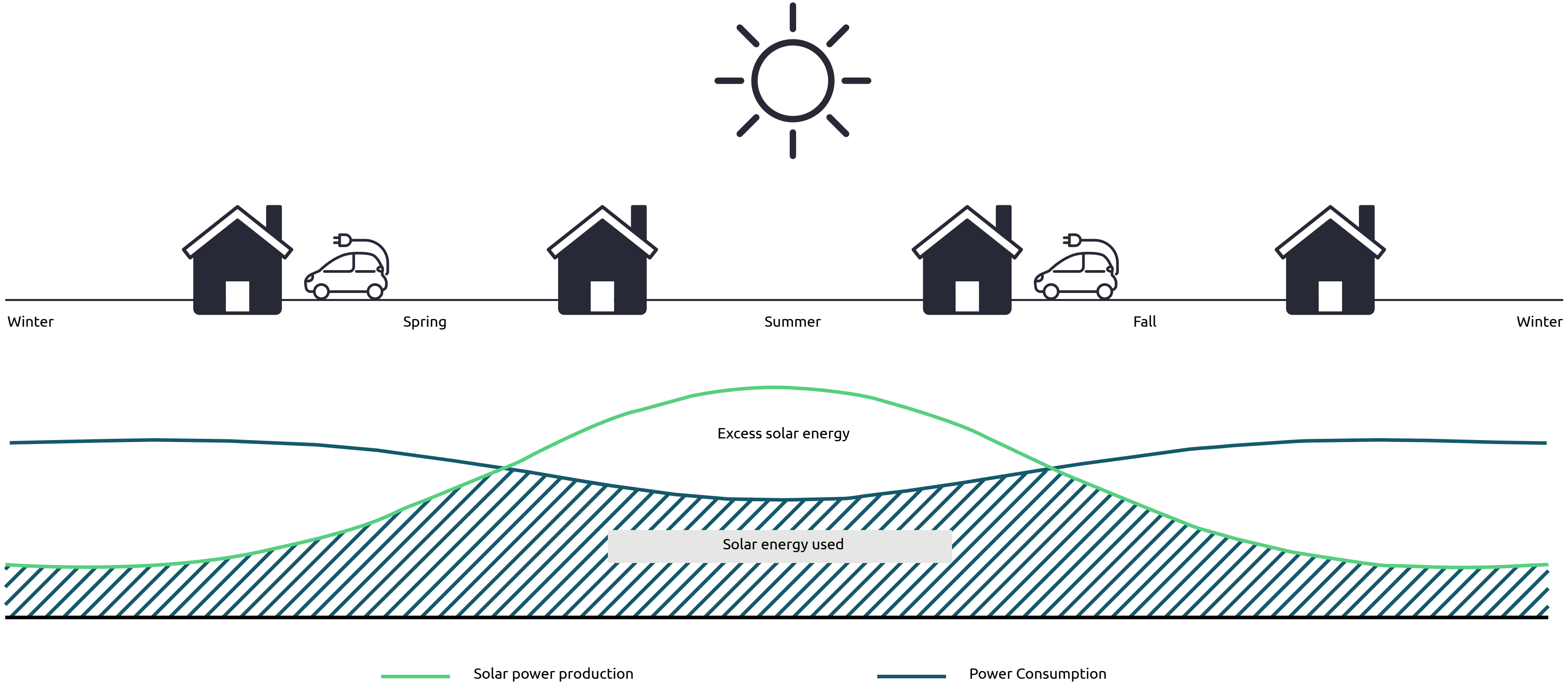
The need to switch to renewable energy production has become increasingly evident as we face the pressing challenges of climate change and environmental degradation. Renewable energy sources, such as wind and solar power, offer a sustainable and clean alternative to traditional fossil fuel-based energy generation. However, the transition to renewable energy is not without its obstacles. In this article, we will explore the progress made so far, the challenges we face when the wind doesn't blow, or the sun isn't shinning and the new business models and technologies that can help mitigate supply and demand gaps.

The energy transition worldwide has been marked by a significant increase in the penetration of renewable energy sources. By the end of 2022, renewable energy sources accounted for approximately 34.7% of global electricity capacity. Concurrently, there has been a phase-out of baseload capacity, such as coal and, to a lesser extent, nuclear power. While this transition is commendable, it presents grid operators with new challenges. As renewable energy deployment increases and fossil fuel baseload generation is phased out, there will be periods of overproduction but also periods of underproduction. In Figure 1, we observe a summer day characterized by abundant solar energy production, surpassing the corresponding demand, resulting in a noticeable mismatch between the two.

Renewable energy generation is inherently volatile and intermittent, unlike traditional power plants that provide constant and stable generation. This volatility can lead to imbalances between production and consumption, jeopardizing grid stability and the security of energy supply.

**FIGURE 1**

Different production and consumption profiles



## Unseen Challenges – behind the curtain

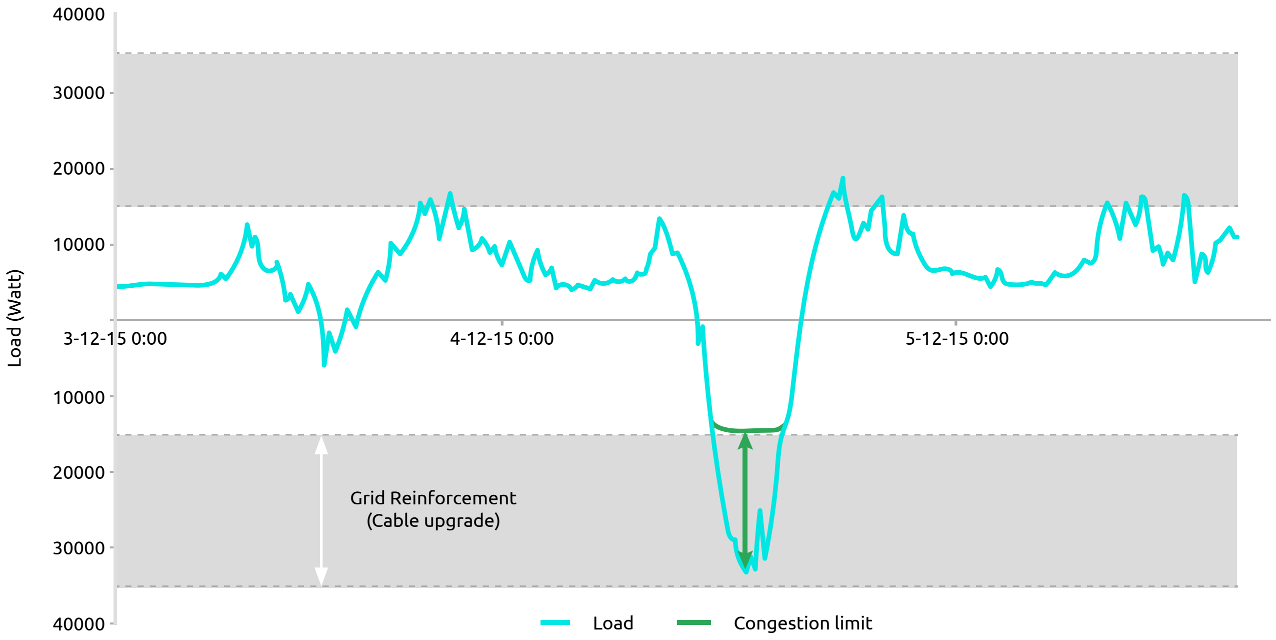
Unlike thermal power plants, which can provide constant generation, renewable sources are dependent on weather conditions. This unpredictability requires accurate forecasting and efficient balancing of supply and demand. When there is an imbalance, several issues can arise. Short-term imbalances can lead to frequency deviations, affecting the lifespan of appliances and causing power failures. Long-term imbalances, resulting from prolonged periods of limited renewable generation, can threaten the security of electricity supply.

The traditional unidirectional flow of electricity from centralized power plants through the grid is evolving. The surplus electricity generated from sources like solar panels now flows back into the grid, resulting in a bi-directional flow. This, along with the increased electrification of mobility and heating, brings forth certain challenges, including grid congestion. Congestion occurs when the load on the grid exceeds its capacity, leading to asset deterioration, higher transportation losses, blackouts, and voltage fluctuations (Figure 2). Connecting new renewable energy sources to the grid is also becoming a challenge in some areas due grid congestion.

Merely reinforcing the grid's capacity is not a cost-effective or sustainable solution in the long run. Reinforcing grid asset implies increasing the capacity of the cables and transformers to ensure the load fits within the capacity of the assets (figure 2). Increasing the capacity of the electricity grid is one way to alleviate strain, but it has limitations. The cost of this endeavor is significant, estimated at …... Also, the process of obtaining licenses and permits for infrastructure upgrades can be time-consuming, leaving the grid susceptible to interim congestion. Moreover, since congestion is temporary and sporadic, relying solely on grid reinforcement is not a cost-effective long-term solution.

**FIGURE 2**

Grid reinforcement to increase grid capacity and mitigate congestion




However, these challenges also bring opportunities for more efficient grid management through flexibility sources. Flexibility can be achieved through demand-side and supply-side management, such as controlling appliances and industrial processes, decentralized generation sources, and storage. For example, scheduling a heat pump to use excess solar energy during the day helps distribute the load and reduce congestion during peak hours. Embracing flexibility can help alleviate the need for extensive grid reinforcement and support the integration of decentralized renewable energy.

## We all have a role to play – the power of large numbers

Customer engagement plays a crucial role in smoothing potential supply/demand gaps. Encouraging consumers to adjust their energy consumption patterns through load shedding and demand-side management can reduce stress on the grid during peak demand periods.

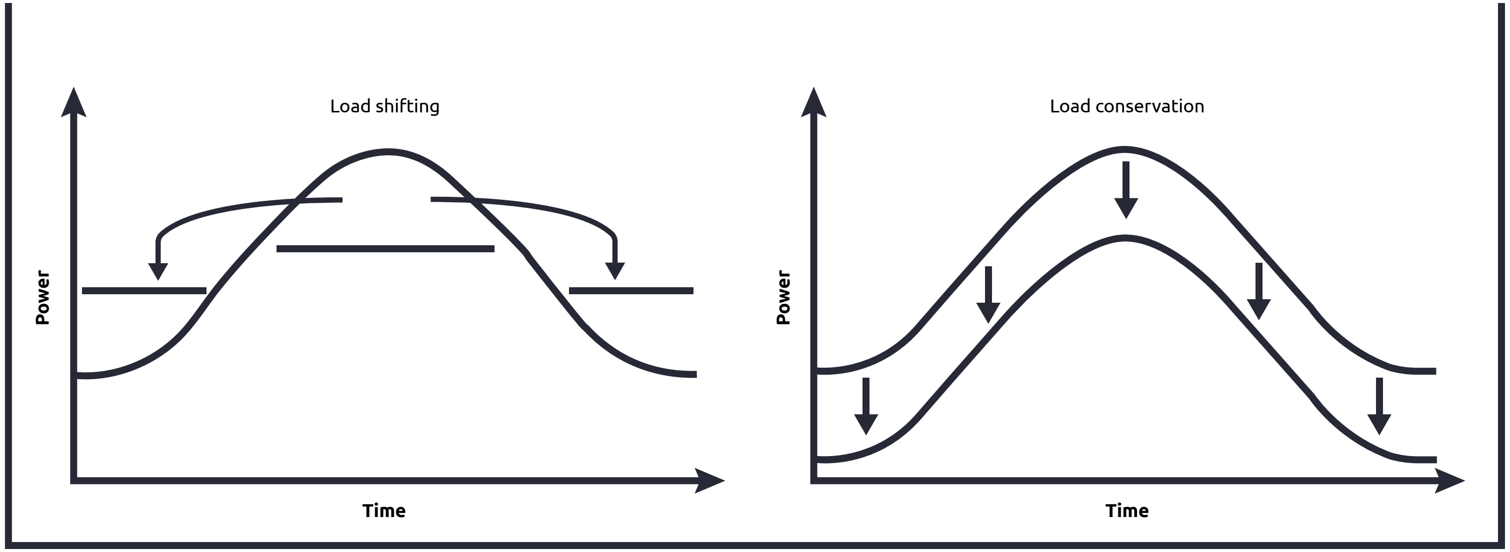
As individuals, it is essential for us to recognize that we can no longer take electricity for granted. For decades, we have enjoyed the luxury of accessing energy whenever and in whatever volume we need, often without questioning its availability. However, it is crucial to understand that traditional power sources are finite and environmentally damaging. If we truly want to transition to more sustainable sources of power, we must fundamentally change our relationship with electricity.

This means adopting a mindset of conscious consumption and recognizing the impact our energy demands have on the environment. We have a role to play in changing our demand patterns to align with renewable energy integration. By adjusting our energy consumption habits and being mindful of peak demand periods, we can contribute to a more balanced and efficient grid. This may involve simple actions like using energy-intensive appliances during off-peak hours or implementing energy-saving measures in our homes and workplaces (see Figure 3).

Furthermore, it is essential to embrace a proactive approach to renewable energy adoption. This can include exploring opportunities to generate our own renewable energy through rooftop solar panels or participating in community energy projects. By becoming active participants in the energy transition, we can help drive the demand for renewable energy solutions and accelerate their adoption.

**FIGURE 3**

Demand side management techniques



## The digitization of power:

Customer engagement is not possible without the digitization of power. Digital technologies have various benefits for the power sector. They enable better monitoring of assets and their performance, allowing for more efficient operations and real-time control. These technologies also facilitate the implementation of new market designs and the emergence of innovative business models.

The widespread adoption of smart meters has already reached over 700 million installations globally, with China alone accounting for around 400 million. Additionally, the Internet of Things (IoT) is expected to connect around 75 billion electrical appliances worldwide by 2025, providing valuable information to consumers, manufacturers, and utility providers.

An example of how digitalization is being utilized is the case of Sonnen, a battery solutions company in Germany. Sonnen has aggregated 30,000 networked home storage systems, allowing them to provide grid services and participate in the country's electricity balancing market.

## The role of data and analytics

To address these challenges, new technologies and business models are emerging. Advanced forecasting techniques, powered by artificial intelligence and advanced analytics, can improve the accuracy of renewable energy forecasts. This helps grid operators better anticipate supply and demand fluctuations and take proactive measures to balance the grid.

By leveraging historical data, weather patterns, and real-time information from various sources, AI-powered forecasting models can provide grid operators with valuable insights into future energy generation levels. For example, by analyzing wind speed data, solar radiation patterns, and historical generation data, these models can forecast the expected output of wind and solar farms with a high degree of accuracy.

This improved forecasting capability allows grid operators to anticipate periods of high or low renewable energy generation in advance. Armed with this knowledge, they can take proactive measures to balance the grid and mitigate potential supply and demand gaps. For instance, if a forecast predicts a period of low wind energy production, grid operators can make arrangements to ramp up alternative generation sources or activate energy storage systems to ensure a continuous and reliable power supply.

Furthermore, advanced analytics can help grid operators optimize the utilization of existing renewable energy resources. By analyzing real-time data on energy consumption patterns, they can identify opportunities for load shifting or demand response initiatives. For example, during times of high renewable energy generation, grid operators can incentivize consumers to shift their energy-intensive activities, such as charging electric vehicles or running heavy machinery, to take advantage of the excess energy supply.

## Bridging the Gap with Storage Technologies

Investment in energy storage is another key solution. Storage technologies, such as batteries and pumped hydro storage, can store excess renewable energy during times of high generation and release it during periods of low generation. This helps bridge the gap between supply and demand, ensuring a reliable and continuous power supply. Behind-the-meter solutions, including home energy storage systems, can empower individual consumers to become more self-sufficient and reduce their reliance on the grid.

As shown in the graph, there has been a substantial increase in the deployment of battery energy storage systems globally. This growth is driven by factors such as declining battery costs, supportive policies, and increasing renewable energy penetration.

Behind-the-meter solutions, including home energy storage systems, have gained traction as they offer consumers the ability to store excess energy generated from rooftop solar panels or during off-peak hours and utilize it when needed. The graph below shows the growth in residential energy storage installations....

# Conclusion

Looking ahead, it is crucial to consider our perspective on the future of renewable energy and whether we are doing enough to achieve a sustainable energy system in time. The transition to renewable energy is a journey filled with challenges and opportunities for efficient grid management. To navigate this path successfully, engaging consumers, embracing flexibility, and harnessing digital technologies are paramount in addressing supply-demand imbalances. With advanced forecasting and cutting-edge energy storage technologies, like batteries, empowering consumers, we have the tools to bridge the gap between supply and demand. By boldly embracing these innovative solutions, we can accelerate the transition towards a sustainable energy future that powers our world.

# 07

# ENERGY IN THE REGIONS

# 07

# REGION 1: EUROPE

Region: European Union in 2022 (EU27 states)

- Population: **448.4 million**
- Size: **4.23 million km**
- GDP: **€15.8 trillion**
- GDP per capita: **€34,358 (nominal)**

## Energy

2022 total energy consumption: **1713 Mtoe**

Primary energy consumption declined in Europe (-4%, including -4.4% in the EU, and around -3% in the UK).

## Natural Gas

Total gas production: **215 bcm**

Total gas consumption: **498 bcm**

## Environment

In 2022, CO2 emissions from fossil fuel combustion for energy use in the EU reached almost 2.4 Gigatons (Gt), indicating a decrease of 2.8%, compared with the previous year.

GHG emissions growth rate: **6.8%** (2022)

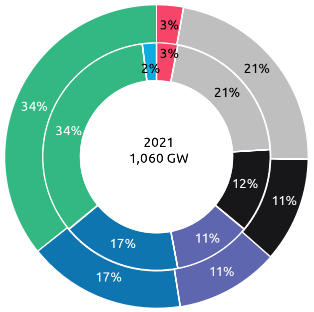
## Renewable energy

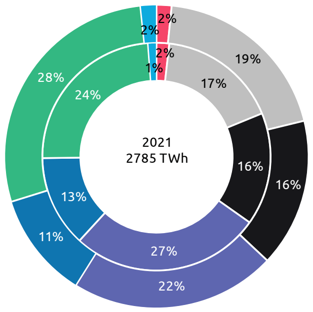
Share of renewables in primary energy consumption: **14.8%**

2022 added wind capacity: **18 GW**

2022 added solar capacity: **37 GW**

## Electricity




## Network

In late 2022, the European Commission unveiled the "Digitalization of the Energy System" plan, anticipating €584 billion ($633 billion) in total investments for the European electricity grid by 2030. Of this, €170 billion ($184 billion) is allocated for digitalization, including smart meters and advanced grid management.

Following Russia's invasion of Ukraine and soaring energy costs, EU natural gas demand plummeted by 55 bcm (13% drop) in 2022.

## Electric vehicles (EVs)

- According to IEA, in Europe, electric car sales increased by more than 15% in 2022 relative to 2021 to reach 2.7 million.
- In 2022, BEV sales rose by 30% relative to 2021 (compared to 65% growth in 2021 relative to 2020) while PHEV sales dipped by around 3%. Europe accounted for 10% of global growth in new electric car sales.
- Europe remained the world's second largest market for electric cars after China in 2022, accounting for 25% of all electric car sales and 30% of the global stock.
- European countries ranked highly for the sales share of electric cars, led by Norway at 88%, Sweden at 54%, the Netherlands at 35%, Germany at 31%, the UK at 23%, and France at 21% in 2022.

## Energy players

Power: Centrica, CEZ, E.ON, EDF, EDP, Enel, ENBW, Engie, Fortum, Iberdrola, Naturgy, Ørsted, RWE, SSE, Uniper, Vattenfall

Oil and gas: BP, Eni, Equinor, Repsol, Shell, TotalEnergies

## Region highlights

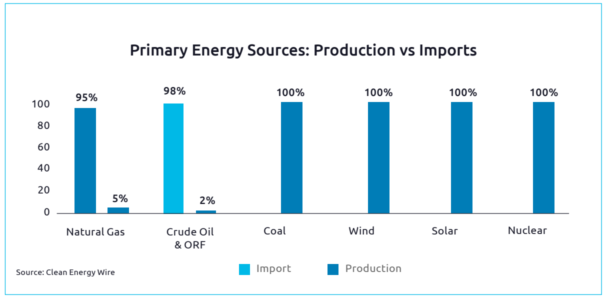
- Corporate Sustainability Reporting Directive (CSRD), effective from January 5, 2023, broadens reporting requirements for large firms and listed SMEs, enhancing transparency on social and environmental impact. As part of CSRD, companies are required to start reporting from 2024. Reporting must comply with mandatory EU sustainability reporting standards and be accompanied by external verification.
- Throughout 2022, many EU countries introduced measures to ease the impact of price spikes on citizens, e.g., by reducing VAT or by offering subsidies to households and companies. The Bruegel think tank estimates that since September 2021, EU countries have spent €657 billion to shield consumers from rising energy costs. In March 2023, the European Commission presented a legislative proposal to reform the energy market and to protect Europeans from similar price shocks in the future.
- (EU-ETS) revenues reached a record high of $ 42.2 billion in 2022; accounted for roughly half of global carbon pricing revenues that year.
- Coal phase-out targets: Germany by 2035, UK by 2024, France by end of 2024, Spain by 2030, Italy by 2025, Netherland by 2030.

