We are *not on track* to meet the Paris Agreement's objectives. What should we do?

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09

SMRs are *part* of the answer

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SMRs are the key to net zero

1. Two fundamental shifts have established nuclear as the key to reaching net zero
    - COP 28 has committed to tripling nuclear energy
    - Nuclear energy is now widely considered clean and enjoys significant public support
2. Massive electricity demand to achieve net zero and rapidly emerging demand from data centers for AI, has tipped the scales towards nuclear.
3. SMRs (AR's) can rapidly be industrialized via proven and defined roadmaps.

Introduction

Nuclear power enjoys strong public support globally as concerns about climate change mount. However, in a watershed moment at COP 28, there was a commitment by 22 members to triple nuclear generation and, most importantly, the formal acceptance for nuclear as a low-zero emissions technology to fight climate change.

The scale for decarbonization of all industries is massive along with the emerging demand for data centers to power AI is driving an unprecedented interest in clean energy. Nuclear with it's dense and firm power is recognized as the key technology to meet this demand.

SMRs, to include Advanced Reactors, broaden the use cases for nuclear as compared to traditional reactors, to address the diverse energy demands for net zero. As result, SMRs have gone from a potential solution to achieve net zero to a critical asset to achieve net zero by 2050.

While nuclear has had it's challenges in the past, the path forward of other renewable technology also has challenges. The difference for nuclear is that theroadmap to success is well understood and proven and all it takes commitment to overcome these obstacles.

Significant Global Support for Nuclear

COP 28

The 28th United Nations Climate Change Conference (COP 28) specifically acknowledged nuclear energy as zero or low emission technology for fighting climate change. Additionally, 22 of the COP member states signed a declaration to triple nuclear generation capacity by 2050 in a clear endorsement of nuclear as a key technology in reaching net zero.

"The OECD Nuclear Energy Agency welcomes the outcome of the COP 28 global stocktake, which for the first time acknowledges the crucial role that nuclear energy could play in helping countries to lower their carbon emissions. Global emissions must reach net zero by 2050."

General Magwood
NEA Director

COP 28 was a fundamental turning point in the acceptance of Nuclear power as a key technology in fighting climate change and sent a strong signal to developers and the finance market, that nuclear enjoys considerable government support – thereby de-risking the development of nuclear power.

Public Acceptance

The Public Attitudes towards Clean Energy index shows strong support for nuclear across 20 countries to include

- 1.5x more people support nuclear than opposing nuclear
- Nuclear is preferred over onshore wind, biomass, or carbon capture and storage

Support for Nuclear

Government and public acceptance of nuclear is a "must have" for the successful development of nuclear, from both a regulatory and a financing perspective. With the spectra of climate change on the horizon and rising energy demands, nuclear is emerging as a clear winner in the path to net zero.

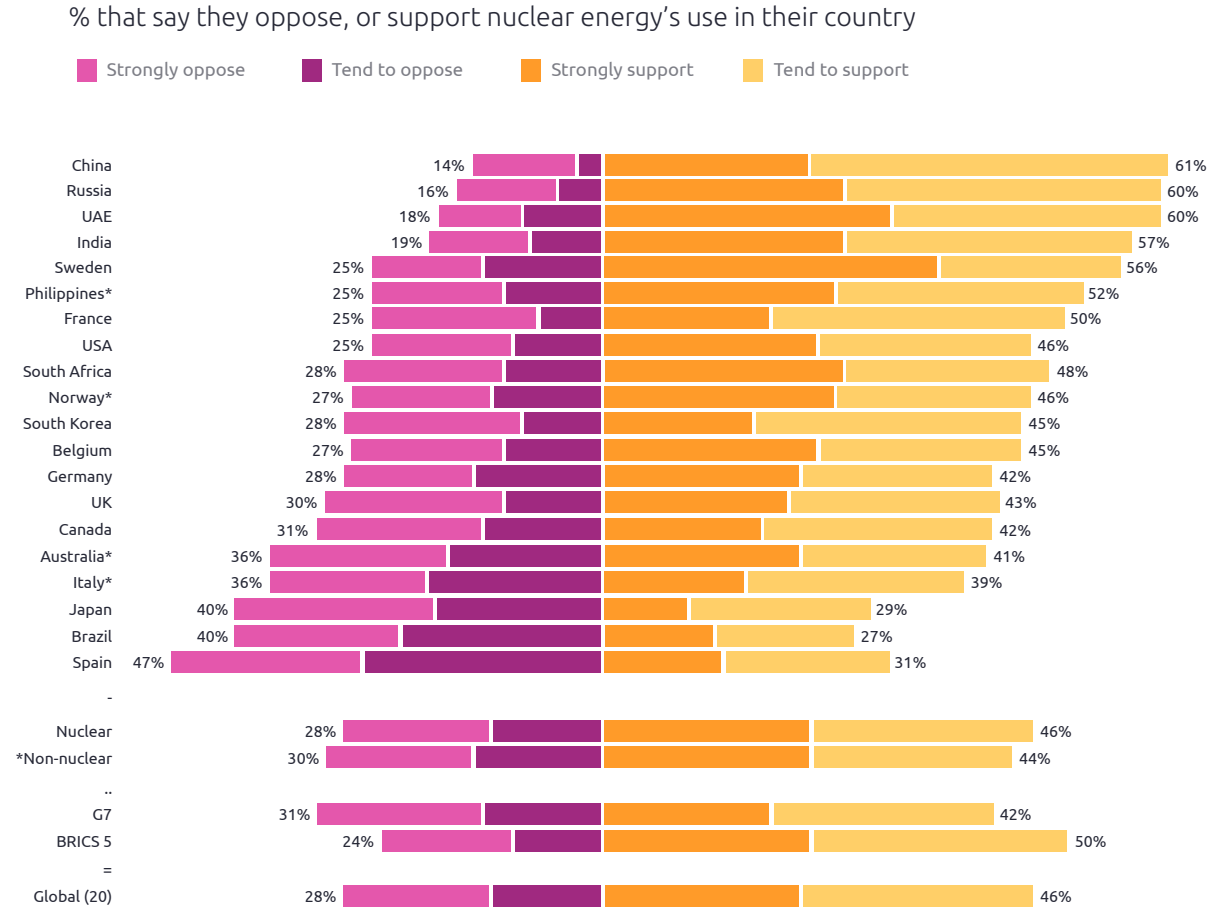
Canada is leading the West

Canada with it's commitment to net zero by 2050, strong government support and incentives, a close cooperation with the government and the crown corporations that generate electricity, and an aggressive carbon tax policy is leading the way for new nuclear.

OPG has placed orders for 4 SMRs, Bruce Power is reviewing RFI's for upwards of 4.8 GW of nuclear power, NB Power as launched two projects; one for advance reactors, and one for SMRs for up to 750W of power, and Sask Power is embarking on a project to become a nuclear utility and bring SMRs to Saskatchewan.

FIGURE 1

More people support using nuclear energy than oppose it



Source: https://www.radiantenergygroup.com/reports/public-attitudes-toward-clean-energy-2023-nuclear