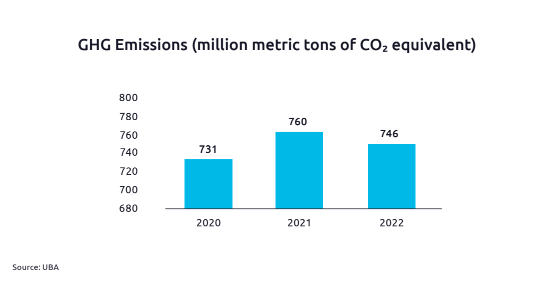
# Germany

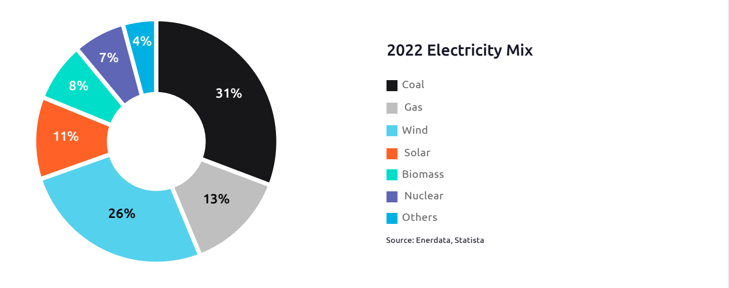
Bundesnetzagentur

Federal Ministry for Economic Affairs and Climate Action


## Renewable energy's share of German power use tops 50% in Q1, 2023 - Wind returns to top of list of German power sources
## Germany has shut down its last three nuclear power plants - Emsland, Isar 2 and Neckarwestheim



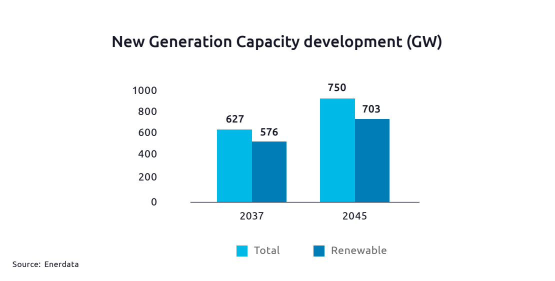



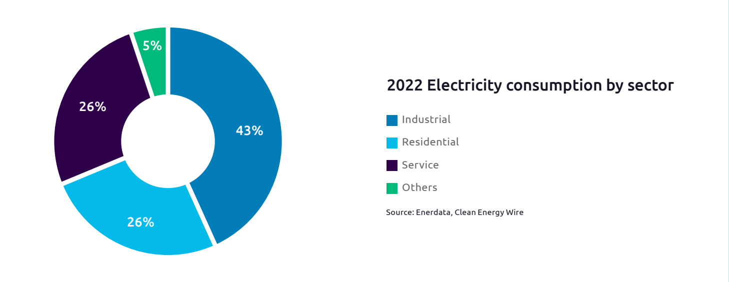

Bundesnetzagentur or BNetzA is the main authority for infrastructure, promoting competition in the markets for energy, telecommunications, post and railways. The agency is also responsible for ensuring non-discriminatory third-party access to power network.

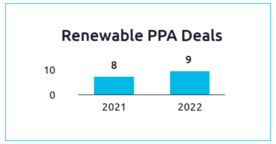
The Federal Ministry for Economic Affairs and Climate Action (BMWK) oversees the country's energy policy and supervises the energy sector.[1]

German government is considering merging the country's four TSOs into a single "German Grid Corporation". The government is in talks with Dutch authorities about a takeover of grid operator Tennet for more than 20 billion euros and has also reached out to operators 50 Hertz, Transnet BW and Amprion.

Bundesnetzagentur has approved the electricity scenario framework for future grid development by 2037 and 2045. The three scenarios forecast a net power consumption comprised between 828 TWh and 982 TWh in 2037 (x1.7 to x2.1 compared to 2020/21 level) and 999 TWh and 1,222 TWh in 2045 (x2.1 to x2.6).[2]

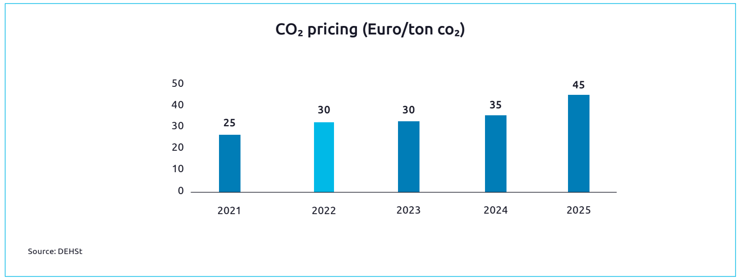



**EEG 2023:** Planning provides that at least **80% of Germany's electricity consumption** is to be covered by **renewable energies by 2030.**[3]

Annual average capture rates of 71% and 78% respectively for German solar and onshore wind in 2030.[4]




**Sources:** 1- BMWK, 2 - Bloomberg, 3 - Bundesnetzagentur, 4 - S&P GlobalGHG Emission
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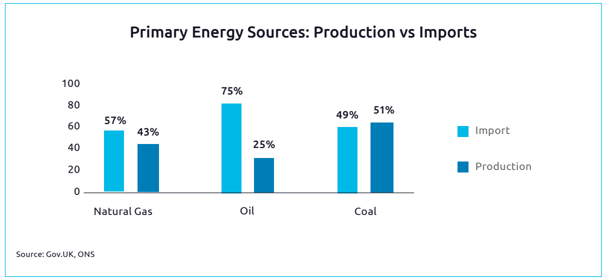
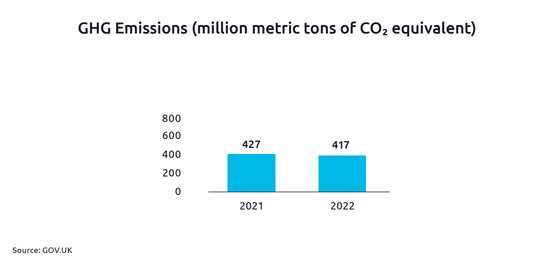
# United Kingdom

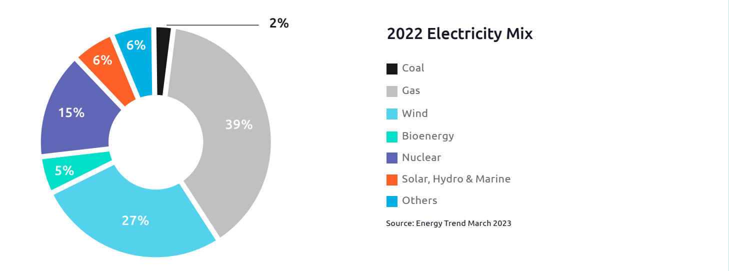
ofgem

npower British Gas SSE EDF e.on SCOTTISHPOWER

**United Kingdom plans to build cross-border electricity link connected to an offshore wind farm called "LionLink" interconnector that will be able to transfer 1.8 gigawatts (GW) of power to Britain from a Dutch wind farm. UK announced plans to scale back energy subsidies for businesses for the next financial year, 2024 by about 85% to 5.5 billion pounds ($6.7 billion), after the government described the current level of support as "unsustainably expensive".**



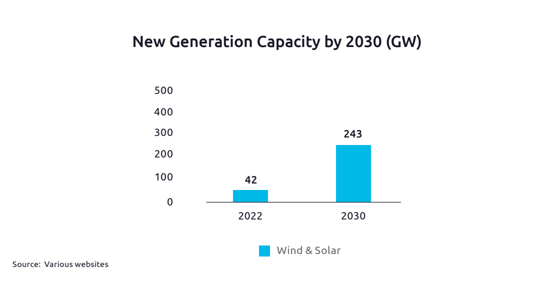

The Office of Gas and Electricity Markets (Ofgem) regulates the monopoly companies which run the gas and electricity networks. It is governed by the Gas and Electricity Markets Authority (GEMA).

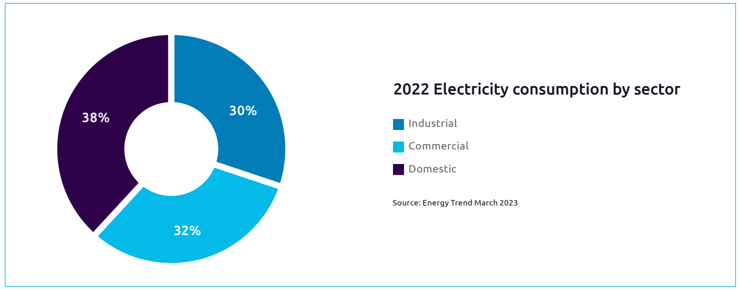
Major review (Review of Electricity Market Arrangement) into Britain's electricity market design launched by UK government to radically enhance energy security and cut costs of electricity for consumers in the long term

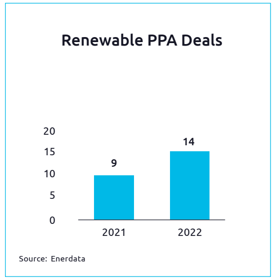
The National Grid runs the transportation (transmission and distribution) of electricity. The price of electricity is determined by retail and wholesale market. Wholesale electricity prices are not regulated.

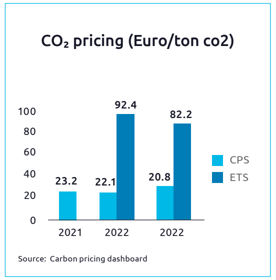
The 'big six' energy companies operating in the UK. are made up of British Gas, EDF Energy, E. ON, npower, Scottish Power and SSE.

UK's energy sector is mostly privatised since the 1990s.




**Following the UK's departure from the EU and enactment of UK ETS, UK's power sector continues to participate in the Carbon Price Support (CPS) with the minimum carbon price of £18/t$CO_2$e between 2021 and March 2024.**

Source: Organisation for Economic Co-operation and Development

**Sources:**
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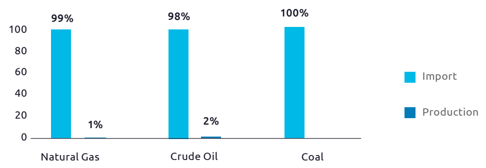
# France

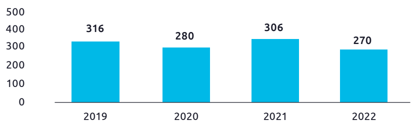
France 2030 is a national investment plan endowed with EUR 34 billion, which includes EUR 30 billion in subsidies and EUR 4 billion in funding schemes to be deployed over 5 years. EUR 3.5 billion are allocated for the year 2022, of which EUR 2.84 billion in grants and EUR 0.66 billion in equity investments. The French government will invest €2 billion in hydrogen through 2022 as part of France Relance, with nearly €7 billion more to be deployed by 2030.

Primary Energy Sources: Production vs Imports



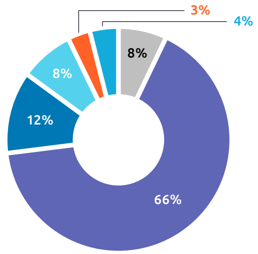

Source: Gov.UK, ONS

CO$_2$ emissions (million tons of CO$_2$ equivalent)




Source: World in Data

2022 Electricity Mix




Source: SP Global

The **French Energy Regulatory Commission (CRE)** created in 2000 to regulate France's electricity and gas markets.

**Electricité de France** was responsible for 79.8% of the electricity production in 2020. Réseau de Transport d'Electricité (RTE) is the only transmission system operator, and Enedis, operates 95% of the metropolitan grid.

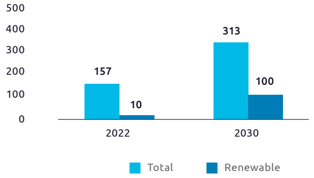
**TotalEnergies SE is the biggest supplier of energy in France** followed by Gaztransport & Technigaz SA, Technip Energies N.V. and others.

**Most French electricity is sourced from nuclear power stations**, however, a growing number of suppliers offer green options from renewable sources.

France has a legal requirement to limit electricity supply losses in line with a **3-hour loss of load expectation (LOLE)** standard, which is part of the Energy code.

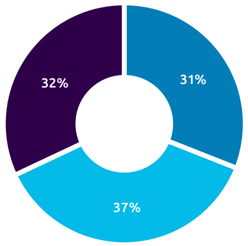
Only **EDF and Engie** offer tariffs regulated by the French government.

New Generation Capacity by 2030 (GW)



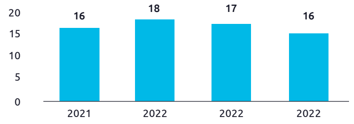

Source: Statista

2022 Electricity consumption by sector




Source: Enerdata, Clean Energy Wire

CO2 pricing (Euro)




Source: The World Bank

French carbon tax applies CO$_2$ emissions from all fossil fuels in mainly the industry, buildings and transport sectors with some exemptions for these and other sectors

**Sources:**
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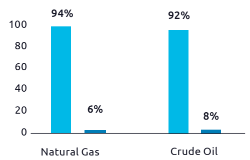
# Italy

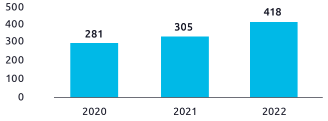
**Terna announced that they have plans to invest €21 billion in Italy's energy grid over the next ten years. The allocated amount is 17% more than Terna's previous ten-year plan and will focus on promoting decarbonization across the country, as well as reducing Italy's dependence on foreign supply sources. This also aims to reduce carbon emissions by 55% by 2030 against their 1990 levels.**

**Primary Energy Sources: Production vs Imports**

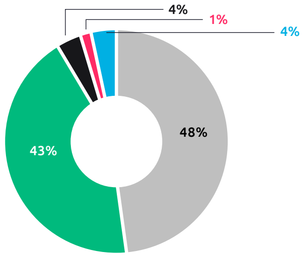



Source: Gov.UK, ONS

**GHG Emissions (million metric tons of $CO_2$ equivalent)**




Source: Enerdata, IEA




**2022 Electricity Mix**

- Natural Gas
- Renewables
- Coal
- Petroleum Products
- Others

Source: Terna

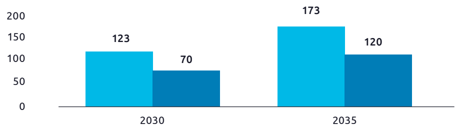
Terna is an electricity transmission system operator that owns virtually all the Italian National Transmission Grid, responsible for operating and managing the national electricity transmission grid.

Terna also handles dispatching of electricity throughout Italy i.e., the activities necessary to maintain a balance between electricity supply and demand.[1]

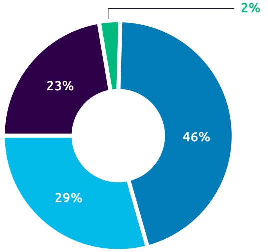
2023 Development Plan: Terna has introduced the 2023 development plan where one of the main features is introducing the Hyper grid network. This will leverage the technologies of the HVDC (High Voltage Direct Current) transmission system to achieve the energy transition and security targets.

Terna will adopt a modular approach to develop a flexible investment model that will allow the development of new grid infrastructure that reflects the actual energy scenario. For this reason, the planning and authorization procedures for the new Hyper grid projects will be launched so that they can be implemented in line with the priorities of the system.[2]

**New Generation Capacity development (GW)**




Source: NASDAQ, EMBER, Power Technology

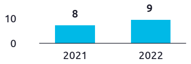



**2022 Electricity consumption by sector**

- Industrial
- Tertiary
- Households
- Agriculture

Source: Statista

**Renewable PPA Deals**




**Italy's Ecology Transition Minister** announced a new target for **renewable generation of 70% by 2030**, significantly above the EU average of 55%.[3]

**Wind power grew 10.8%** in 2022 but solar power **increased** slightly by **2.1%.**[4]

**Carbon Tax 2022**

In Italy, a proper carbon tax has never been introduced ever. They are trying to follow the European Union Emission Trading System (ETS).

In 2021, this covered. 36.2% of GHG emissions. In total, 81.8% of the emissions were subjected to a positive Net Effective Carbon Rate in 2021 under ETS.

**Sources:** 1 - Terna 2 - Terna 3 - Ember; 4 - Trade.gov
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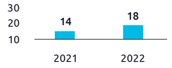
https://www.oecd.org/tax/tax-policy/carbon-pricing-italy.pdf

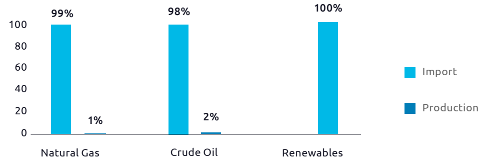
# Spain

PPA deals



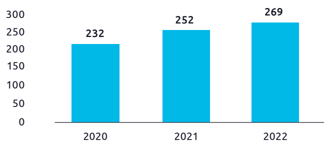

**According to forecasts from Spain's national grid, Spain will reach 50 percent renewable electricity generation in 2023. In July 2022, France and Spain announced a breakthrough in a long-running impasse over hefty costs of what would be their first undersea electricity link and the estimated cost is around $3.42 billion**

Primary Energy Sources: Production vs Imports

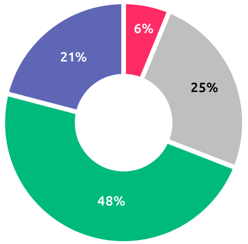



Source: Gov.UK, ONS

GHG Emissions (million tons of $CO_2$ equivalents)




Source: Statistical Review of World Energy 2023




2022 Electricity Mix

- Solid fossil fuel & Oil
- Natural Gas
- Renewable, biofuels, biomass
- Nuclear

Source: DG ENER and Eurostat

**Red Eléctrica de España, SA (REE)** is the sole TSO for the Spanish electricity system. Spain's Long-Term Decarbonisation Strategy (ELP 2050) will reduce greenhouse gas (GHG) emissions by 90% by 2050. The two largest companies represent 43% of electricity generation in Spain. **These are Iberdrola (24%) and Endesa (19%).**

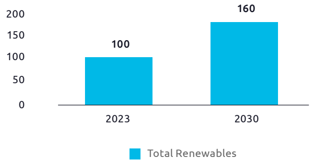
In terms of demand, **most energy is contracted on the free market at a fixed price (77%) and the rest (23%) pays the daily market price.**

Spain was the largest PPA market in 2022, with around 3.2 GW of disclosed capacity across 31 deals

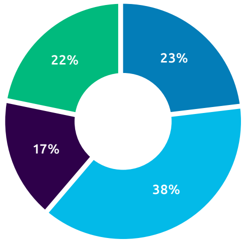
In 2022, The Council of Ministers has approved a Royal Decree-Law on economic sustainability measures, which includes a Shock Plan for Energy Saving and Management in Air Conditioning to reduce energy consumption in administrative buildings,

Spain's renewable energy market is moderately fragmented and the **installed capacity of wind turbines is anticipated to more than double by 2030**

New Generation Capacity (GW)




Source: Enerdata

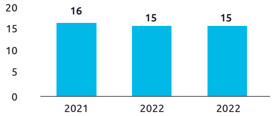



2022 Electricity consumption by sector

- Industrial
- Transport
- Residential
- Commercial and Services

Source: Various sources, Internal analysis

CO2 pricing (Euro/ton $co_2$)




Source: The World Bank

The Spanish carbon tax only applies to fluorinated GHG emissions (HFCs, PFCs, and SF6) from Annex I of the Regulation 517/2014.

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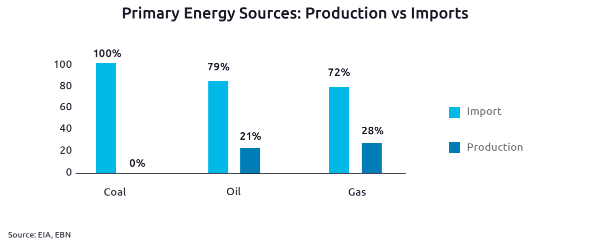
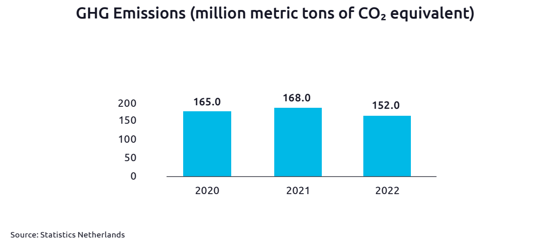
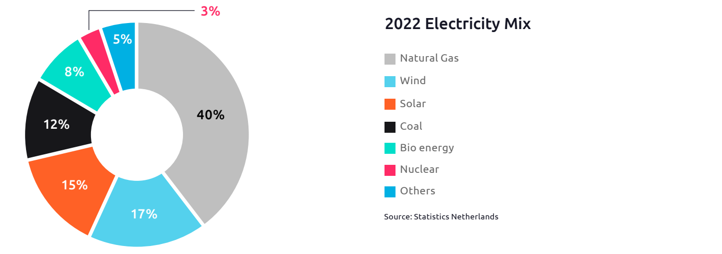
# Netherlands

**Netherlands will shut down tremor-prone Groningen gas field despite energy security concerns due to concerns about subsidence and tremors at the onshore gas field location, in the country's northwest near the German border. Government officials in the Netherlands have earmarked more than $350 million to fund further development of nuclear energy in the country, including extending the operating license of the 485-MW Borssele nuclear power plant.**



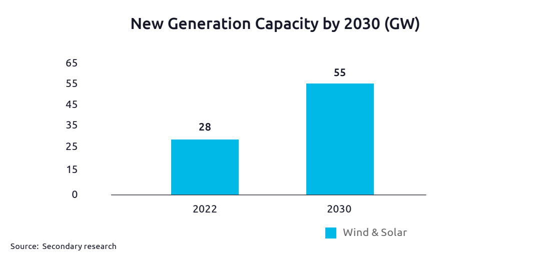

The Authority for Consumers and Markets is responsible for the regulation of the electricity sector in the Netherlands, together with the Minister of Economic Affairs and Climate. The ACM is appointed as regulator under the Electricity Act, the Gas Act and the Heat Act.

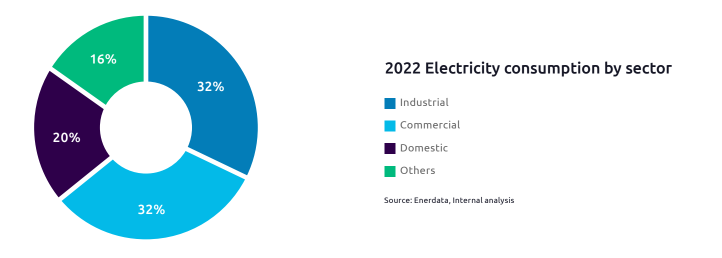
The system operator, TenneT, is the only stakeholder responsible for managing the high-voltage grid (between 110 kV to 380 kV) in the Netherlands

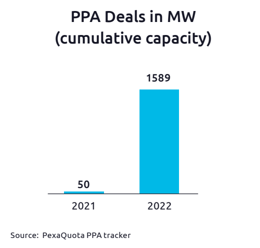
The Dutch government has set targets of 16% of all energy to be generated from renewable energy by 2020 and 100% by 2050

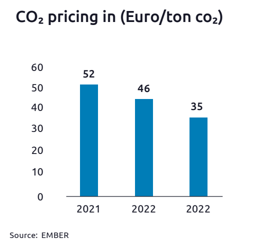
For the year 2023, prices will be capped at €40c/kWh for electricity (from €70c/kWh) and €1.45/cm for gas, for a maximum of 2,900 kWh and 1,200 cm respectively.

The Netherlands has one nuclear power reactor in operation, one nuclear power plant (NPP) in safe enclosure, two research reactors, one enrichment plant (Urenco) and one central storage facility for radioactive waste (COVRA).




**The Netherlands carbon tax comprises a $CO_2$ levy for industry ,a minimum carbon price for industry and a minimum carbon price for electricity**
**The minimum carbon price for electricity and the minimum carbon price for industry act as a floor for the EU ETS price and rise each year.**

**Sources:**
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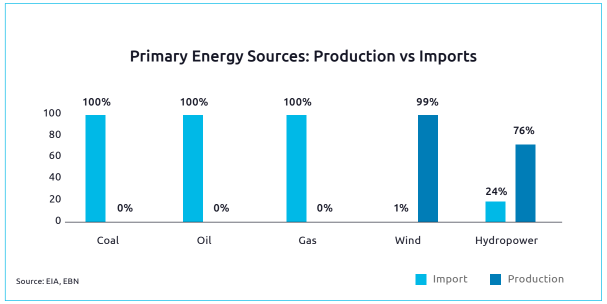
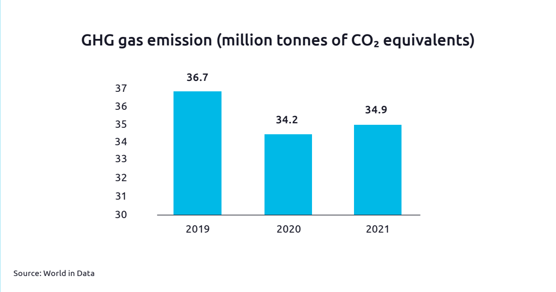
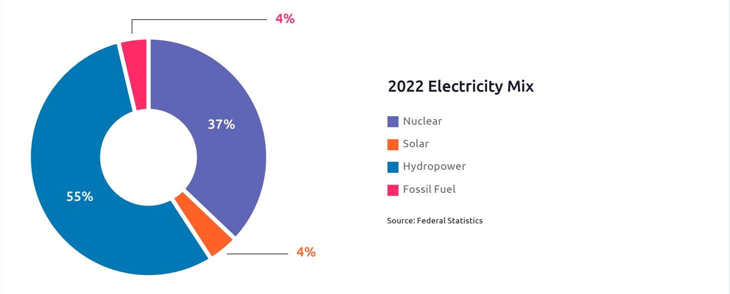
# Switzerland

**In 2022 Switzerland introduced a market stability mechanism to its ETS where, due to a large number of allowances in circulation, the auction volume was reduced by 50%**
**Switzerland plans to call for bids later in 2023 to build new power plants that it expects will be connected to its energy grid in 2025 or 2026**




Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

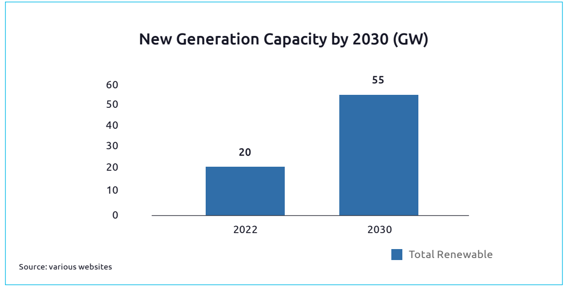
**ElCom** is Switzerland's independent regulatory authority in the electricity sector. It is responsible for monitoring compliance with the Swiss Federal Electricity Act and the Swiss Federal Energy Act.

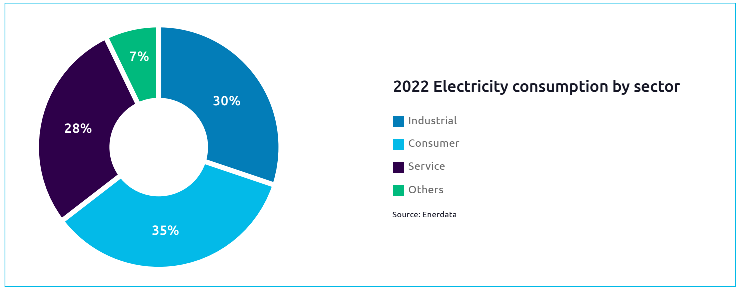
It also monitors electricity supply security and regulates issues relating to international electricity transmission and trading.

Federal Council of Switzerland pursues the goal of negotiating an electricity agreement with the EU. This is intended to allow full access for Switzerland to the single market for electricity and ensure cooperation in this sector with the EU in the future.

The four still-active nuclear reactors on Swiss soil produce almost 40% of the country's electricity.

According to a new report from the Swiss Energy Foundation (SES), Switzerland is only able to rely on its own sources of energy for 29,7 percent of the year, before the country has to import resources from abroad.

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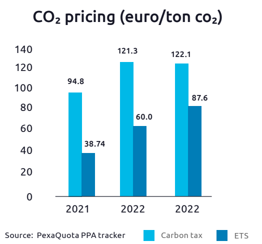



The Switzerland carbon tax is a central instrument in the Swiss climate policies under the $CO_2$ Act.

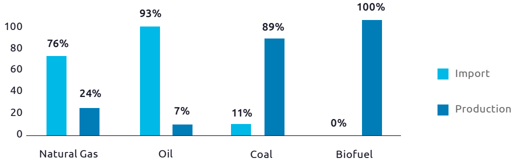
The Switzerland Emissions Trading System is a mandatory cap-and-trade system. The total amount of emission allowances is determined top-down and decreases annually

**To date, there are very few opportunities for PPAs in Switzerland as electricity is mainly produced from a mix of nuclear and hydropower and there is a very low number of large-scale wind and solar installations in the country. It did not had PPA capacity till 2021.**

# Poland

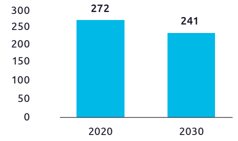
**Poland plans to generate 74% of its power from renewables and nuclear by 2040; Under the updated strategy, by 2040, renewables could reach a capacity of 88 GW, providing 51% of the country's needed power. These figures include energy from solar, wind and hydro, as well as biomass and biogas.**

### Primary Energy Sources: Production vs Imports



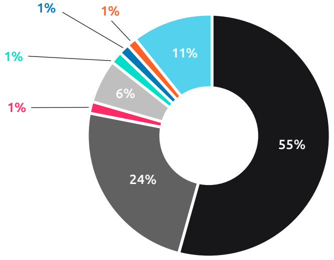

Source: EIA

### GHG Emissions (million metric tons of $CO_2$ equivalent)




Source: IEA

### 2022 Electricity Mix




Source: Statista

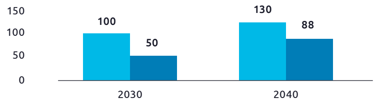
Energy Regulatory Office

The President of Energy Regulatory Office is a central body of state administration nominated based on the Energy Law is responsible for regulation in energy sector as well as promotion of competition.

PAA PAŃSTWOWA AGENCJA ATOMISTYKI

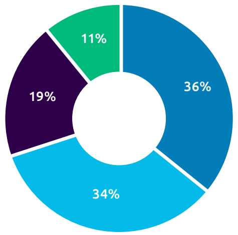
National Atomic Energy Agency is another government regulatory body responsible for nuclear regulations. They conduct activities that are significant for ensuring nuclear safety and radiological protection.[1]

### New Generation Capacity by 2030 (GW)




Source: Reuters, Ember Climate

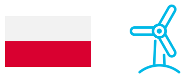
### 2022 Electricity consumption by sector




Source: Enerdata

Poland Government Officials stated that they need a huge upgrade of its power grids to cope with the transmission of energy from renewable and nuclear sources.

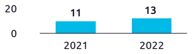
They need to invest € 112.5 Billion in transmission and distribution grids by 2040. Poland's new energy strategy forecasts 74% of energy coming from zero-emission sources, including renewables and nuclear power.[2]



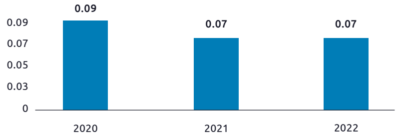
**Poland Government** finds huge opportunity in off-shore wind development. **By 2040** a large amount of coal production will be reduced.[3]

Installed capacity of **offshore wind may reach up to 5.9 GW in 2030** and by 2040 they are targeting to **reach 11 GW.**[4]

### PPA Deals




### $CO_2$ pricing (Euro/ton)




Source: Green Fiscal Policy, Tax Foundation

**Sources:** 1- Energy Regulatory Office, Poland Government, 2 - XMZA, 3 - Poland Government; 4 - Poland Government
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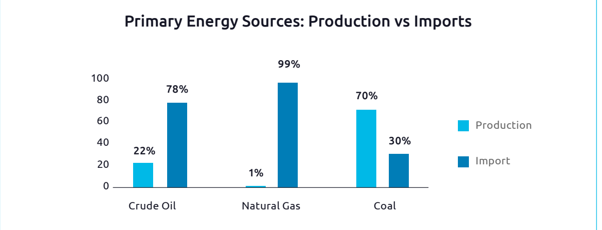
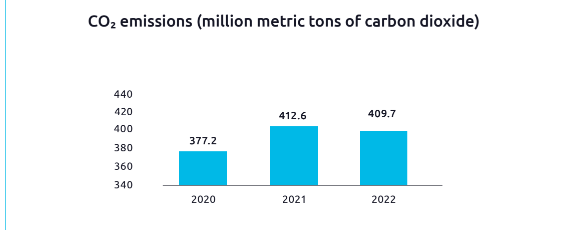
# Turkey

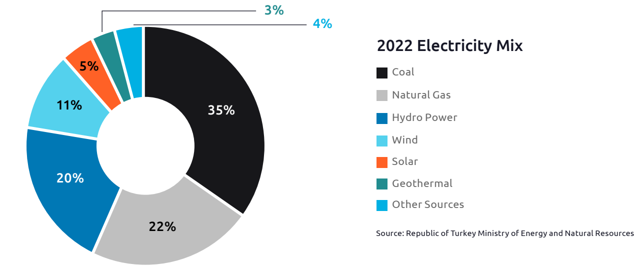
## Turkey has discovered natural gas reserves valued at $1 billion in Gabar Mountain in southeastern Sirnak province; the government has rolled out a series of large infrastructure and defence projects.




Source: U.S. Energy Information Administration




Source: Statistical Review of World Energy 2023




Source: Republic of Turkey Ministry of Energy and Natural Resources

The energy market in Turkey is primarily governed by **The Ministry of Energy and Natural Resources (MENR)**, which has been responsible to supervise the market activities as well as to determine the energy and natural resources requirements.

While, the **Energy Market Regulatory Authority (EMRA)**, is the main regulatory authority for the electricity, natural gas, oil, and liquefied petroleum gas markets. The **General Directorate of Energy Affairs (EIGM)**, acts as the main policy-making body, takes measures regarding energy policies and coordinates programs.

T.C. ENERJİ PİYASASI DÜZENLEME KURUMU

Wholesale electricity market activities are carried out by state-owned EUAS as well as private entities with licences from EMRA.

Private entities licensed by EMRA carry out the retail electricity market activities. Each distribution company established an incumbent supply company to sell electricity to non-eligible consumers.

Turkey's electricity distribution network has been primarily divided into 21 distribution regions. Although the distribution system assets are still owned by the state-owned Turkish Electricity Distribution Company (TEDAŞ), such assets are operated and the distribution activities are carried out by the private sector now.

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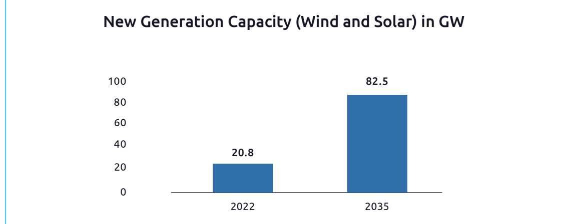
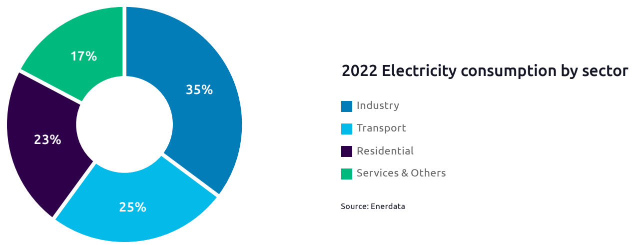



Source: Enerdata, IRENA




Source: Enerdata

| Public Utilities | Private Utilities |
|---|---|
| • EUAS, Electricity Generation Corporation is the major state-owned electricity generation company in Turkey.<br>• EUAS holds 20% share of the total market. | • Major private utilities include:<br>o ENKA<br>o Enerjisa Enerji<br>o Zorlu Enerji<br>• Share of private sector in electricity generation increased to 80% |

**Carbon Pricing: ETS**

**Turkey has been planning for the possible use of carbon pricing instruments to help achieve its mitigation targets for several years.**

**In 2022, Turkey organized its first Climate Council meeting with participation by public and private institutions as well as nongovernmental organizations. The council has proposed the launch of a pilot ETS in 2024 to align the development of a national ETS in Turkey with 2053 net zero target.**

Source: World Bank Group» Carbon pricing dashboard

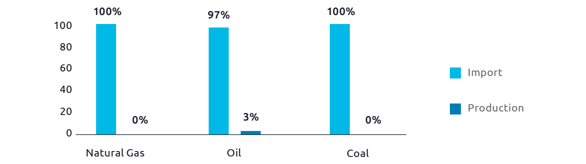
# Sweden

Government Offices of Sweden

Swedish Energy Agency

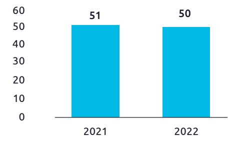
**Swedish Energy Agency had granted € 1.1 Million for a tech company Blixt that is helping in upgradation of Sweden's electricity grid (yet to decide). On March 31, 2023, Swedish Energy Agency announced they have installed 800 MW solar capacity reaching a record of 2.4 GW of installed capacity. Swedish Energy Agency has issued a report for Sweden's marine planning of 120 TWh of offshore wind energy production as the area can accommodate 20-30 TWh which is not sufficient to meet increased electricity demand**

### Primary Energy Sources: Production vs Imports



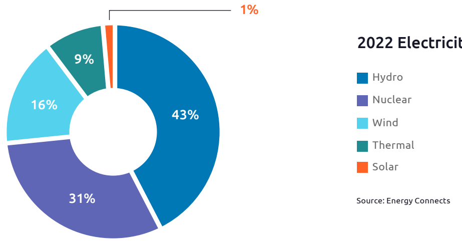

Source: IEA, Energy in Sweden

### GHG Emissions (million metric tons of $CO_2$ equivalent)




Source: Statistics Sweden

### 2022 Electricity Mix




Source: Energy Connects

**Swedish Energy Agency** is working with the promotion of energy efficiency measures and investments in renewable energy technologies. The organization is regulated by the Government through the instruction and annual appropriations directives.

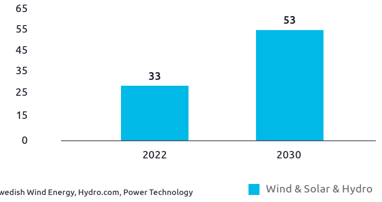
Swedish Energy Agency is responsible for matters of the supply and use of energy in Sweden. It also supports and funds national research on new and renewable energy technologies, smart grids, vehicles.[1]

Svenska Kraftnät, the Swedish transmission system operator is planning to strengthen the electrical grid of northern Sweden with a ~ € 1 Billion investment.

This expansion of the electrical grid is majorly due to increasing data centers and other industrial players in northern Sweden and this is driven by the demand for green and competitively priced energy.

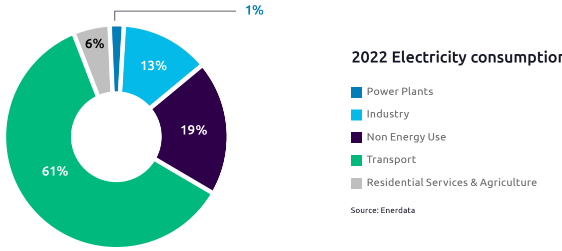
The expansion will increase the available capacity in the region by 5 GW and allow another 4 GW of renewable energy production.[2]

### New Generation Capacity by 2030 (GW)



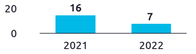

Source: Statista, Swedish Wind Energy, Hydro.com, Power Technology

### 2022 Electricity consumption by sector




Source: Enerdata

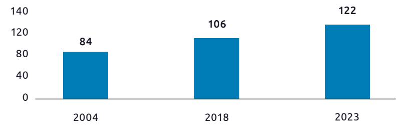
### Renewable PPA Deals




**The government has planned that 100% of Sweden's electricity consumption** is to be covered by **renewable energies by 2040**.[3]

Swedish government approved two offshore wind farms in 2022 that will be able to supply 6.5 TWh of electricity per year.[4]

### $CO_2$ pricing (Euro/ton $co_2$)




Source: Government Offices of Sweden

**Sources:** 1- Swedish Energy Agency, 2 - Nodepole, 3 - Government Offices of Sweden; 4 - Offshore Winds

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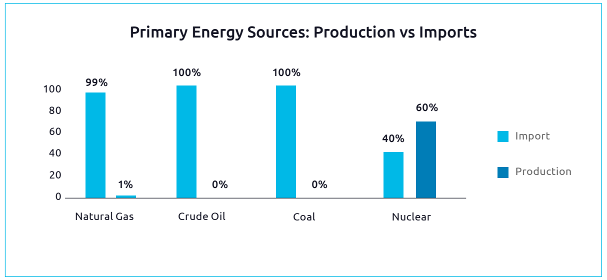
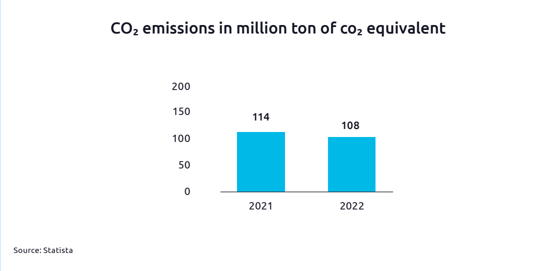
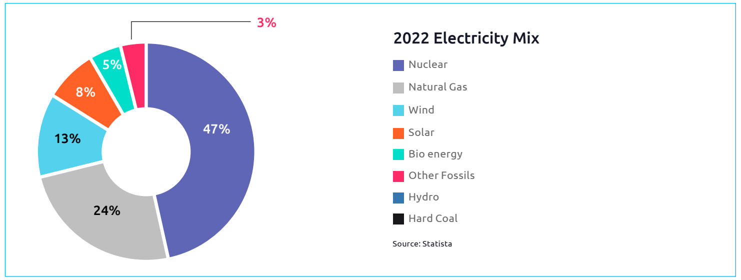
# Belgium


**Through the Paris Agreement, Belgium has committed to achieve net-zero emissions of greenhouse gases by 2050, but Belgium's emissions per capita are among the most intensive in Europe. Belgium has already been accelerating across sectors in recent years. For instance, between 2021 and 2022, the percentage of renewable-energy production from solar and wind in Belgium rose by 15%, while adoption of EVs increased by 75%**



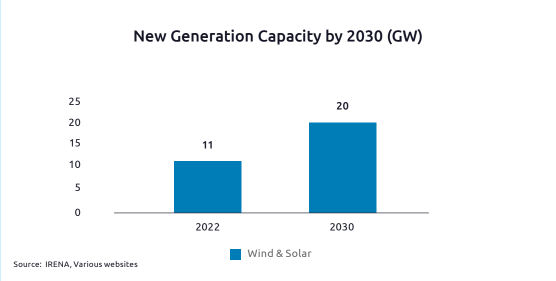

Belgium has four energy regulators: **the federal regulator, CREG; the Flemish regulator, VREG; the Walloon regulator, CWaPE; the Brussels regulator, BRUGEL.**

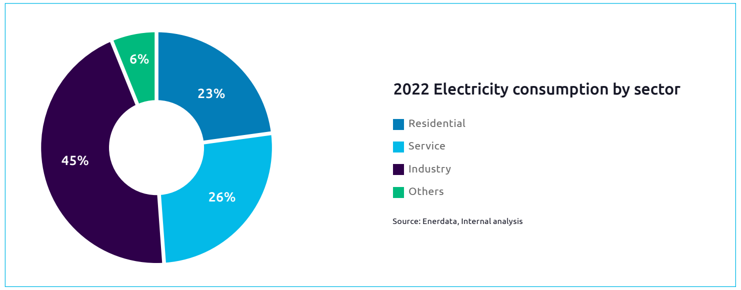
**Elia operates the high-voltage electricity transmission network** (30-380 kilovolts [kV]) that supports transmission of electricity across Belgium and electricity trading via the cross-border interconnectors.