Demand

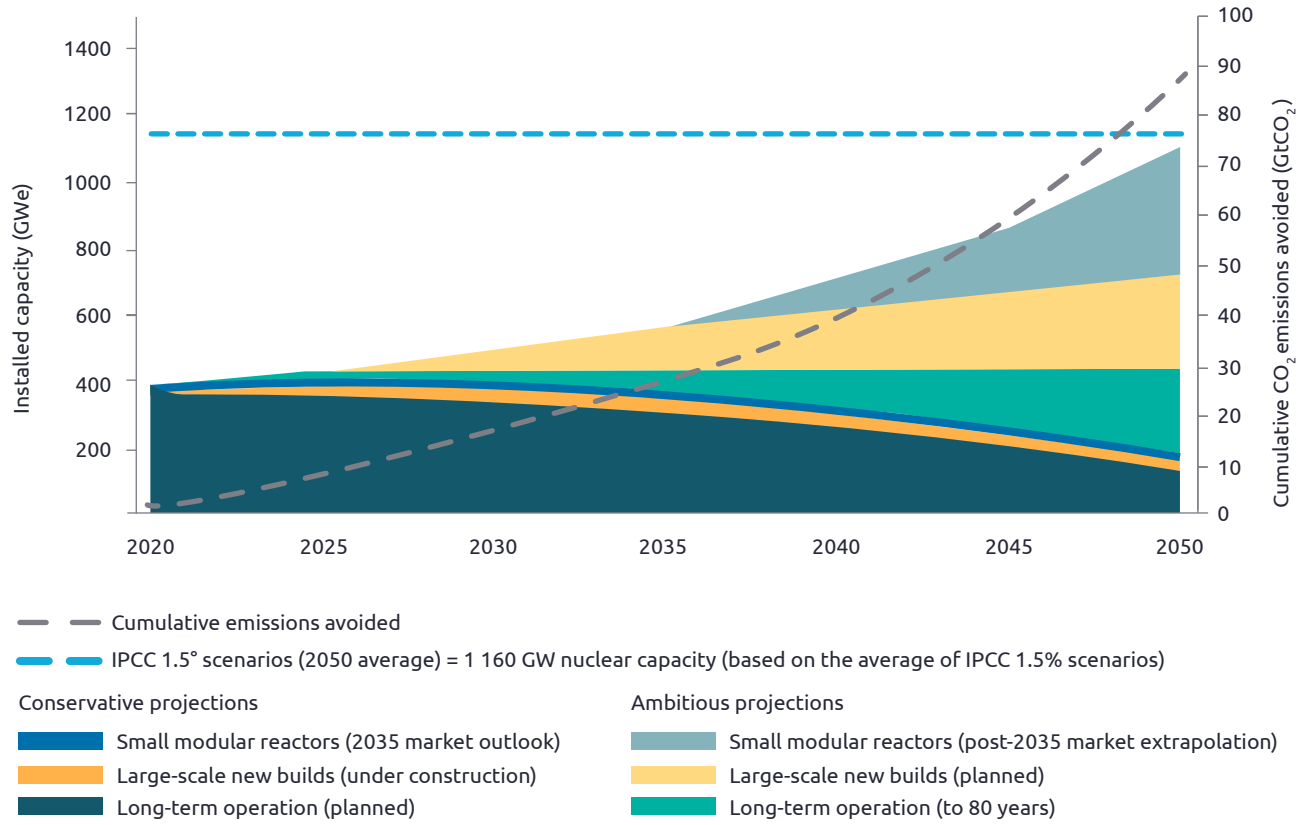
Global Demand

The U.S. Energy Information Administration's 2023 International Energy Outlook predicts global energy demand will increase by 30% - 76% by 2050, with most of that demand met with zero-carbon technologies, like nuclear. To meet that demand the OECD-NEA projects up to 1160 MW of nuclear capacity by 2050, with SMRs contributing >50% of new nuclear as shown:

To meet net zero industrial users will need convert energy usage for electricity and process steam to clean energy. While electricity can be provided by renewables and nuclear, high-temperature process steam will require nuclear to meet this demand at scale. For example, at the SMR Conference 2024 Dow Chemical spoke of an annual all-in energy demand of 7GW at their facilities – this represents about 7 large nuclear plants, or 21 utility -scale SMRs, or 70 advanced reactors. That is just one industrial client, which helps put in perspective the enormity of decarbonization.

FIGURE 2

Full potential of nuclear contributions to net zero



Source: https://www.oecd-nea.org/jcms/pl_90816/the-nea-small-modular-reactor-dashboard-second-edition