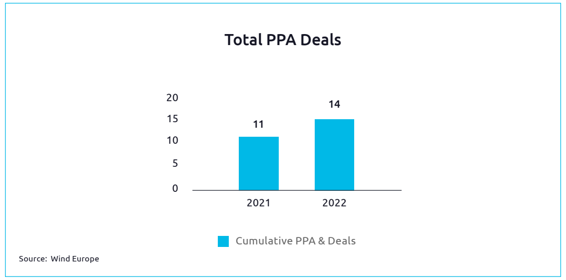
**The Belgian electricity market is still dominated to a high extent by Electrabel** (GDF Suez) for both generation and supply.

Belgium's National Energy and Climate Plan sets a 2030 target to reduce greenhouse gas emissions from the energy sector by 35% from 2005 levels.

**Belgium has five nuclear reactors generating about half of its electricity.** Plans to close all nuclear power plants by 2025 were delayed in March 2022 by 10 years, with the country's two newest reactors, Doel 4 and Tihange 3, allowed to remain in operation to 2035.




**Belgium did not have an explicit carbon tax.. In 2021, explicit carbon prices in Belgium consist of emissions trading system (ETS) permit prices, which cover 38.8%of greenhouse gas (GHG) emissions in CO2e. In total, 80.7% of GHG emissions in Belgium are subject to a positive Net Effective Carbon Rate (ECR) in 2021, down from 81.4% in 2018.**

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# Norway

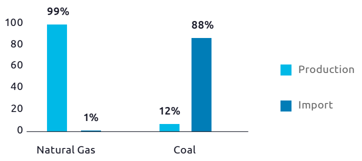
NORWEGIAN MINISTRY OF PETROLEUM AND ENERGY

NVE

OLJEDIREKTORATET

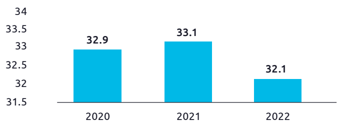
**Norway's government has given approval for oil companies to develop 19 oil and gas fields with investments exceeding 200 billion Norwegian crowns ($18.51 billion), part of the country's strategy to extend production for decades to come.**

### Primary Energy Sources: Production vs Imports



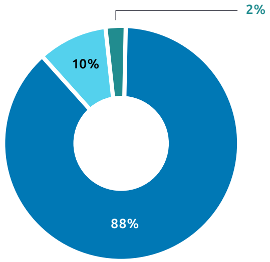

Source: U.S. Energy Information Administration

### $CO_2$ emissions (million metric tons of $CO_2$ equivalent)




Source: Statista

### 2022 Electricity Mix

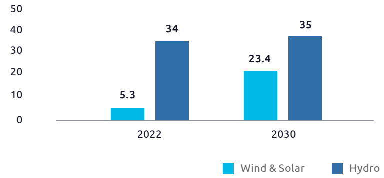



Source: Statista

The Ministry of Petroleum and Energy is primarily responsible for managing the power sector in Norway. Norwegian Energy Regulatory Authority (NVE-RME) is responsible for cybersecurity in the metering value chain, which includes smart metering systems and Elhub. While, the Norwegian Petroleum Directorate is responsible for the regulation of the petroleum resources on the Norwegian continental shelf.

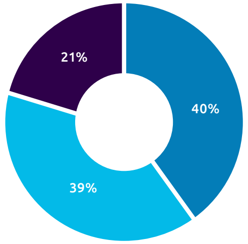
The regulations implemented by Norwegian Petroleum Directorate include the Resource Management Regulations, Measurement Regulations, and regulations relating to documentation in connection with storage of $CO_2$ on the shelf.

### New Generation Capacity (Renewables) in GW




Source: IEA

### 2022 Electricity consumption by sector

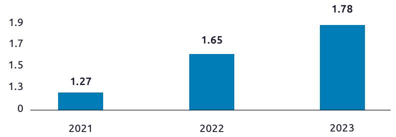



Source: Enerdata

The Norwegian electricity grid consists of three levels: the transmission grid (operated by Statnett), the regional grid and the distribution grid. The transmission grid connects producers with consumers in a nationwide system. The regional grid often links the transmission grid to the distribution grid, and may also include production and consumption radials carrying higher voltages. The distribution grid consists of the local electricity grids that normally supply power to smaller end users.
The state-owned transmission system operator(TSO), Statnett owns 98% of the transmission grid. The rest is owned by 13 regional grid companies and rented to Statnett.

| Public Utilities | Private Utilities |
|---|---|
| • **Municipal, county and central authorities** own around 90% of Norway's electricity production capacity.<br>• Statkraft SF, State owned company owns around 35% of production capacity | • It has been found that there is also some amount of private ownership, with around 10% |

### Carbon tax NOK (per standard cubic meter of gas or per litre of oil)




Source: Norwegian petroleum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# REGION 2: ASIA AND PACIFIC

Region: Southeast Asia (SEA) - (Hong Kong, Singapore, Malaysia, the Philippines, Vietnam, and Taiwan)

Population: 0.68 billion (2022)

## Electricity generation

Total electricity generation (2022): 938.7 TWh

- Hong Kong: **36.2 TWh**
- Malaysia: **182.9 TWh**
- The Philippines: **114.4 TWh**
- Singapore: **57.1 TWh**
- Taiwan: **288.1 TWh**
- Vietnam: **260.0 TWh**

## Renewable energy

**Renewables generation in Southeast Asia : 72.2 Twh**

(Hong Kong - 0.1 TWh, Malaysia - 3.9 TWh, the Philippines-15.5 TWh, Singapore - 1.7 TWh, Taiwan - 16.2 TWh, Vietnam - 34.8 Twh)

## Energy-related $CO_2$ emissions (2022): 1,228.7 million tons $CO_2$

- Hong Kong: **58.1 million tons $CO_2$**
- Malaysia: **272.9 million tons $CO_2$**
- The Philippines: **146.5 million tons $CO_2$**
- Singapore: **208.8 million tons $CO_2$**
- Taiwan: **272.4 million tons $CO_2$**
- Vietnam: **270.0 million tons $CO_2$**

## EV charging

- Hong Kong: **5,434 chargers** (December 2022)
- Malaysia: **1,000 charging stations** (June 2023)
- The Philippines: **300 charging stations** (December 2022)
- Singapore: **over 3,600 chargers** (December 2022)

## Major energy players

- **Hong Kong:** CLP Group and Hong Kong Electric Company
- **Malaysia:** Tenaga Nasional Berhad, Malakoff Corporation Berhad, Sarawak Energy
- **The Philippines:** Manila Electric Company (Meralco)
- **Singapore:** Singapore Power Ltd
- **Taiwan:** Taiwan Power Company (Taipower)
- **Vietnam:** Vietnam Electricity Group (EVN).

## Recent developments

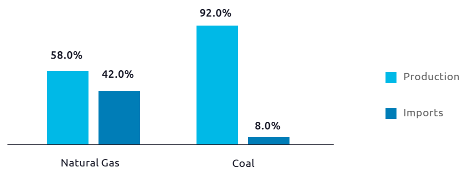
- **Hong Kong:** The CLP Group is working with the Hong Kong SAR government on the Development Plan for 2024 to 2028, which is expected to represent a key step in Hong Kong's decarbonization roadmap beyond 2035 and towards the government's target of achieving carbon neutrality before 2050.
- **Malaysia:** The Ministry of Economy of Malaysia has announced a new renewable energy target, aiming to reach 70% of renewables in the power mix by 2050 while also announcing the end of cross-border trade barriers for renewable energy.
- **The Philippines:** The Philippines aims to increase the share of renewable energy in the power generation mix to 35% by 2030 and 50% by 2040. This involves increasing geothermal capacity by 75%, expanding hydropower capacity by 160%, increasing wind power capacity to 2,345 MW, and adding an additional 277 MW of biomass power.
- **Singapore:** Singapore has doubled its solar capacity since 2020, with more than 700 megawatt-peak (MWp) currently installed. The country aims to increase solar capacity to at least 2 gigawatt-peak (2 GWp) by 2030, which is expected to meet around 3% of projected electricity demand.
- **Taiwan:** The Renewable Energy Development Act passed in 2009, by the government (further amended in 2019) sets a target of 27GW of installed capacity coming from renewables by 2025.
- **Vietnam:** Vietnam aims to double its installed capacity by 2030, surpassing 158 GW (compared to 77 GW as of end-2021). About 19% of the capacity is expected to come from coal-fired power in 2030 (about 30 GW).

# China

NRDC 发改委

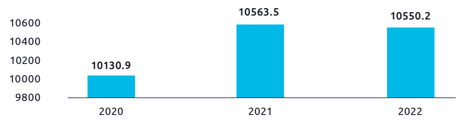
**China spent $546 billion in 2022 on investments that included solar and wind energy, electric vehicles and batteries; which is nearly four times the amount of U.S. investments, which totaled $141 billion. The European Union was second to China with $180 billion in clean energy investments.**

### Primary Energy Sources: Production vs Imports

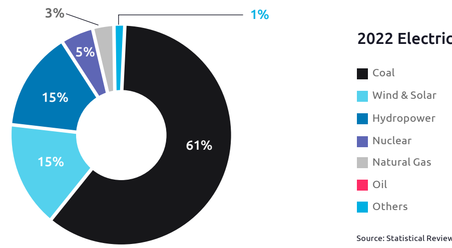



Source: U.S. Energy Information Administration

### $CO_2$ emissions (million metric tons of $CO_2$ equivalents)




Source: Statista, Statistical Review of World Energy 2023




Source: Statistical Review of World Energy 2023

Government agencies such as the National Development and Reform Commission (NDRC) and the National Energy Administration are primarily responsible for establishing policies and standards for the electricity sector.

These agencies are also responsible for overseeing the operation of the electricity market and regulating electricity prices.

Electricity grid in China is operated by the **State Grid Corporation of China in the North and China Southern Power Grid Co Ltd in the South**. State Grid covers about 26 provinces in eastern, central, and northern regions, while the latter covers five provinces in southern China.

Currently, China's power market is based primarily on provinces balancing electricity supply and demand, with thermal power playing a key role. Inter-provincial power transactions are governed by government contracts, which are based on prices that do not directly reflect actual supply or demand.

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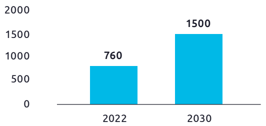
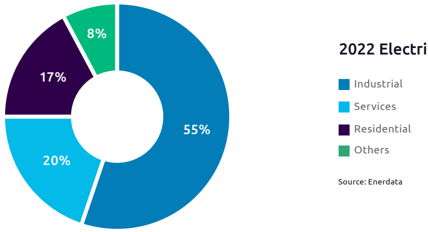
### New Generation Capacity (Wind and Solar) in GW

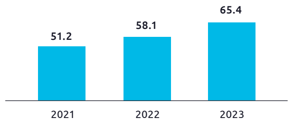



Source: Enerdata, IRENA




Source: Enerdata

### $CO_2$ pricing (Yuan/mt$CO_2$e)




Source: S&P Global

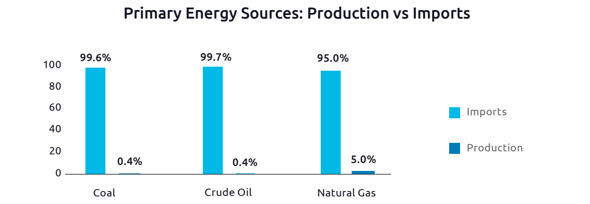
The China's energy sector is dominated by State-Owned Enterprises (SOEs), in particular, State Grid Corporation and China Southern Power Grid.

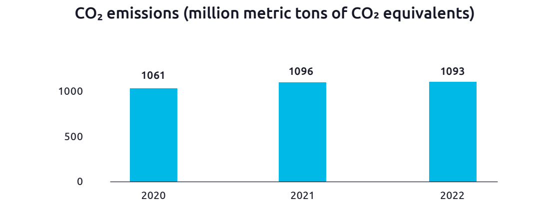
State Grid Corporation supplies power to over 1.1 billion population, covering 88% of Chinese national territory.

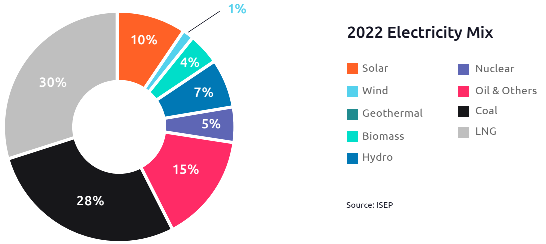
Source: State Grid Corporation of China Website

# Japan

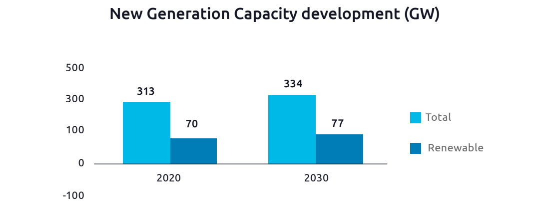
**Japan has accelerated the steps taken to achieve decarbonization to meet two ambitious goals–namely, carbon neutrality by 2050 and a 46% reduction in greenhouse gases (GHG) in fiscal 2030; further growth will be achieved by ensuring a stable and affordable energy supply for the future.**

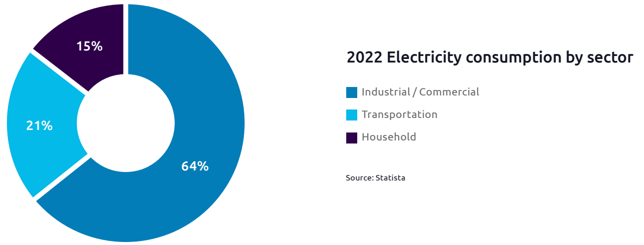



The electricity sector in Japan is governed by the Electricity Business Act (EBA). JEPX is Japan's wholesale electricity exchange acting as an intermediary for electricity sales between producers and retailers.
The energy industry in Japan, which encompasses electric power, gas and other energy resources, is regulated by the Ministry of Economy, Trade and Industry (METI)




As of January 2022, there are 33 operable reactors in Japan, of which 10 reactors are currently operating. Additionally, 7 reactors have been approved for restart and further 8 have restart applications under review.

The Japanese government plans to invest 15 trillion yen ($107.5 billion) over the next 15 years to supply the country with hydrogen
Japan's targets for 46% reduction in greenhouse gases by 2030 and climate neutrality by 2050

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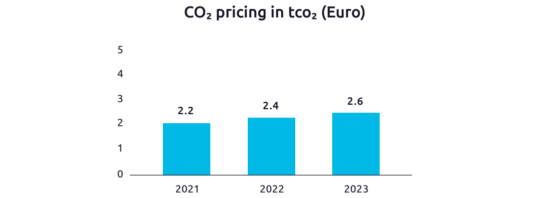


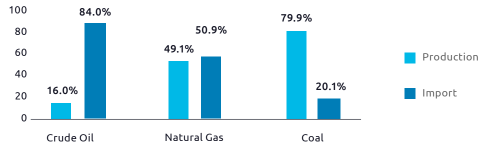

Japanese government has allocated 8 billion yen to support the introduction of independent solar power generation equipment and storage batteries including electric vehicles through on-site PPA.
The cost of a PPA ranges from 10 JPY/kWh

Japan, the latest among Asian nations started carbon pricing scheme in stages from April 2023 to encourage companies to curb emissions and achieve its goal of carbon neutrality by 2050.

# India

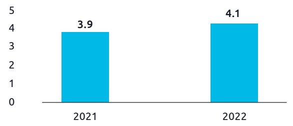
**India has allocated $4.3 billion for the energy transition in the shape of increased power transmission for renewables, biogas and green fertilizer support. Further, Finance Ministry has stated that the budgeted sum would improve energy security and help achieving the target of net zero emissions by 2070.**

### Primary Energy Sources: Production vs Imports



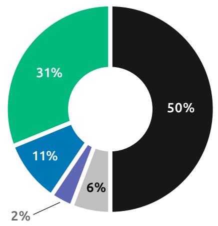

Source: U.S. Energy Information Administration

### GHG Emissions (billion metric tons of $CO_2$ equivalent)

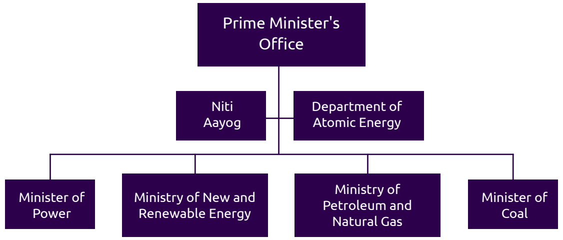



Source: Statista, Statistical Review of World Energy 2023

### 2022 Electricity Mix

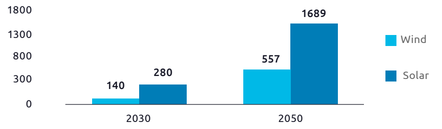



Source: Central Electricity Authority (CEA)



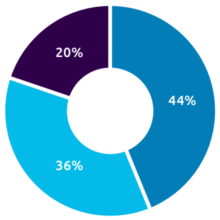

Each Ministry has agencies and Public Sector Undertakings operating under them.

### New Generation Capacity development (GW)




Source: Ministry of New and Renewable Energy, CEEW

### 2022 Electricity consumption by sector




Source: Enerdata


Individual State grids were interconnected to form five regional grids covering mainland India. The five power grids consist of Northern Region, Eastern Region, Western Region, North-eastern Region, and Southern Region grids.

**Saint-Gobain signs Power Purchase Agreement (PPA) in India with Vibrant Energy.** The 20-year PPA is set to commence delivery in 2024 and is expected to increase India's renewable electricity share to 65% by 2025, according to Saint-Gobain. As part of the agreement, Vibrant Energy will provide Saint-Gobain with 189 GWh of renewable electricity annually, sourced from solar and wind energy.

Sources: ET EnergyWorld

**Carbon Pricing**
India does not have an explicit carbon pricing mechanisms like carbon tax, though it does have an array of schemes and implicit taxation mechanisms that put an implicit price on carbon, such as Coal Cess, Perform Achieve Trade schemes and Renewable energy certificates

Bureau of Energy Efficiency, Ministry of Power, along with Ministry of Environment, Forest & Climate Change are developing the Carbon Credit Trading Scheme.

Source: CBGA, Ministry of Power

**Sources:** 1 - Central Electricity Authority, 2 - Enerdata, Statista, 3 - Invest India, 4 - U.S. Energy Information Administration
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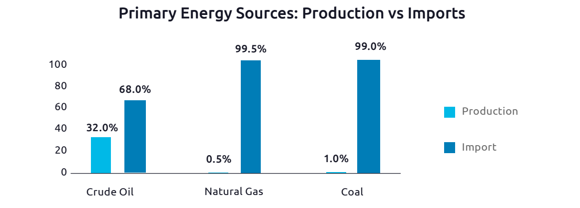
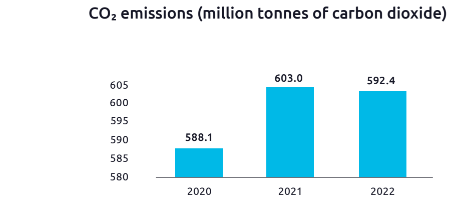
# South Korea

Ministry of Trade, Industry and Energy

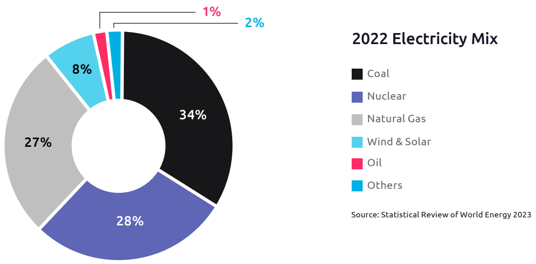
## European companies will invest in projects worth a total of 1.2 trillion won ($929 Million) in South Korea; Imerys, Umicore, Continental, Nylacast, Copenhagen Infrastructure Partners and Equinor will invest in fields including batteries, automotive materials and offshore wind




Source: EIA




Source: Statista, Statistical Review of World Energy 2023



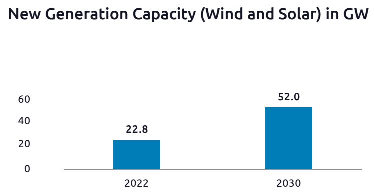

Source: Statistical Review of World Energy 2023

The Ministry of Trade, Industry and Energy (MOTIE), is concerned with regulating some economic policy, especially with regard to the industrial and energy sectors. MOTIE has taken on expanded roles and responsibilities, to help transform South Korea into a dynamic and economic powerhouse.