Rapidly Evolving Demand

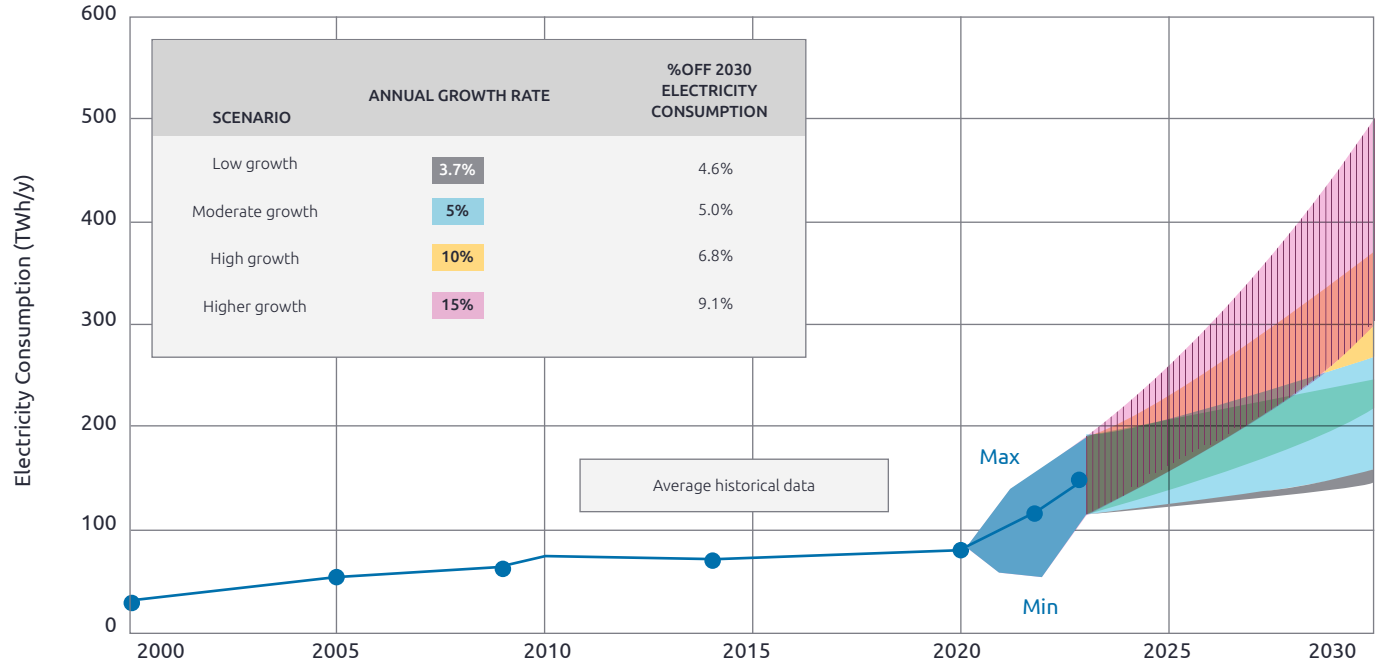
The above reference report was released in October, 2023 and well before the exponential growth of AI that was observed in 2023 after the late 2022 release of ChatGPT. AI is a wild-card in the already rapidly evolving demand forecasting to support net zero targets.

As a result, there are several interesting development by the hyperscalers to secure clean energy. In March of 2024, AWS acquired a 960MW nuclear powered data center from Talen at their Susquehanna Nuclear Station. Microsoft, Google, and Nucor joined forces to aggregate their energy demands to promote and secure clean energy, to include nuclear power.

Electric Power Research Institute's Powering Intelligence 2024 White Paper projects data center demand will double by 2026 and represent 9% of the total USA demand by 2030.

FIGURE 3

Projections of potential electricity consumptions by USA data centers: 2023-2030. % of 2030 electricity consumption projections assume that all other (non-data center load increases at 1% annually.