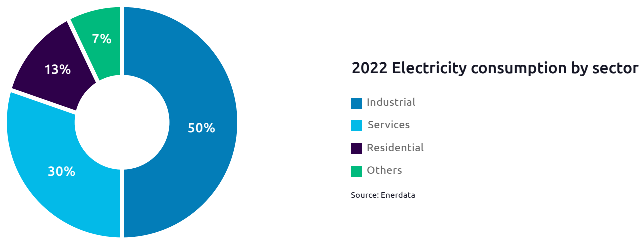
While, the Electricity Regulatory Commission (KOREC), a government agency functioning under the ministry, is responsible for the regulatory matters.

**South Korea's electric grid is isolated from the neighbouring countries, and it imports most of its fuel needs.**

In the domestic electric power industry, 6 power generation companies, independent power producers, and community energy systems are producing electric power, and KEPCO transports the electric power it purchased from the Korea Power Exchange through the transmission and distribution network and sells it to general customers.




Source: Wood Mackenzie




Source: Enerdata

| Public Utilities | Private Utilities |
|---|---|
| • Korea Electric Power Corporation's (KEPCO) wholly owned power generation subsidiaries, collectively referred to as the GENCOs, sustained approximately 69.5% of South Korea's electric power generation | • The local Independent Power Producers (IPPs) accounted for 30.5% |

Source: International Trade Administration

**Carbon Pricing**
The carbon prices have strengthened to around $30 a ton and new mechanisms will enable the carbon price to drive fuel switching away from coal in the power sector and open the door to significant auctioning that strengthens the carbon price signal and raises climate finance.

Source: Nikkei Inc.

**Sources:**
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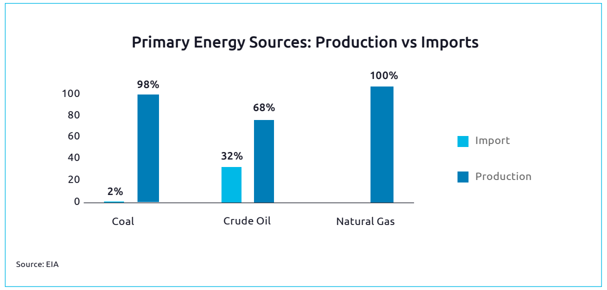
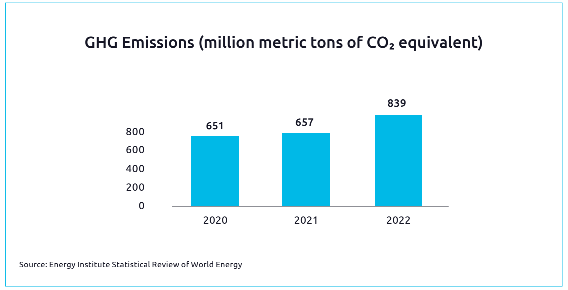
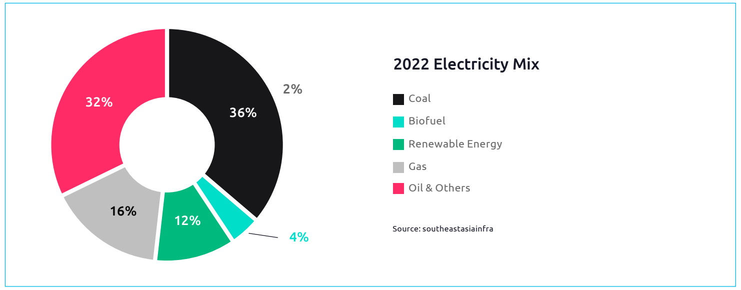
## Indonesia

**Indonesia needs $172 billion investment to increase renewable energy use, and upgrades for its electricity grid to add 60 GW of new renewable power capacity; $172 billion investment until 2040 would also include $5 billion spending for a smart grid, which would allow more penetration of variable renewable energy such as solar and wind power to Indonesia's electricity system.**



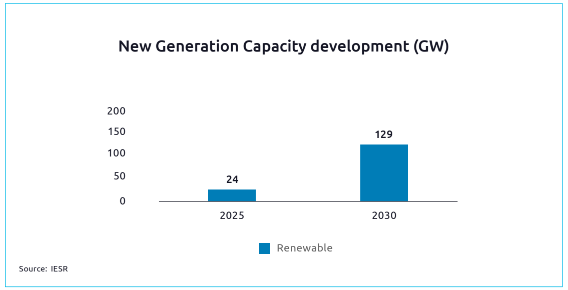



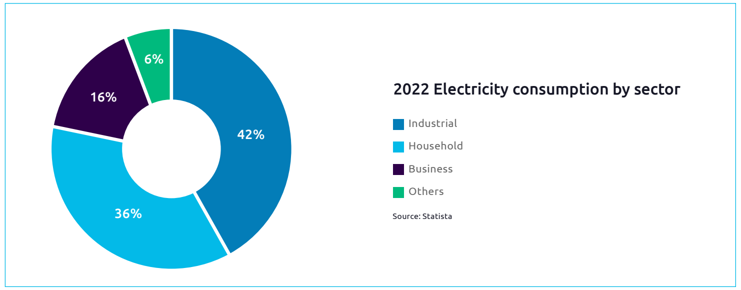

The main regulator for the energy industry in Indonesia is MEMR (Ministry of Energy and Mineral Resources)

PT Perusahaan Listrik Negara (Persero), an Indonesian government-owned corporation, has a monopoly on electric power distribution in Indonesia

In 2022, Indonesia had an electrical capacity of 81.2 GW with a projected capacity of 85.1 GW for 2023

In 2022, the value of investments in the renewable energies sector in Indonesia was approximately 1.55 billion U.S. dollars.
In March 2023, The USA and Indonesia have announced a strategic partnership to help Indonesia develop its nuclear energy programme, supporting Indonesia's interest in deploying small modular reactor (SMR) technology to meet its energy security and climate goals.
Indonesia, the world's largest exporter of coal aims to increase the proportion of renewables in its energy mix to 23% by 2025, but has only reached around 12% so far.




**Total Eren, partners sign 70-MW wind PPA in Indonesia in May 2023**

**Amazon signs 210MW solar PPA with PLN in Indonesia in 2022**

On 22 February 2023, the Ministry of Energy and Mineral Resources (MEMR) announced the launch of the mandatory, intensity-based ETS for the power sector,

Indonesia does not levy an explicit carbon price. However, Indonesia is working towards a mandatory domestic ETS for the power sector as one of the policy mechanisms to help meet its NDC targets and foster low-carbon sustainable development

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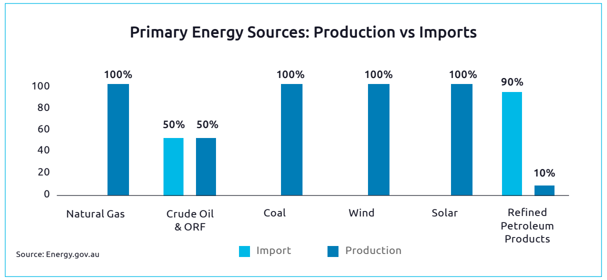
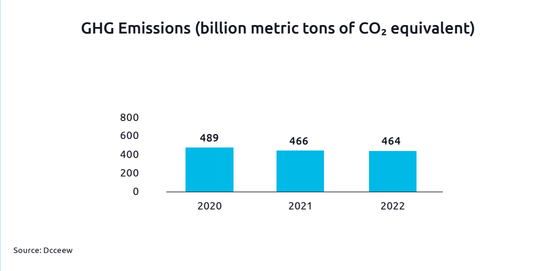
# Australia

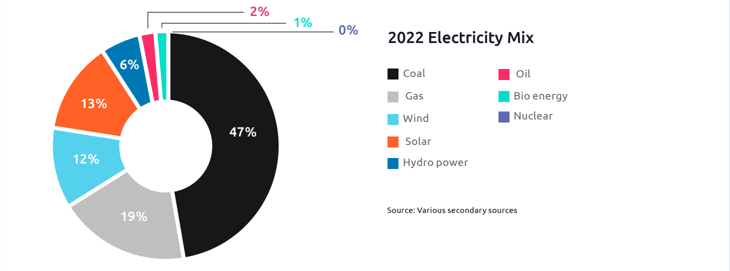
**Australian Government is opting for a collaborative approach to push renewables with states and territories under the new National Energy Transformation Partnership (NETP) with a broad scope of action. The Australian Government in its Budget October 2022–23 has committed record funding of almost $25 AUD billion to clean energy spending, providing greater direction and backing the Government's net zero commitment by 2050.[1]**



Source: Energy.gov.au



Source: Dcceew

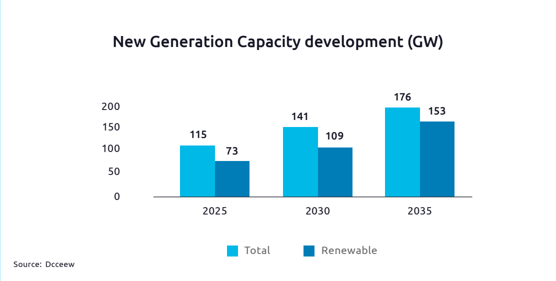


Source: Various secondary sources

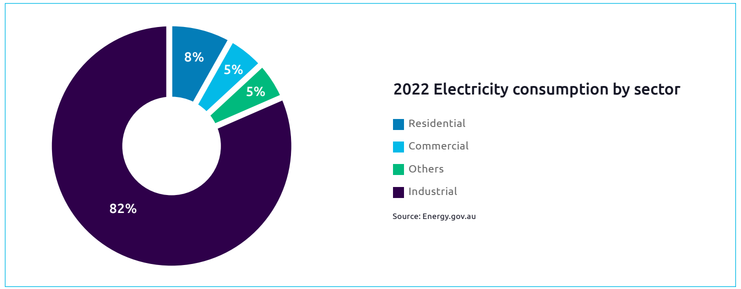
**AEMO** manages electricity and gas systems and markets across Australia, helping to ensure Australians have access to affordable, secure and reliable energy.

**ARENA** is the Australian Renewable Energy Agency aims to support improvements in the competitiveness of renewable energy and enabling technologies, increase the supply of renewable energy in Australia.

**Clean Energy Regulator (CER)** is responsible for measuring, managing, reducing or offsetting Australia's carbon emissions.



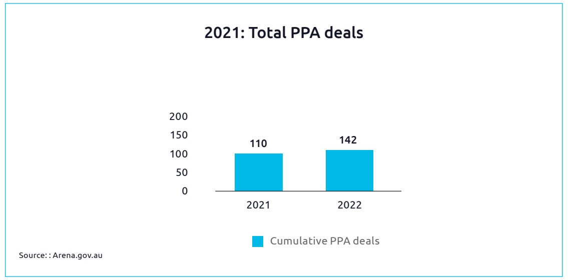
Source: Dcceew



Source: Energy.gov.au

Australia has ensued the Climate Change Act in 2022, which doubles the target for emissions reductions by 2030 and sets the aim of achieving net zero emissions by 2050. The Australian government also signed up to the Global Methane Pledge in 2022, joining 130 governments who are jointly targeting a decline in methane emissions of at least 30% by 2030.

In recent months, the Australian government has exhibited a host of policy strategies to fast-track the country's energy transition including the Rewiring the Nation Plan, the National Energy Transformation Partnership, and National Energy Performance Strategy.[2]



Source: : Arena.gov.au

**Australia does not levy an explicit carbon price. Fuel excise taxes, an implicit form of carbon pricing, cover 14.9% of emissions in 2021, unchanged since 2018.**

Source: Organisation for Economic Co-operation and Development

**Sources:** 1- Globalaustralia.gov.au, 2 - iea.org
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# REGION 3: MIDDLE EAST

Region: Middle East (Iran, Iraq, Israel, Kuwait, Oman, Qatar, Saudi Arabia, the United Arab Emirates, other Middle East)

Population: 197.5 million

## Electricity generation

**Total electricity generation (2022): 1365.1 TWh**

- Iran: **348.1 TWh**
- Iraq: **117.2 TWh**
- Israel: **76.5 TWh**
- Kuwait: **83.0 TWh**
- Oman: **41.4 TWh**
- Qatar: **50.0 TWh**
- Saudi Arabia: **401.6 TWh**
- The United Arab Emirates: **154.7 TWh**
- Other Middle East: **92.6 TWh.**

## Renewable energy

**Renewables generation in the Middle East: 27.0 Twh**

(Israel - 7.2 Twh, United Arab Emirates - 7.0 Twh, Iran - 2.0 Twh, Oman -1.6 Twh)

## Energy-related $CO_2$ emissions (2022): 2,200 million tons $CO_2$

- Iran: **667.4 million tons $CO_2$**
- Iraq: **153.1 million tons $CO_2$**
- Israel: **65.8 million tons $CO_2$**
- Kuwait: **95.4million tons $CO_2$**
- Oman: **80.6 million tons $CO_2$**
- Qatar: **110.8 million tons $CO_2$**
- Saudi Arabia: **612.5 million tons $CO_2$**
- The United Arab Emirates: **292.5 million tons $CO_2$**
- Other Middle East: **121.9 million tons $CO_2$**

## Electric vehicles and charging

- **Israel:** EV car sales of 43,000 in 2022 with 1,200 public AC charging outlets and 150 public DC charging outlets.
- **Qatar:** In 2022, 800 E-vehicles were sold in Qatar and the country has nearly 100 charging stations.
- **Saudi Arabia:** Saudi to produce 500,000 EVs annually by 2030 backed by various investments, deals and partnerships.
- **UAE:** According to the Dubai Water and Electricity Authority, the number of EVs in Dubai is estimated to be 7,331 in 2023 and expected to reach 12,852 by 2025.

## Major energy players

- **Iran:** National Iranian Oil Company, Pars Oil and Gas Company, Isfahan Refinery
- **Qatar:** QatarEnergy, Qatar General Electricity and Water, Qatargas
- **Saudi Arabia:** Saudi Aramco, MARAFIQ Power And Water Utility Company For Jubail And Yanbu, ACWA Power Co, Saudi Electricity Company
- **UAE:** ADNOC, TAQA, Dubai Electricity and Water Authority.

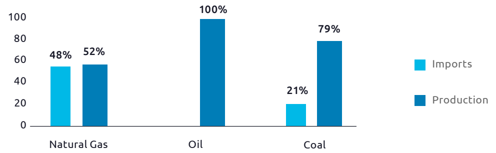
## Recent developments

- **Iran:** The total capacity of renewable power plants in Iran has now reached 1,085 megawatts, which is a significant milestone for the country. The Iranian Energy Ministry has set a target of adding 10,000 megawatts to the country's renewable power plant capacity by the end of 2025.
- **Iraq:** In July 2023, Iraq and French oil major TotalEnergies signed a long-delayed $27 billion energy deal that aims to increase oil production and boost the country's capacity to produce energy with four oil, gas, and renewables projects. The Gas Growth Integrated Project (GGIP) will play a crucial role in improving Iraq's electricity supply by utilizing flared gas from oilfields and developing a solar power plant.
- **Israel:** Israel's Ministry of Energy and Infrastructure has announced that the country will allocate more than 2 additional GW of power in the national electricity grid to connect renewable energy facilities, which will be primarily solar. Israel targets 20% of power produced from renewable sources in 2025.
- **Kuwait:** The Ministry of Electricity, Water, and Renewable Energy of Kuwait has stressed the importance of speeding up national plans to produce no less than 15% of the grid's consumption of renewable energy by 2023.
- **Oman:** Oman aims to produce at least 1 million tons of renewable hydrogen a year by 2030, up to 3.75 million tons by 2040 – and up to 8.5 million tons by 2050, which would be greater than total hydrogen demand in Europe today.
- **Qatar:** In September 2022, state-owned oil and gas company Qatar Energy signed a deal with TotalEnergies for the Northfield South (NFS) Expansion. In mid-2022, Qatar Energy and Total Energies made five separate partnership announcements for the Northfield East (NFE) project, which will cost around $29 billion to construct.
- **Saudi Arabia:** The King Salman Renewable Energy Initiative, under Saudi Arabia's Vision 2030, sets renewable targets of 27.3 GW (20 GW of solar PV and 7 GW of wind) by 2023. It has also been stated that the next goal is set at 58.7 GW (40 GW of solar PV, 16 GW of wind and 2.7 GW of CSP) by 2030.
- **The UAE:** The UAE is planning to invest $54 billion on renewables over the next seven years as part of its strategies to reach net-zero emissions by 2050. The UAE approved its national energy strategy with the aim of tripling its share of energy coming from renewable sources.

# Saudi Arabia

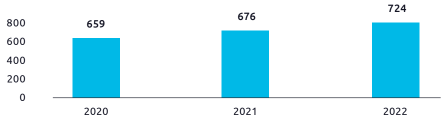
**Saudi Arabia will invest up to one trillion riyals ($266.40 billion) to generate "cleaner energy"; investments aim also to "add transport lines and distribution networks in order to eventually export the energy to the world and produce clean hydrogen**

Primary Energy Sources: Production vs Imports



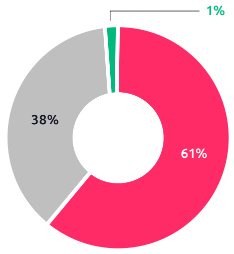

Sources: Clean Energy Wire

$CO_2$ emissions (million metric tons of $CO_2$ equivalents)




Source: Energy Institute Statistical Review of World Energy

2022 Electricity Mix

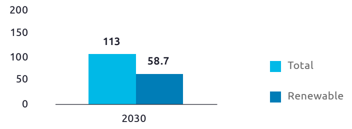



Sources: BP Statistical Review of World Energy 2022, IRENA

**The Water and Electricity Regulatory Authority (WERA)** regulates the electricity and water desalination sector within the Kingdom. It also preserves these services from economic fluctuations to maintain financial growth and the prosperity of the national economy.

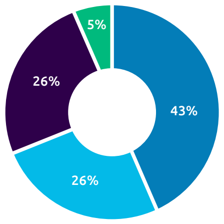
**Saudi Arabia qualifies over 100 firms for small solar projects:** The Water and Electricity Regulatory Authority (WERA) has certified 106 ESCOs that will be authorized to carry out small solar power projects in the country. The move is part of the Gulf Kingdom's plan to shift towards cleaner energy sources under Vision 2030.

New Generation Capacity development (GW)




Source: Enerdata

2022 Electricity consumption by sector




Source: Enerdata, Clean Energy Wire

**Sources:** IRENA_RE_Capacity_Statistics_2023.
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**Saudi Arabia approves framework for renewable energy systems for self-use:** The Water and Electricity Regulatory Authority has approved the regulatory framework for renewable energy systems for self-consumption. The decision will enable consumers to install renewable energy systems for self-use, expanding beneficiaries of renewable energy technologies.

Saudi Arabia's Water and Electricity Holding Co. (Badeel) and ACWA Power signed power purchase agreements with the Saudi Power Procurement Co. for three huge solar projects for a combined 4.55 GW of capacity. The Ar Rass 2, Saad 2 and Al Kahfah projects have projected capacities of 2.0 GW, 1.1 GW and 1.4 GW, respectively

# REGION 4: AFRICA

Region: Algeria, Egypt, Morocco, South Africa, eastern Africa, central Africa, western Arica, and other northern and southern African countries

Population: 1.4 billion

## Electricity generation

**Total Africa electricity generation (2022): 892.7 TWh**

- Algeria : **91.6TWh**
- Egypt: **200.8 TWh**
- Morocco: **41.2 TWh**
- South Africa: **234.8 TWh**
- Eastern Africa: **123.1 TWh**
- Central Africa: **45.4 TWh**
- Western Africa: **91.7 TWh**
- Other northern Africa: **58.7 TWh**
- Other southern Africa: **5.4 TWh**

## Renewable energy

**Renewables generation in Africa : 50.8 Twh**

(Algeria: 0.7 TWh, Egypt: 10.2 TWh, Morocco: 6.8 TWh, South Africa: 16.3TWh, Eastern Africa: 12.4 TWh, Central Africa: 0.5 TWh, Western Africa: 2.1 TWh, other northern Africa: 1.0 TWh, other southern Africa: 0.7 TWh)

## Energy-related $CO_2$ emissions (2022): 1,306.7 million tons $CO_2$

- Algeria: **141.4 million tons $CO_2$**
- Egypt: **235.5 million tons $CO_2$**
- Morocco: **67.1 million tons $CO_2$**
- South Africa: **420.4 million tons $CO_2$**
- Eastern Africa: **123.7 million tons $CO_2$**
- Central Africa: **41.2 million tons $CO_2$**
- Western Africa: **179.1 million tons $CO_2$**
- Other northern Africa: **82.9 million tons $CO_2$**
- Other southern Africa: **15.4 million tons $CO_2$**

## Electric vehicles and charging

- South Africa: 300+ fast and slow charging points, EV car sales: 620 (in 2022 according to IEA)
- Morocco to build 2,500 charging stations by 2026
- EV charging network provider Infinity-E is in talks with the Egyptian government over plans to roll out 6,000 charging stations across the country.

## Major energy players

- **South Africa:** Eskom, Sasol, PetroSA, Exxaro
- **Morocco:** TAQA Morocco S.A., ONEE
- **Nigeria:** Seplat Energy, NNPC
- **Egypt:** Middle East Oil Refinery (MIDOR), North Cairo Electricity Distribution Company

## Recent developments

- **Egypt:** Egypt seeks to boost reliance on renewably energy to make up 42% of the country's total electricity needs by 2030, to reach renewable energy capacity share of 60% by 2040.
- **Morocco:** The Moroccan government published its long-term strategy, committing to increase the share of renewable energy in the electricity mix to 80% by 2050.
- **South Africa:** South Africa takes major step towards a clean energy future with a 3,740 MW renewable energy tender released under the Integrated Renewable Energy and Resource Efficiency Program (IREREP).
- **Nigeria:** The Federal Government of Nigeria had a sustainable electricity vision of achieving 30GW by 2030 with 30% renewable energy; the government collaborated with the German Agency for International Cooperation under the Nigeran Energy Support program.
- **Algeria:** Algeria aims to produce 27% of its electricity from renewable resources by 2035, mostly from solar power. To reignite the country's energy transition, in 2021, the Algerian government made a new push to develop strategic partnerships in the field of renewable energies with multiple countries, including China, Germany, and the United States.

# REGION 5: NORTH AMERICA

Region: North America

Population: **369 million**

GDP: **$27,610.09 billion**

## Energy

2022 total energy consumption: **2842 Mtoe**

## Gas

Total gas production: **1203.9 bcm**

Total gas consumption: **1099.4 bcm**

## Environment

Total $CO_2$ equivalent emissions from energy, process emissions, methane, and flaring: 6,466.6 million tons of $CO_2$ equivalent

Energy-related $CO_2$ emissions: 5,851 million tons of $CO_2$ equivalent

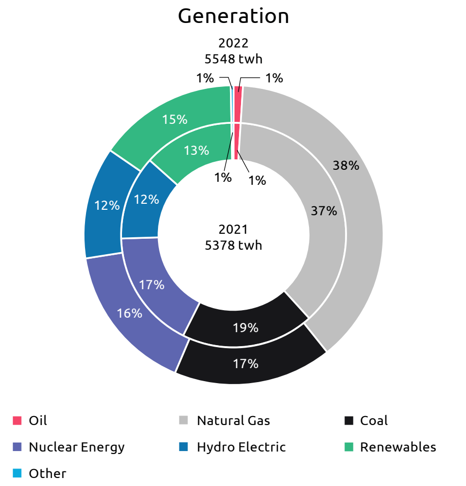
## Renewable energy

Renewables share in energy generation: **15%**

Renewables generation: **817.8 Twh**

2022 added renewable capacity: **29.1 GW**

## Electricity




## Network

- In November 2022, The Biden-Harris Administration, through the US Department of Energy (DOE), announced an investment of $13 billion in the expansion and modernization of the nation's electric grid.
- The Government of Canada supports 12 Clean Energy Projects in Alberta with over $175 million in federal investments.
- Mexico has long-term plans to connect Baja California to the national grid, and the conditional approval of a $254 million transmission line from the Puerto Peñasco plant to Baja California would make that a reality.

## Electric vehicles (EVs)

- By the end of 2022, fully electric vehicles accounted for 7% of North American car production, up from 4.7% in 2021.
- According to a Nikkei estimate, global investment in electric vehicles is growing rapidly in North America, with North American EV investments to surpass $140 billion.
- President Biden's Bipartisan Infrastructure Law invests $7.5 billion in EV charging, $10 billion in clean transportation, and over $7 billion in EV battery components, critical minerals, and materials.

## Energy players

**The United States:** NRG Energy, Duke Energy, Southern Company, Pacific Gas & Electric, NextEra Energy, American Electric Power, Exelon, Edison International, Consolidated Edison, Sempra Energy, FirstEnergy, the AES Corp.

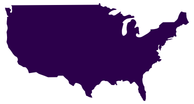
**Canada:** Hydro-Québec, BC Hydro, Hydro One, Ontario Power Generation, ENMAX, TransAlta.

**Mexico:** PEMEX, CFE (Commission Federal de Electricidad), Iberdola Mexico, Sempra Infrastructure, Naturgy Mexico, AES Mexico, TC Energy Mexico.

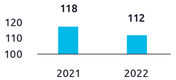
## Region highlights

- North America witnessed the largest increase in planned hydrogen projects in 2022. For instance, Biden administration's Inflation Reduction Act has earmarked $369 billion for green energy programs, and the US currently offers generous tax credits to clean hydrogen producers.
- Canadian and US hydropower resources represent approximately 80% of total renewable electricity generation in North America, with 175,000 megawatts of installed hydro capacity in Canada and the US.

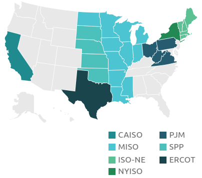
# U.S.A.

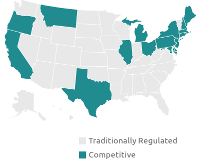


PPA deals



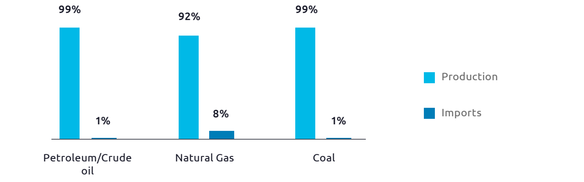

Source: Sustainable Energy in America 2023 Factbook

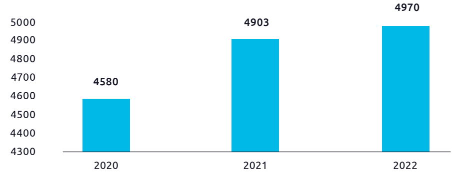

**In U.S., the private sector has announced more than $110 billion in new clean energy manufacturing investments, including more than $70 billion in the electric vehicle (EV) supply chain and more than $10 billion in solar manufacturing In the last 12 months since the Inflation Reduction Act was signed into law.**

Primary Energy Sources: Production vs Imports



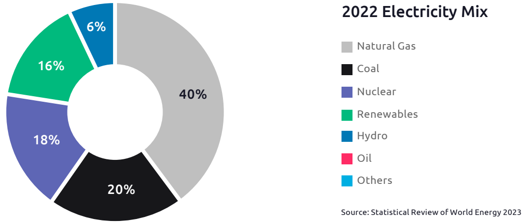

Source: Sustainable Energy in America 2023 Factbook

$CO_2$ emissions (million metric tons of $CO_2$ equivalents)




Source: Statista

2022 Electricity Mix




Source: Statistical Review of World Energy 2023

Regulations in the U.S. are enforced by several federal and state government entities; **Federal Energy Regulatory Commission (FERC)** for interstate transmission of electricity, natural gas and oil, and regulation of hydropower projects and natural gas terminals, **Nuclear Regulatory Commission** for the regulation of nuclear energy.[1]

**Inflation Reduction Act (IRA)** enacted in August 2022 has extended tax credits for renewables until 2032. The IRA has further infused **around $370 billion** in green subsidies and tax credits aimed at cutting carbon emissions in half by 2030.[2]

Some parts of U.S. wholesale electricity market are traditionally regulated; Other parts of the wholesale market **(Northeast, Midwest, Texas, and California) are restructured competitive markets run by ISOs.** ISOs includes both regional transmission organizations RTOs and ISOs.

Retail markets are determined at the state level and can be traditionally regulated or competitive. **Traditionally regulated electricity markets dominate most of the Southeast, Northwest and much of the West** (excluding California).

Competitive retail electricity markets allow electricity consumers to choose between competitive retail suppliers. Some states, like **California, are partially restructured markets** and only permit certain consumers to engage in retail choice.[3]

**Sources:** 1 - U.S. Energy Information Administration, 2 - BloombergNEF and Statista, 3 - Statistical Review of World Energy 2023
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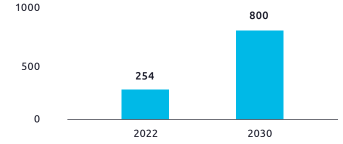
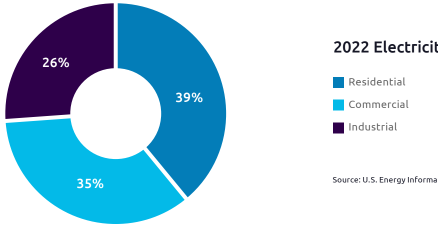
2023%20BCSE%20BNEF%20Sustainable%20Energy%20in%20America%20Factbook.pdf

New Generation Capacity (Wind and Solar in GW)




Source: IRENA and Canada Energy Regulator

2022 Electricity consumption by sector




Source: U.S. Energy Information Administration

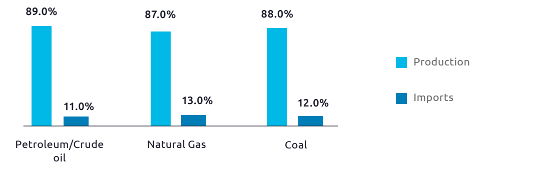
| | Investor owned utilities | Publicly owned utilities & cooperatives |
|---|---|---|
| Net Generation | 38% | 15% |
| Transmission | 80% | 12% |
| Distribution | 50% | 50% |

Source: Forbes

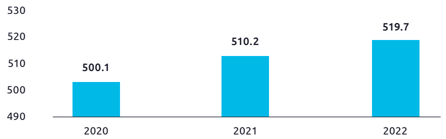
| Energy tax credits and subsidies | |
|---|---|
| U.S. subsidies for the fossil fuel | **$10 to $50 billion per year (est.)** |
| Credit for carbon capture and storage | **$85 per metric ton** |
| New clean electricity credit | **up to 30%, plus 10% bonus** |
| Renewable electricity production tax credit | **up to 1.3 cents/kWh** for electricity generated from solid waste, or up to **2.6 cents/kWh** for electricity generated from wind, closed-loop biomass and geothermal resources. |

# Canada

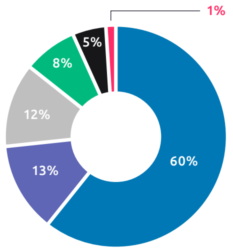
## Canada has unveiled an $80bn investment plan aimed at promoting clean energy and sustainable infrastructure in response to the U.S. Inflation Reduction Act.



Source: U.S. Energy Information Administration



Source: Statistical Review of World Energy 2023



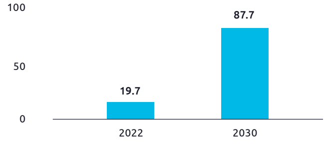
Source: Statistical Review of World Energy 2023

The **federal government** plays a supporting role by investing in research and development and supporting the commercialization of new technologies.
**The Canada Energy Regulator** exercises federal jurisdiction over electricity exports and over international and interprovincial power lines; **The Canadian Nuclear Safety Commission regulates** the use of nuclear energy and materials to protect health, safety, security and the environment, and to implement Canada's international commitments on the peaceful use of nuclear energy.[1]

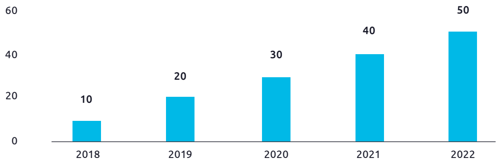
Canada has three power grids such as **the Western grid, the Eastern grid, and the Quebec grid.** Canada's grids are also tied into the United States' grids through 37 major transmission lines from New England to the Pacific Northwest.[2]

The Canada Energy Regulator describes Canada's electricity grid as "fragmented," with few grid connections that link different locations together. The large grid connections primarily connect provinces to the United States and electricity flows north to south.[3]

The corporate PPA sector has been experiencing recent growth in Alberta, which has a fully deregulated electricity market along with strong wind and solar resource potential.[4]



Source: IRENA and Canada Energy Regulator



Source: Government of Canada

| | | |
|---|---|---|
| Public (municipal, provincial): Around 60% of the utilities are municipally owned | Private (Investor-Owned) | Co-operative 20% are owned by co-operatives |

Provincial governments exercise their jurisdiction through provincial Crown utilities and regulatory agencies. Traditionally, electricity has been provided mainly by vertically-integrated electric utilities that were often provincial Crown corporations with monopoly rights (e.g., Manitoba Hydro).

| Energy tax credits and subsidies | |
|---|---|
| Refundable tax credit for clean energy investments, including solar photovoltaic, wind, storage and small modular nuclear reactors. | **30% of up to C$ 6.7 billion over five years** |
| Investment Tax Credit for Clean Electricity | **15%** |
| Investment Tax Credit for Clean Hydrogen | at least **40%** the lowest carbon intensity tier that meets all eligibility requirements |

**Sources:** 1 - Statistics Canada, 2 - Government of Canada, 3 - Canada Energy Regulator
https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2510001501&pickMembers%5B0%5D=1.1&pickMembers%5B1%5D=2.1&cubeTimeFrame.startMonth=01&cubeTimeFrame.startYear=2022&cubeTimeFrame.endMonth=12&cubeTimeFrame.endYear=2022&referencePeriods=20220101%2C20221201
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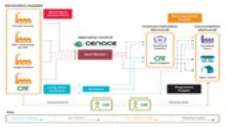
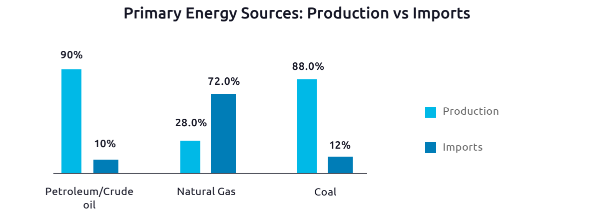
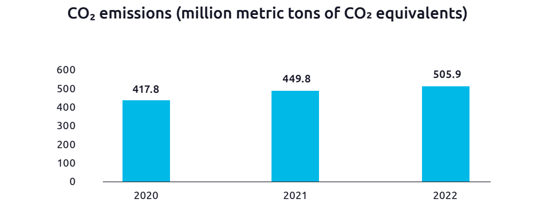
https://climateinstitute.ca/wp-content/uploads/2021/09/CICC-Improving-integration-and-coordination-of-provincially-managed-electricity-systems-in-Canada-by-Pierre-Olivier-Pineau-FINAL.pdf
https://iea.blob.core.windows.net/assets/7ec2467c-78b4-4c0c-a966-a42b8861ec5a/Canada2022.pdf

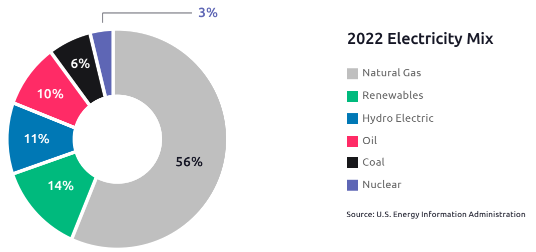
# Mexico



**On April 2023, Mexico's president announced a deal to acquire 13 power plants operated Iberdrola in the country for estimated $5.94 billion Mexico's Plan Sonora aims to attract $48 billion in solar photovoltaic and wind farms between 2023 and 2030.**



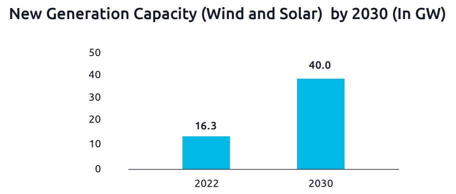



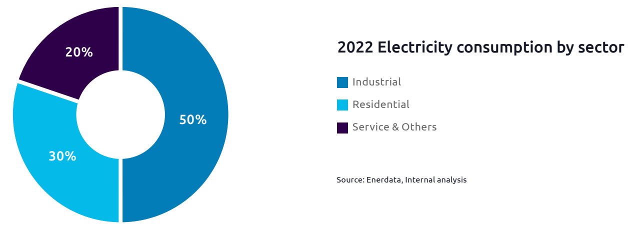

Mexico's National Electric System (Sistema Eléctrico Nacional or SEN) is comprised of nine regions, plus a binational electricity system in Baja California. Most of the nine regions are interconnected, forming the National Interconnected System (SIN). The Baja California system operates in the Western Interconnection of the United States, overseen by the Western Electricity Coordinating Council (WECC).

Further, North America is comprised of two major and three minor alternating current (AC) power grids or "interconnections". The Western Interconnection stretches from Western Canada South to Baja California in Mexico, reaching eastward over the Rockies to the Great Plains.

Power Purchase Agreements (PPAs) is one of the main ways to trade energy in Mexico. Several Private energy utilities like Iberdrola, Enel, ENGIE, and Mitsui offers attractive PPAs in Mexico for large consumers.

The other mechanism to trade energy is the wholesale market. **Mexican Wholesale Electricity Market (MEM)** is a short-term market where prices are determined one day in advance or in real-time. Electricity producers send bids to the National Center for Energy Control (CENACE) that indicate the amount of energy they are offering at a specific price. Currently, CFE and some private companies are participating in the markets.




| Role of Government and regulators | |
|---|---|
| Energy Ministry (SENER) | preparation, enforcement and supervision of the electricity energy policy |
| Energy Regulatory Commission (CRE) | Government regulator for Mexico's oil, natural gas, biofuels, and electricity sectors |
| CENACE (Centro Nacional de Control de Energía), a subdivision of a State-owned electric utility company, CFE (Comisión Federal de Electricidad), | manages the wholesale electricity market and power grid. It regulates the purchase and sale market of electric energy |

**Public Utilities**

- State-owned electric utility company, CFE (Comisión Federal de Electricidad) holds 55.5% share of the electricity market
- In 2022, CFE produced 74% of the electricity consumed in Mexico, covering 99.2% of the population's needs.

**Private Utilities**

- Few of the major private power utilities include:
  - Iberdrola
  - Naturgy
  - Sempra Energy
  - Fermaca
  - TC Energy

Source: Economic Times, Mexico Business

**Sources:** https://energy.economictimes.indiatimes.com/news/power/mexico-power-plant-purchases-touted-as-new-nationalization/99258761
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WORLD ENERGY MARKETS OBSERVATORY

# SHAPING TOMORROW'S ENERGY LANDSCAPE

## About WEMO

The World Energy Markets Observatory (WEMO) is Capgemini's annual thought leadership and research report created in partnership with Vaasa ETT and Enerdata, that tracks the development and transformation of electricity and gas markets in Europe, North America, Australia, Southeast Asia, India, and China. Now in its 25th edition, the report includes in-depth coverage of: commodities markets, climate change and regulatory policies; energy transition and related technologies; infrastructure and adequacy of supply; supply and final customer; transformation; financials; and the Oil & Gas industry's shift from fossil fuels to low carbon (route to net zero).

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# Glossary

### ACER
Agency for the Cooperation of Energy Regulators, created under the EU Third Legislative Package, adopted in April 2009

### ACORE
Stands for American Council on Renewable Energy, is a national non-profit organization that unites finance, policy and technology to accelerate the transition to a renewable energy economy.

### AEMC
Set up by the Council of Australian Governments through the Ministerial Council on Energy in 2005, the Australian Energy Market Commission makes and amends the National Electricity Rules, National Gas Rules and National Energy Retail Rules, and also provides market development advice to governments.

### AEMO
The Australian Energy Market Operator is responsible for operating Australia's largest gas and electricity markets and power systems, including the NEM and Wholesale Electricity Market (WEM) and power system in Western Australia.

### AGA
American Gas Association Representing more than 200 local energy companies that deliver clean natural gas throughout the United States.

### AMI
Stands for Advanced Metering Infrastructure, it is the collective term to describe the whole infrastructure from Smart Meter to two way-communication network to control center equipment and all the applications that enable the gathering and transfer of energy usage information in near real-time.

### Asian Renewable Energy Hub
The Asian Renewable Energy Hub (AREH) is a proposal to create one of the world's largest renewable energy plant in the Pilbara region of Western Australia. It was first proposed in 2014, with plans for the project concept changing several times since then. As of June 2022, the project developers BP, Intercontinental Energy, CWP Global, Vestas and Pathway Investments were planning to build a mixture of wind power and solar energy power generators which would generate up to 26 gigawatts of power.

### Backwardation/Contango
"Contango" means that long-term prices are more expensive than short-term prices, depicting a relaxed short-term market, whereas "backwardation" reveals more tension in the short-term reflected in higher short-term prices than in the long-term

### Base load
The minimum amount of electricity delivered or required over a given period, at a constant rate

### Battery of the Nation
The Battery of the Nation initiative is investigating and developing a pathway of future development opportunities for Tasmania to make a greater contribution to the NEM.

### Bilateral contracts/OTC
A contractual system between a buyer and a seller agreed directly without using a third party (exchanges, etc.). Also named as OTC for Over The Counter

### Black Certificates
Exchangeable or tradable CO2 allowances or quotas within the European Trading Scheme and Kyoto protocol (see EUA)

### CAISO
Stands for California Independent System Operator is the non-profit Independent System Operator serving California that oversees the operation of California's bulk electric power system, transmission lines, and electricity market generated and transmitted by its member utilities.

### CAPEX
Capital Expenditure, funds used by a company to acquire or upgrade physical assets

### Carbon Budget
Carbon budget' is the cumulative quantity of CO2 emissions that are allowed in order to keep global warming below a certain warming threshold

### Carbon Cost Coalition
A multi-state coalition of state legislators from 12 states of the USA, who are focused on reducing carbon emissions, ensuring equity in policy proposals, developing market based solutions, creating a resilient local economy and improving public health.

### CCGT/Combined cycle power plant
Combined Cycle Gas Turbine. Thermal power plant, usually running on gas-fired turbines, where electricity is generated at two consecutive levels: firstly by gas combustion in the turbines, and secondly by using energy from the product of the gas combustion process in boilers, which supply heat to steam turbo-generators. This process provides high levels of thermal output (55 to 60%, compared with only 33 to 35% for conventional thermal power plants)

### CCS
Carbon Capture and Storage. Technologies used for isolating carbon dioxide from fuel gas (at combustion plants) and storing it. This means that a significantly lower amount of CO2 is emitted into the atmosphere

### CDM
Clean Development Mechanisms, a mechanism under the Kyoto Protocol through which developed countries may finance greenhouse-gas emission reduction or removal projects in developing countries, and receive credits for doing so which they may apply towards meeting mandatory limits on their own emissions

### CEER/ERGEG
Council of the European Energy Regulators and European Regulators Group for Electricity and Gas. ERGEG was dissolved with the creation of ACER, all ERGEG works are found in CEER website

### CER
Certified Emission Reduction. Quotas issued for emission reductions from Clean Development Mechanism (CDM) project activities

### CHP/Cogeneration
Combined Heat and Power. System of simultaneous generation of electricity and heat. The output from cogeneration plants is substantially better than it would be if they produced only electricity

### Churn/Switch
Free (by choice) movement of a customer from one supplier to another

### Clean Coal
New technologies and processes allowing electricity generation from coal while lowering CO2 emissions

### Clean Dark Spread/Clean Spark Spread
The Clean Dark Spread is the difference between electricity's spot market price and the cost of electricity produced with coal plus the price of related carbon dioxide allowances while the Clean Spark Spread is the same indicator but with electricity produced with natural gas

### Climate Change
Climate change is any significant long-term change in the expected patterns of average weather of a region (or the whole Earth) over a significant period of time.

### Climate Risk Index
Climate Risk Index is released by Germanwatch which analyses to what extent countries and regions have been affected by impacts of weather-related loss events (storms, floods, heat waves etc.)

### Copenhagen Accord
A voluntary agreement between the United States, China, Japan, Canada, Mexico, Russia and hundreds more making up over 80% of the global population and over 85% of global emissions that is based on goodwill of each member country assuming that each country will live up to their part in saving the climate by reducing greenhouse gases.

### CSIRO
Commonwealth Scientific and Industrial Research Organization is an independent Australian federal government agency responsible for scientific research.

### Decentralized generation
Production of electricity near the point of use, irrespective of size and technology, capacity and energy sources

**Demand response**
Any program which communicates with the end-users regarding price changes in the energy market and encourages them to reduce or shift their consumption

**Demand-side participation**
Demand side participation (DSP) reflects the capability of demand side resources (customer load reductions or generation from customers' embedded generators) to reduce operational demand at times of high wholesale prices or emerging reliability issues

**DER**
Distributed Energy Resources refer to distribution level resources that produce electricity or actively manage consumer demand such as solar rooftop PVs, batteries; and demand response activities that manage hot water systems, pool pumps, smart appliances and air conditioning control.

**Deregulated Market**
A "deregulated electricity market" allows for the entrance of competitors to buy and sell electricity by permitting market participants to invest in power plants and transmission lines

**Discom**
Power Distribution Company of the state, responsible for distribution of electrical power in the region and associated activities.

**DG Competition**
European Union's Directorate General for Competition which role is to enforce the competition rules of the Community Treaties

**DG TREN**
European Union's Directorate General for Transport & Energy that develops EU policies in the energy and transport sectors

**Distributed generation**
Any technology that provides electricity closer to an enduser's site. It may involve a small on-site generating plant or fuel cell technology

**Distribution System Loss**
Distribution System Losses are losses pertaining to distribution of electricity. While technical losses are at times under the control of utilities, non-technical losses are external forces that impact the efficiency of the system and lead to revenue leakage

**Dividend per share**
Dividend per share (DPS) is the sum of declared dividends issued by a company for every ordinary share outstanding. The figure is calculated by dividing the total dividends paid out by a business, including interim dividends, over a period of time by the number of outstanding ordinary shares issued

**DMO**
Default market offers also known as the 'standing offers' are default, government-regulated energy offers which do not include any discount.

**DOE (Philippines)**
The Philippines' Department of Energy is the executive department of the Philippine Government responsible for preparing, integrating, manipulating, organizing, coordinating, supervising and controlling all plans, programs, projects and activities of the Government relative to energy exploration, development, utilization, distribution and conservation

**Domestic consumers**
Residential customers

**Dual Monopoly**
A situation wherein; two companies dominate the market. In other words two companies control production and supply of a product

**EBIT**
Earnings Before Interest and Taxes. EBIT may also be called operating income; i.e. the product of the company's industrial and commercial activities before its financing operations are taken into account. EBIT is a key ratio for gauging the financial performance of companies

**EBITDA**
Earnings Before Interest, Taxes, Depreciation and Amortization. EBITDA is a key ratio for gauging the cash flow of companies

**Economic Regulation Authority**
The ERA is Western Australia's independent economic regulator. The ERA's work ensures that Western Australian consumers and businesses have a fair, competitive and efficient environment.

**EERS**
Stands for Energy Efficiency Resource Standards establishes specific, long-term targets for energy savings that utilities or non-utility program administrators must meet through customer energy efficiency programs.

**Electricity Tariffs**
The amount of money frame by the supplier for the supply of electrical energy to various types of consumers in known as an electricity tariff

**Eligible customer**
Electricity or gas consumer authorized to turn to one or more electricity or gas suppliers of his choice

**Energy Efficiency**
Energy efficiency means using less energy to perform the same task

**Energy Innovation and Carbon Dividend Act of 2019**
The Energy Innovation and Carbon Dividend Act of 2019 is a bill in the United States House of Representatives that proposes a fee on carbon at the point of extraction to encourage market-driven innovation of clean energy technologies to reduce greenhouse gas emissions.

**Energy Mix**
Refers to the combination of the various primary energy sources used to meet energy needs in a given geographic region. It includes fossil fuels (oil, natural gas and coal), nuclear energy, non-renewable waste and the many sources of renewable energy (wood, biofuel, hydro, wind, solar, geothermal, heat from heat pumps, renewable waste and biogas).

**Energy Regulatory Commission**

Power Generation in Philippines is regulated by Energy Regulatory Commission (ERC). It is an independent electric power industry regulator that equitably promotes and protects the interests of consumers and other stakeholders, to enable the delivery of long-term benefits that contribute to sustained economic growth and an improved quality of life

**Energy Transition Index**
The Energy Transition Index(ETI) benchmarks countries on the performance of their energy system, as well as their readiness for transition to a secure and sustainable energy future. The ETI aggregates indicators from 40 different energy, economic and environmental datasets in order to provide a comprehensive of the world's energy system

**Energy Trilemma Index**
The World Energy Trilemma Index is an annual comparative ranking of 125 countries on their ability to balance energy priorities Stands for El Niño-Southern Oscillation which is a recurring climate pattern involving changes in the temperature of waters in the central and eastern tropical Pacific Ocean, affecting the climate of much of the tropics and subtropics. The warming phase of the sea temperature is known as El Niño and the cooling phase as La Niña.

**ENTSO-E**
European Network of Transmission System Operators for Electricity. ENTSO-E, the unique association of all European TSOs, was created at the end of 2008 and is operational since July 1, 2009. All former TSOs associations such as UCTE or ETSO are now part of ENTSO-E

**ENTSO-G**
European Network of Transmission System Operators for Gas. ENTSO-G was created at the end of 2009 and comprises 32 gas TSOs from 22 European countries

**EPIC**
Stands for Energy Policy Institute at Chicago, it is an interdisciplinary research and training institute focused on the economic and social consequences of energy policies.

**EPR**
European Pressurized Reactor. Third generation of nuclear plant technology using advanced Pressurized Water Reactor (PWR)

**ERU**
European Reduction Unit. A unit referring to the reduction of greenhouse gases, particularly under the Joint Implementation where it represents one ton of $CO_2$ reduced

**ETS**
Emissions Trading Scheme. An administrative approach used to control pollution by providing economic incentives for achieving reductions in the emissions of pollutants. The European Union

Emissions Trading Scheme has been in operation since January 1, 2005

**EUA**
European Union Allowances. Quotas allocated by the National Allocation Plans in compliance with the European Trading Scheme

**Eurelectric**
Professional association which represents the common interests of the Electricity industry at pan-European level

**European Commission (EC)**
A governing body of the European Union that oversees the organization's treaties, recommends actions under the treaties, and issues independent decisions on EU matters

**European Council**
A body formed when the heads of state or government of European Union member states meet. Held at least twice a year, these meetings determine the major guidelines for the EU's future development

**European Parliament (EP)**
The assembly of the representatives of the Union citizens

**European Union (EU)**
The European Union (EU) is a group of 28 countries that operates as a cohesive economic and political block

**EVs**
Electric vehicles is an alternative fuel automobile that uses electric motors and motor controllers for propulsion, in place of more common propulsion methods such as the internal combustion engine (ICE).

**EWEA**
European Wind Energy Association

**FERC**
Stands for The Federal Energy Regulatory Commission, is the United States federal agency that regulates the transmission and wholesale sale of electricity and natural gas in interstate commerce and regulates the transportation of oil by pipeline in interstate commerce.

**FID**
Final Investment Decision

**FLNG**
Stands for Floating Liquefied Natural Gas, efers to waterbased liquefied natural gas (LNG) operations employing technologies designed to enable the development of offshore natural gas resources

**Forwards**
A standard contract agreement for delivery of a given quantity at a given price, for a given maturity (OTC markets)

**Futures**
A standard contract agreement for delivery of a given quantity at a given price, for a given maturity (organized exchanges). The maturities may differ across power exchanges (weekly, half-yearly, quarterly, monthly, annually). Maturity Y+1 corresponds to the calendar year after the current year

**GCF**
The Green Climate Fund is a global fund that was formed to support climate change vulnerable nations, especially the "Least Developed Countries" to fulfil their climate change goals and lower their GHG emissions.

**GDP**
Stands for Gross Domestic Product, is a monetary measure of the market value of all the final goods and services produced in a country over a specific time period, often annually.

**GECF**
Gas Exporting Countries Forum. GECF is a gathering of the world's leading gas producers

**GIE**
Gas Infrastructure Europe. GIE is the association representing gas transmission companies (GTE), storage system operators (GSE) and LNG terminal operators (GLE) in Europe

**Green Bond**
A green bond is a bond specifically earmarked to be used for climate and environmental projects. These bonds are typically

asset-linked and backed by the issuer's balance sheet, and are also referred to as climate bonds

**Green Certificates**
A Guarantee of Origin certificate associated with renewable targets fixed by national governments. Green Certificates are often tradable

**Greenhouse effect**
The warming of the atmosphere caused by the build up of 'greenhouse' gases, which allow sunlight to heat the earth while absorbing the infrared radiation returning to space, preventing the heat from escaping. Excessive human emissions including carbon dioxide, methane and other gases contribute to climate change

**Grid**
An electrical grid, electric grid or power grid, is an interconnected network for delivering electricity from producers to consumers.

**Grid 2.0**
Grid 2.0 refers to the grid system which will transform how gas, solar and thermal energy is managed into a single intelligent network efficiently. This builds on Singapore's past investments in smart meters, grid storage, solar photovoltaics, as well as various energy efficiency and demand management solutions to address Singapore's unique energy challenges, and also grow the base of capabilities.

**Guarantee of Origin**
A certificate stating a volume of electricity that was generated from renewable sources. In this way the quality of the electricity is decoupled from the actual physical volume. It can be used within feed in tariffs or Green Certificate systems

**HHI**
Herfindahl-Hirschman Index, a commonly accepted measure of market concentration. It is calculated by squaring the market share of each firm competing in a market, and then summing the resulting numbers. The HHI number can range from close to zero to 10,000

**Hub (gas)**
Physical or virtual entry/exit points for natural Gas

**Hub (retail)**
Inter Company Data Exchange platform primarily enabling Suppliers and Distribution companies to exchange client related data and making supplier's switching more reliable

**ICPT Mechanism**
The ICPT is a mechanism approved by the Government and implemented by ST since 1 January 2014 as part of a wider regulatory reform called the Incentive Based Regulation ("IBR"). ICPT mechanism allows TNB to reflect changes in fuel and generation costs in consumer's electricity tariff every six months. This mechanism is implemented according to Section 26 of Electricity Supply Act 1990 [Act 447]. The impact of ICPT implementation is neutral on TNB and will not have any effect to its business operations and financial position

**IED**
Industrial Emissions Directive, a European Union Directive that sets strict limits on the pollutants that industrial installations are allowed to spew into the air, water and soil. Installations have until 2016 to comply with the limits

**Incentive Based Regulation**
An incentive-based regulatory approach aims to reduce environmentally-harmful pollutants by offering inducements to polluters who limit their emissions

**Installed capacity**
The installed capacity represents the maximum potential net generating capacity of electric utility companies and autoproducers in the countries concerned

**International Energy Consultants**
IEC is a Perth-based consulting firm which specializes in providing power market advisory services to companies operating in and associated with the IPP sector within the Asia-Pacific region

**Investment Tax Credits**
A tax related incentive that allows individuals or entities to deduct a certain percentage of specific investment related costs from their tax liability apart from usual allowances for depreciation.

**IPCC**
Intergovernmental Panel on Climate Change, the leading body for the assessment of climate change, established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to provide a clear scientific view on the current state of climate change and its potential environmental and socio- economic consequences

**IUS**
Stands for the Integrated Utility Services, developed by Rocky Mountain Institute wherein utility companies could seamlessly blend an array of products, services and financing tools that have not previously been integrated.

**JI**
Joint Implementation, a mechanism under the Kyoto Protocol allowing industrialised countries with a greenhouse gas reduction commitment to invest in emission reducing projects in another industrialised country as an alternative to emission reductions in their own countries

**Kyoto Protocol**
The United Nations regulatory frame for greenhouse gases management, adopted in December 1997 and entered into force in February 2005. It encompasses 6 greenhouse gases: CO2, CH4, N2O, HFC, PFC, SF6 LCOE (levelized cost of energy) LCOE is the cost of electricity produced by a generator calculated by accounting for all of a system's expected lifetime costs (including construction, financing, fuel, maintenance, taxes, insurance and incentives), which are then divided by the system's lifetime expected power output (kWh).

**LCOS (levelized cost of storage)**
It quantifies the discounted cost per unit of discharged electricity for a specific storage technology and application.

**LCPD**
Large Combustion Plant Directive, a European Union Directive that aims to reduce acidification, ground level ozone and particulates by controlling the emissions of sulphur dioxide, oxides of nitrogen and dust from large combustion plant. All combustion plant built after 1987 must comply with the emission limits in LCPD. Those power stations in operation before 1987 are defined as 'existing plant'. Existing plant can either comply with the LCPD through installing emission abatement (Flue Gas Desulphurization) equipment or 'opt-out' of the directive. An existing plant that chooses to 'opt-out' is restricted in its operation after 2007 and must close by the end of 2015

**LNG**
Liquefied Natural Gas. Natural gas that has been subjected to high pressure and very low temperatures and stored in a liquid state. It is returned to a gaseous state by the reverse process and is mainly used as a peaking fuel

**LNG Netback Price**
A measure of an export parity price that a gas supplier can expect to receive for exporting its gas.

**Load balancing**
Maintaining system integrity through measures which equalize pipeline (shipper) receipt volumes with delivery volumes during periods of high system usage. Withdrawal and injection operations into underground storage facilities are often used to balance load on a short-term basis

**Load factor**
Ratio of average daily deliveries to peak-day deliveries over a given time period

**LTIFR: Lost Time Injury Frequency Rate**
LTIFR refers to Lost Time Injury Frequency Rate, the number of lost time injuries occurring in a workplace per 1 million man-hours worked.

**LULUCF**
Referred to as Forestry and other land use defined as the greenhouse gas inventory sector that covers emissions and removals of greenhouse gases resulting from direct human induced land use such as settlements and commercial uses, land-use change, and forestry activities.

**Market coupling**
Market coupling links together separate markets in a region, whereas market splitting divides a regional market into prices zones. Market coupling minimizes prices differences and makes them converge wherever transmission capacity is sufficient. Cross-border market coupling also drives better use of interconnection capacity

**Market Liberalization**
The process of removing government control and opening up the markets to private companies

**Merit order**
The merit order is a way of ranking available sources of energy, especially electrical generation, in ascending order of their short-run marginal costs of production, so that those with the lowest marginal costs are the first ones to be brought online to meet demand, and the plants with the highest marginal costs are the last to be brought online

**MESI 2.0**
The Malaysian Electricity Supply Industry (MESI) under the MESI 2.0 initiative, has three key aims, which are to increase industry efficiency, future-proof the industry, and empower consumers

**Metering**
Measurement of the various characteristics of electricity or gas in order to determine the amount of energy produced or consumed

**MyPower**
MyPower, (which is a part of Malaysian Energy Supply Industry-MESI) stands for Malaysia Programme Office for Power Electricity Reform, will design and drive the implementation of energy reform over the next three years

**MSCI ACWI IMI**
MSCI (Morgan Stanley Capital Index) ACWI (All Country World Index) IMI (Investable Market Index) captures large, mid, and small cap representation across 23 Developed Markets (DM) and 24 Emerging Markets (EM) countries

**NAP**
National Allocation Plan. List of selected industrial and power installations with their specific emissions allowance (under the ETS system)

**Natural Gas**
Mixture of gases which are rich in hydrocarbons. Gases such as methane, nitrogen, carbon dioxide etc. are naturally found in atmosphere. Natural gas reserves are deep inside the earth near other solid & liquid hydrocarbons beds like coal and crude oil.

**NDC**
Stands for the Nationally Determined Contributions, it implies the achievement of long-term goals made under the Paris Agreement which embodies efforts by each country to reduce national emissions and adapt to the impacts of climate change.

**NEEAPs**
National Energy Efficient Action Plans, plans providing detailed roadmaps of how each Member State expects to reach its energy efficiency target by 2020

**NEG**
National Energy Guarantee was an energy policy proposed by the Turnbull government in late 2017 to deal with rising energy prices in Australia and lack of clarity for energy companies to invest in energy infrastructure.

**NEM**
The National Electricity Market of Australia interconnects five regional market jurisdictions – Queensland, New South Wales (including the Australian Capital Territory), Victoria, South Australia, and Tasmania.

**Nomination**
A request for a physical quantity of gas under a specific purchase or transportation agreement

**Non-Domestic Consumers**
Commercial and industrial customers, and others

**NREAPs**
National Renewable Energy Action Plans, plans providing detailed roadmaps of how each Member State expects to reach its legally binding 2020 target for the share of renewable energy in their final energy consumption

**NTC**
Net Transfer Capacity. NTC is the expected maximal electrical generation power that can be transported through the tie lines of two systems without any bottlenecks appearing in any system

**Off-peak**
Off-peak energy is the electric energy supplied during periods of relatively low system demand as specified by the supplier

**On-peak**
On-peak energy is electric energy supplied during periods of relatively high system demand as specified by the supplier

**Optimal development path**
The ODP comprises a range of projects classified as either actionable, committed and anticipated, or future. Together, these projects entail the development of 10,000 km of new transmission lines by 2050 under the Step Ch¬an¬ge and Progressive scenarios.

**OPEC**
Organization of the Petroleum Exporting Countries

**Open season**
A period (often 1 month) when a pipeline operator accepts offering bids from shippers and others for potential new transportation capacity. Bidders may or may not have to provide "earnest" money, depending upon the type of open season. If enough interest is shown in the announced new capacity, the pipeline operator will refine the proposal and prepare an application for construction before the appropriate regulatory body for approval

**OPEX**
Operational Expenditure, expenditures that a business incurs as a result of performing its normal business operations

**P/E**
Price / Earning ratio. The ratio of the share price to the Earning per share (EPS). P/E ratio is one of the tools most commonly used for valuing a company share

**Paris Agreement**
The Paris Agreement is an agreement within the United Nations Framework Convention on Climate Change, dealing with greenhouse-gas-emissions mitigation, adaptation, and finance, signed in 2016.

**Peak load**
The highest electrical level of demand within a particular period of time

**Peak shaving**
Reduction of peak demand for natural gas or electricity

**PPA**
Stands for Power Purchase Agreements that freezes a price and a notional energy volume for both the buyer and seller of electricity for a specific period of time. This price agreement acts as the final agreed price for a development project that is either achieving financial close or remaining on the shelf. The agreement also includes reference to cases of failure to meet the contract terms and conditions including, the payment of liquidated damages.

**PPU**
(Programmations pluriannuelles de l'énergie) Multi-year Energy Programming, a tool for planning and steering national energy policy, which defines the priorities for actions and the specific objectives to be achieved over the period 2016-2023, targeting all energy sources, in order to achieve the national objectives set by the LTE

**REBA**
Stands for Renewable Energy Buyers Alliance, is a membership association of large clean energy buyers, energy providers, and service providers that, together with NGO partners, are committed to unlocking the marketplace for all nonresidential energy buyers to lead a rapid transition to a cleaner, prosperous, zero-carbon energy future.

**Regulated Market**
A regulated electricity market contains utilities that own and operate all electricity

**Retailer of Last Resort**
The Retailer of Last Resort (RoLR) scheme was created under the energy laws to protect electricity and gas supply consumers if a retailer is no longer able to operate, ensuring your energy supply is not disrupted.

**RES**
Renewable Energy Sources. Energy (electricity or heat) produced using wind, sun, wood, biomass, hydro and geothermal. Their exploitation generates little or no waste or pollutant emissions

**RGGI**
Stands for Regional Greenhouse Gas Initiative, which is the first mandatory market based program in the United States to reduce greenhouse gas emissions is a cooperative effort among the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont to cap and reduce carbon dioxide (CO2) emissions from the power sector.

**Rhodium Group**
Rhodium Group is an independent research provider combining economic data and policy insight to analyze global trends.

**South Australia Power Networks (SAPN)**
SA Power Networks is the sole electricity distributor in the state of South Australia

**SAIDI**
Stands for System Average Interruption Duration Index that measures the average outage duration for each customer served in units of time, often minutes or hours.

**SGIG**
NA

**Shippers**
The party who contracts with a pipeline operator for transportation service. A shipper has the obligation to confirm that the volume of gas delivered to the transporter is consistent with nominations. The shipper is obligated to confirm that differences between the volume delivered in the pipeline and the volume delivered by the pipeline back to the shipper is brought into balance as quickly as possible

**SLCP**
Stands for Short-lived Climate Pollutants that identifies black carbon, methane, tropospheric ozone, and fluorinated gases. Currently, fluorinated gases (HFCs, perfluorocarbons (PFCs), SF6, and NF3) account for 3 percent of domestic greenhouse gas emissions in terms of carbon dioxide equivalency (CO2e)

**Smart Grid**
An electricity supply network that uses digital communications technology to detect and react to local changes in usage.

**Solar Power Europe**
European Photovoltaic Industry Association. The association that represents the photovoltaic (PV) industry towards political institutions at European and international level.

**Spot contract**
Short-term contract, generally a day ahead

**State Ownership**
State ownership is the ownership of an industry, asset, or enterprise by the state or a public body representing a community as opposed to an individual or private party

**Super Pollutants**
Methane and black carbon identified as the Super Pollutants being some of the most aggressive contributors to global warming.

**System Loss**
System losses occur when 100% efficiency isn't achieved in either conversion or transport of energy. System losses are of two types:1. Technical Loss, driven by the characteristics for the equipment and materials 2. Non-technical Loss, driven by theft, meter readings, pilferage etc.

**Take-or-pay contract**
Contract whereby the agreed consumption has to be paid for, irrespective of whether the consumption has actually taken place

**TCI**
Stands for Transportation and Climate Initiative, it is a regional collaboration of 12 Northeast and Mid-Atlantic states and the District of Columbia that seeks to improve transportation, develop the clean energy economy and reduce carbon emissions from the transportation sector.

**Third Energy Package**
Third Energy Package. A legislative package proposed on September 19, 2007 by the EC in order to pursue the liberalization of the electricity and gas markets

**TPA**
Third Party Access. Recognized right of each user (eligible customer, distributor, and producer) to access in a non discriminatory and efficient manner transmission or distribution systems in exchange for payment of access rights

**UFC**
Federal Union of Consumers

**Unbundling**
Separation of roles according to the value chain segment (generation, transmission, distribution, retail) required by European Directives for enabling fair competition rules

**UNEP**
United Nations Environment Program

**US Climate Alliance**
The United States Climate Alliance is a bipartisan coalition of governors committed to reducing greenhouse gas emissions consistent with the goals of the Paris Agreement

**US Energy Information Administration**
The U.S. Energy Information Administration (EIA) is a principal agency of the U.S. Federal Statistical System responsible for collecting, analyzing, and disseminating energy information to promote sound policymaking, efficient markets, and public understanding of energy and its interaction with the economy and the environment.

**Utility Death Spiral**
In 2013, the Edison Electric Institute (EEI) released a report positing that an eroding revenue stream, declining profits, rising costs, and ever-weakening credit metrics would diminish the ability of electric utilities to survive in an increasingly off-the-grid world.

**Victorian Default Offer**
The Victorian Default Offer is a simple and trusted electricity price that is set by us, not energy companies.

**Vehicle-to-grid**
V2G technology refers to the process of feeding the electricity contained in an electric car's batteries back into the electrical grid while it is parked.

**White Certificate**
A certificate stating a volume of engaged energy savings (electricity, gas, fuel, …) at end-users' site, like a home or a business. They are tradable or not

**Wholesale Electricity Market**
The wholesale market is where electricity is traded (bought and sold) before being delivered to end consumers (individuals, households or businesses) via the grid

## List of Acronyms

- AACCC: Australia Competition and Consumer Commission
- ACEEE: American Council for an Energy Efficient Economy
- ACORE: American Council on Renewable Energy
- ACT: Australian Capital Territory
- ADIT: Accumulated Deferred Income Tax
- AEMC: Australian Energy Market Commission
- AEMO: Australian Energy Market Operator
- AER: Australian Energy Regulator
- AGA: Advanced Grid Analytics
- AGD: Ausgrid
- AMI: Advanced Metering Infrastructure
- APEC: Asia-Pacific Economic Cooperation
- APGCC: ASEAN Power Grid Consultative Committee
- APRA: Australian Prudential Regulation Authority
- APS: Announced Pledges Scenario
- AREH: Asian Renewable Energy Hub
- ARENA: Australian Renewable Energy Agency
- ARFVTP: Alternative and Renewable Fuel and Vehicle Technology Program
- ARRA: American Recovery and Reinvestment Act
- ASEAN: Association of Southeast Asian Nations
- ASEP: Access to Sustainable Energy Program
- ASIC: Australian Securities & Investments Commission
- ATF: Aviation Turbine Fuel
- B2C: Business-to-Consumer
- BAU: Business-as-usual
- Bcm: Billion cubic meters
- BESS: Battery Energy Storage System
- BEV: Battery Electric Vehicle
- Bloomberg NEF: Bloomberg New Energy Finance
- BNEF: Bloomberg New Energy Finance
- BoM: Bureau of Meteorology
- CAFD: Cash Available for Distribution
- CAFÉ: Corporate Average Fuel Economy
- CAGR: Compound Annual Growth Rate
- CAISO: California Independent System Operator
- CapEx: Capital Expenditure
- CARC: Customer Acquisition and Retention Costs
- CAT: Climate Action Tracker
- CC: Contestable Consumers
- CCA: Climate Council Authority
- CCC: Climate Change Commission
- CCGT: Combined Cycle Gas Turbine
- CCPI: Climate Change Performance Index
- CCS: Carbon Capture and Storage
- CCUS: Carbon Capture, Usage and Storage
- CEFC: Clean Energy Finance Corporation
- CER: Clean Energy Regulator
- CEVS: Carbon Emissions-Based Vehicle Scheme
- CFD: Contract for Difference
- CO2: Carbon dioxide
- CO2e: Carbon dioxide Equivalent
- COAG: Council of Australian Governments
- COP22: 22nd Conference of the Parties
- COP26: Conference of the Parties - 26th United Nations Climate Change conference
- CPI: Consumer Price Index
- CPP: Clean Power Plan
- CPPA: Corporate Power Purchase Agreement
- CREZ: Competitive Renewable Energy Zones
- CRI: Climate Risk Index
- CRM: Customer relationship management
- CSI: California Solar Initiative

- CSI: Customer Satisfaction Index
- CSIRO: Commonwealth Scientific and Industrial Research Organization
- CSP: Competitive Selection Process
- CSRD: Corporate Sustainability Reporting Directive
- CSS: Customer self-service
- CST: Concentrated Solar Thermal
- CTA: Cost to Acquire
- CTS: Costs to Serve
- DEE: Department of Environment and Energy
- DER: Distributed Energy Resource
- DES: Distributed Electricity and Storage
- DfE: Design for Efficiency
- DILG: Department of the Interior and Local Government
- DMIRS: Department of Mines, Industry Regulation and Safety
- DMO: Default Market Offer (aka 'standing offers')
- DMO: Distribution Market Operator
- DNSP: Distribution Network Service providers
- DoE: Department of Energy
- DPPA: Direct Power Purchase Agreement
- DREAMS: Development for Renewable Energy Applications Mainstreaming and Market Sustainability
- DSL: Distribution System Loss
- DSM: Demand-side Management
- DSO: Distribution System Operator
- DSP: Demand-side participation
- DU: Distribution Utilities
- EASe: Energy Efficiency Improvement Assistance Scheme
- EBA: European Battery Alliance
- EBITA: Earnings before Interest, Taxes, and Amortization
- EBITDA: Earnings before Interest, Tax, Depreciation and Amortization
- EBSS: Efficiency Benefit Sharing Scheme
- EC: Energy Commission
- eceee: European Council for an Energy Efficient Economy
- ECF: Equity Crowd Funding
- EE: Energy Efficiency
- EERS: Energy Efficiency Resource Standards
- EIA: Energy Information Administration
- EMA: Electricity Market Authority
- EMC: Energy Market Company
- EMS: Energy Management System
- END: Endeavour Energy
- ENSO: El Niño-Southern Oscillation
- ENTR: Electricity Network Transformation Roadmap
- ENX: Energex
- EPA: Environmental Protection Agency
- EPBC: Environment Protection and Biodiversity Conservation
- EPIC: Energy Policy Institute at University of Chicago
- EPS: Earnings per Share
- ERA: Economic Regulation Authority
- ERC: Energy Regulatory Commission
- ERCOT: The Electric Reliability Council of Texas
- ERF: Emissions Reduction Fund
- ERG: Ergon
- ERP: Enterprise resource planning
- ESB: Energy Security Board
- ESCO: Energy Service Company
- ESOO: Electricity Statement of Opportunities
- ESS: Essential Energy
- ETI: Energy Transition Index
- ETS: Emissions Trading Scheme
- EV: Electric Vehicle
- EVN: Vietnam Electricity Company
- FERC: The Federal Energy Regulatory Commission
- FFO: Funds from Operation

- FFR: Fast Frequency Response
- FIT: Feed-in-Tariffs
- FLNG: Floating liquefied natural gas
- FMRS: Faster More Reliable Switching
- FPA: Federal Power Act
- FPSS: Future Power System Security
- FRC: Full Retail Contestability
- FUM: Forecast Uncertainty Measure
- GCF: Green Climate Fund
- GDP: Gross Domestic Product
- GEOP: Green Energy Option Program
- GHG: Greenhouse Gas
- GIS: Geographic Information System
- GJ: Gigajoules
- GMI: Grid Modernization Initiative
- GMLC: Grid Modernization Lab Consortium
- GMRG: Gas Market Reform Group
- GREET: Grant for Energy Efficient Technologies
- GSOO: Gas Statement of Opportunities
- GSSF: Grid Scale Storage Fund
- GTFS: Green Technology Financing Scheme
- GW: Gigawatt
- GWh: Gigawatt-hours
- HDB: Housing and Development Board
- HEV: Hybrid Electric Vehicle
- HFCs: Hydrofluorocarbons
- HGL: Hydrocarbon Gas Liquids
- HK Electric: Hongkong Electric Company
- HKSAR: Hong Kong Special Administrative Region
- HVAC: Heating, Cooling & Ventilation
- IA: Investment Allowance
- IBR: Incentive Based Regulation
- ICE: Internal combustion engine
- ICPT: Imbalance Cost Pass-Through
- ICT: Information and Communication Technologies
- IEA: International Energy Agency
- IEC: International Energy Consultants
- IEMOP: Independent Electricity Market Operator of the Philippines
- IEP: International Environmental Partnership
- IFC: The International Finance Corp
- INDC: Intended Nationally Determined Contribution
- IoT: Internet of Things
- IOUs: Investor-owned Utilities
- IPCC: Intergovernmental Panel on Climate Change
- IPP: Independent Power Producer
- IPv6: Internet Protocol version 6
- IRS: Internal Revenue Service
- ISEM: Institute for Superconducting and Electronic Materials
- ISO: International Organization for Standardization
- ISP: Integrated System Plan
- ITC: Investment Tax Credits
- IUS: Integrated Utility Services
- IVR: Interactive Voice Response
- kgoe: Kilograms of oil equivalent
- KV: Kilovolt
- KW: Kilowatt
- KWh: Kilowatt-hours
- LCOE: Levelized Cost of Energy/Electricity
- LDC: Least Developed Countries
- LDV: Light Duty Vehicle
- LED: Light Emitting Diode
- LNG: Liquefied Natural Gas
- LPE: Local Planning Energy
- LPG: Liquefied Petroleum Gas
- LRET: Large-scale Renewable Energy Target

- LSS: Large Solar Scale
- LTIFR: Lost Time Injury Frequency Rate
- LULUCF: Land Use, Land Use Change and Forestry
- M&A: Merger and Acquisition
- M2M: Machine to Machine
- MDB: Multilateral development banks
- MDM: Meter Data Management
- MENA: Middle East and North Africa region
- MESI: Malaysian Energy Supply Industry
- MESTECC: Minister of Energy, Science, Technology, Environment and Climate Change
- MIDA: Malaysian Investment Development Authority
- MIT: Massachusetts Institute of Technology
- MMBTU: Million Metric British Thermal Units
- MMHS: Market-wide Half Hourly Settlement
- MMT: Million Metric Tonnes
- MMTPA: Million Metric Tonnes Per Annum
- MNCAA: The Mayors National Climate Action Agenda
- MOEA: Ministry of Economic Affairs
- MOIT: Ministry of Industry and Trade
- MoT: Ministry of Transport
- MOU: Memorandum of Understanding
- MSCI: Morgan Stanley Capital International
- Mt: Million Tonnes
- MtCO2-e: Million Tonnes of Carbon Dioxide Equivalent
- Mtoe: Million Tonnes of Oil Equivalent
- MW: Megawatt
- MWe: Mega Watt Electrical
- MWh: Megawatt-hours
- MWp: Mega Watt Peak
- NAFTA: North American Free Trade Agreement
- NAPCC: National Action Plan on Climate Change
- NCOS: National Carbon Offset Standard
- NDC: Nationally Determined Contributions
- NEA: National Environment Agency
- NEA: Nuclear Energy Agency
- NEB: National Energy Board
- NECF: National Energy Customer Framework
- NEM: National Electricity Market
- NEM: Net Energy Metering
- NEMEMF: National Electricity Market Emergency Management Forum
- NEMS: National Energy Modeling System
- NEPA: National Environmental Policy Act
- NEV: New Energy Vehicle
- NGERAC: National Gas Emergency Response Advisory Committee
- NGV: Natural Gas Vehicle
- NIA: National Irrigation Administration
- NIC: Network Interface Card
- NOAA: National Oceanic and Atmospheric Administration
- NOL: Net Operating Loss
- NREP: National Renewable Energy Program
- NSP: Network Service Providers
- NSPS: New Source Performance Standards
- NSW: New South Wales
- NT: Northern Territory
- NWIS: Northwest Interconnected System
- NZE: Net Zero Emissions
- OBPS: Output Based Pricing System
- OCBC: Oversea-Chinese Banking Corporation
- ODP: Optimal development path
- OECD: Organization for Economic Co-operation and Development
- OEM: Open Electricity Market
- OWZ: Offshore Wind Zones

- PACE: Property Assessed Clean Energy
- PAG: Providence Asset Group
- PASA: Projected Assessment of System Adequacy
- PBR: Performance-Based Ratemaking
- PDP: Power Development Plan
- PEV: Plug-in Electric Vehicle
- PHES: Pumped Heat Electrical Storage
- PHEV: Plug-in Hybrid Electric Vehicle
- PJ: Petajoule
- PLI: Production Linked Incentive
- PNOC: Philippine National Oil Company
- PPAs: Power Purchasing Agreements
- PPI: Producer Price Index
- PPM: Parts per million
- PPP: Public Private Partnership
- PSA: Power Supply Agreements
- PV: Photovoltaic
- PVN: PetroVietnam
- QLD: Queensland
- R&D: Research and Development
- RAB: Regulated Asset Base
- RE: Renewable Energy
- REBA: Renewable Energy Buyers Alliance
- REC: Renewable Energy Certificate
- REDD+: Reduce Emissions from Deforestation and Forest Degradation
- REJI: Renewable Energy (Jobs and Investment)
- REP: Retail Electric Provider
- REPI: Retail Electricity Pricing Inquiry
- REPPA: Renewable Energy Power Purchase Agreement
- RERT: Reliability and Emergency Reserve Trader
- RES: Renewable Energy Sources
- RET: Renewable Energy Target
- RETF: Renewable Energy Trust Fund
- RETR: Renewable Energy Transition Roadmap
- REZ: Renewable Energy Zones
- RGGI: Regional Greenhouse Gas Initiative
- RIT-T: Regulatory Investment Test for Transmission
- ROLR: Retailer of Last Resort
- RPS: Renewable Portfolio Standards
- RRO: Regional Reliability Organizations
- RTO: Regional Transmission Organization
- S&P: Standard & Poor's
- SA: Southern Australia
- SAIDI: System Average Interruption Duration Index
- SAIFI: System Average Interruption Frequency Index
- SAPN: South Australia Power Networks
- SARE: Supply Agreement for Renewable Energy
- SCA: Scheme of Control Agreement
- SCADA: Supervisory Control and Data Acquisition
- SCC: Social Cost of Carbon
- SCEM: Singapore Certified Energy Manager
- SDS: Sustainable Development Scenario
- SEA: Southeast Asia
- SGER: Specified Gas Emitters Regulation
- SGIG: Smart Grid Investment Matching Grant
- SLCP: Short-lived Climate Pollutants
- SMOC: Streaming Media Online Charging System
- SMR: Small Modular Reactors
- SoC: Scheme of Control
- SRES: Small-scale Renewable Energy Scheme
- SSR: Summer Saver Rebate
- STEPS: Stated Policies Scenario
- SWIS: Southwest Interconnected System
- T&D: Transmission and Distribution
- TAITRA: Taiwan External Trade Development Council

- TAS: Tasmania
- TCF: Trillion cubic feet
- TCI: Transportation and Climate Initiative
- TNB: Tenaga Nasional Berhad
- TNSP: Transmission Network Service Providers
- ToU: Time-of-Use
- TWh: Terawatt-hours
- UNCED: United Nations' Conference on Environment and Development
- UNEP: United Nations Environment Programme
- UNFCCC: United Nations Framework Convention on Climate Change
- UOB: United Overseas Bank
- US EIA: United States Energy Information Administration
- USAID: United States Agency for International Development
- USTDA: United States Trade and Development Agency
- UTP: Uniform Tariff Policy
- V2G: vehicle-to-grid
- VDO: Victorian Default Offer
- VES: Vehicular Emissions Scheme
- VIC: Victoria
- V-LEEP: Vietnam Low Emission Energy Program
- VPP: Virtual Power Plant
- VRE: Variable Renewable Electricity
- VRET: Victorian Renewable Energy Target
- VWEM: Vietnam Competitive Wholesale Electricity Market
- WA: Western Australia
- WEM: Wholesale Electricity Market
- WESM: Wholesale Electricity Spot Market
- WPI: Wholesale Price Index
- WSD: Water Supplies Department
- WTE: Waste-to-Energy
- WTO: The World Trade Organization
- WWII: World War II
- YTD: Year to date
- ZEV: Zero-Emission Vehicle
- NCI: Non-controlfeling interest
- BEE: Bundesverband Erneuerbare Energien
- EFET: European Federation of Energy Traders
- BDI: Bundesverband der Deutschen Industrie
- BDEW: Bundesverband der Energie- und Wasserwirtschaft
- EIB: European Investment Bank
- WECC: Western Electricity Coordinating Council
- TSO: Transmission system operators
- EEG: Renewable Energy Sources Act or Erneuerbare-Energien-Gesetz
- OFGEM: Office of Gas and Electricity Markets
- CRE: French Energy Regulatory Commission
- REE: Red Eléctrica de España
- WERA: Water and Electricity Regulatory Authority
- IRA: Inflation Reduction Act

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VaasaETT is a leading retail energy consultancy, specialized in complex market issues in six continents and over 90 jurisdictions around the world. We support a global client base of energy companies, governments, regulators, innovators, investors and enterprise consumers, based on the most extensive insight and advanced market analytics.

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