Source: https://www.epri.com/research/products/3002028905

Why are SMRs the Key to net Zero

Nuclear the Clear Choice

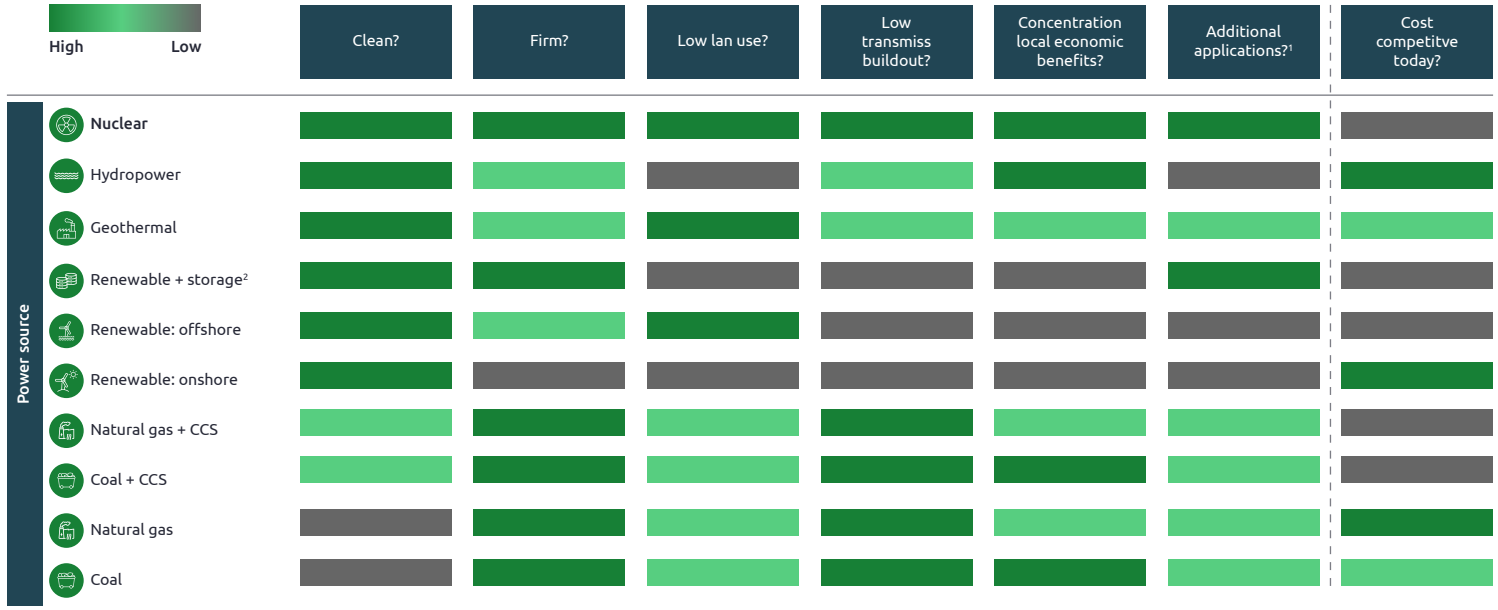
With strong government and public support for nuclear coupled with a strong growth forecast along with converting the existing demand to clean energy, the market requires large scale expansion of clean energy. The U.S. DOE Liftoff Report provides a telling comparison of technologies showing a clear advantage for nuclear as the obvious choice for clean energy.

Traditional Large Nuclear

Large, light water reactors, like those that are in service today are sized over 1GW can and will bring significant clean energy capacity to the grid. However, the primary use case for large nuclear is to power the established grid, which does not address the many use cases required for decarbonization.

FIGURE 4

Nuclear the clear choice



1. Additional applications include clean hydrogen generation, industrial process heat, desalination of water, district heating, off-grid power, and craft propulsion and power
2. Renewables + storage includes renewables coupled with long duration energy storage or renewables coupled with hydrogen storage

Source: https://liftoff.energy.gov/advanced-nuclear/

SMR Use Cases

SMRs are sized from 10-300 MW using either existing light-water reactor technology. AMRs (Advanced Modular Reactors) use processes developed in large USA federal laboratories or in institutes as the French CEA. There were not built at a large scale, thus the industrialization will be more complex. However, they can offer advantages as simultaneous heat and power production, no need for cooling water, burning nuclear waste.. As a result, SMRs have a variety of use cases that make them the Key to achieving net zero targets:

- On-Grid - to serve more rural areas, repower existing fossil plants, new utility entrants to nuclear, site closer to demand
- Off-Grid – micro-grids, behind the meter supply, Cogeneration, powering industrial and or data center facilities, remote communities, mining, oil/gas extraction
- District Heating – sited close to the demand and replace fossil, biomass, or trash to energy facilities
- Process Heat – as well as electricity for industrial applications
- Shipping
- Desalination
- Hydrogen and SynFuel production

Real World Examples

- Dow Chemical: 4 advance reactors to provide process heat and steam to its Seadrift facility
- Diamondback Energy: Nuclear for drilling operations in the Permian Basin
- Synthos Green Energy: Planning to repower its industrial base in Poland
- Ontario Power Generation: Building 4 SMRs for on-grid application
- Green Energy Partners: A nuclear-powered data center next to Surry Nuclear Station
- Norway: SMRs to power data centers and as well as powering an isolated community

Challenges ahead

Not First of a Kind

SMRs aren't really new, and that fact is often lost in the discussions re the viability of SMRs. Hundreds of small light water reactors have been built and in service today for naval reactors in several nations. Whereas advanced reactors have been proven in national labs with decades of experience. So, the challenge is not technology, but industrialization of the technology. For example, the industrialization of the French SMR Nuward has proven complex and has led to a delay in the design of this platform.

Industrialization

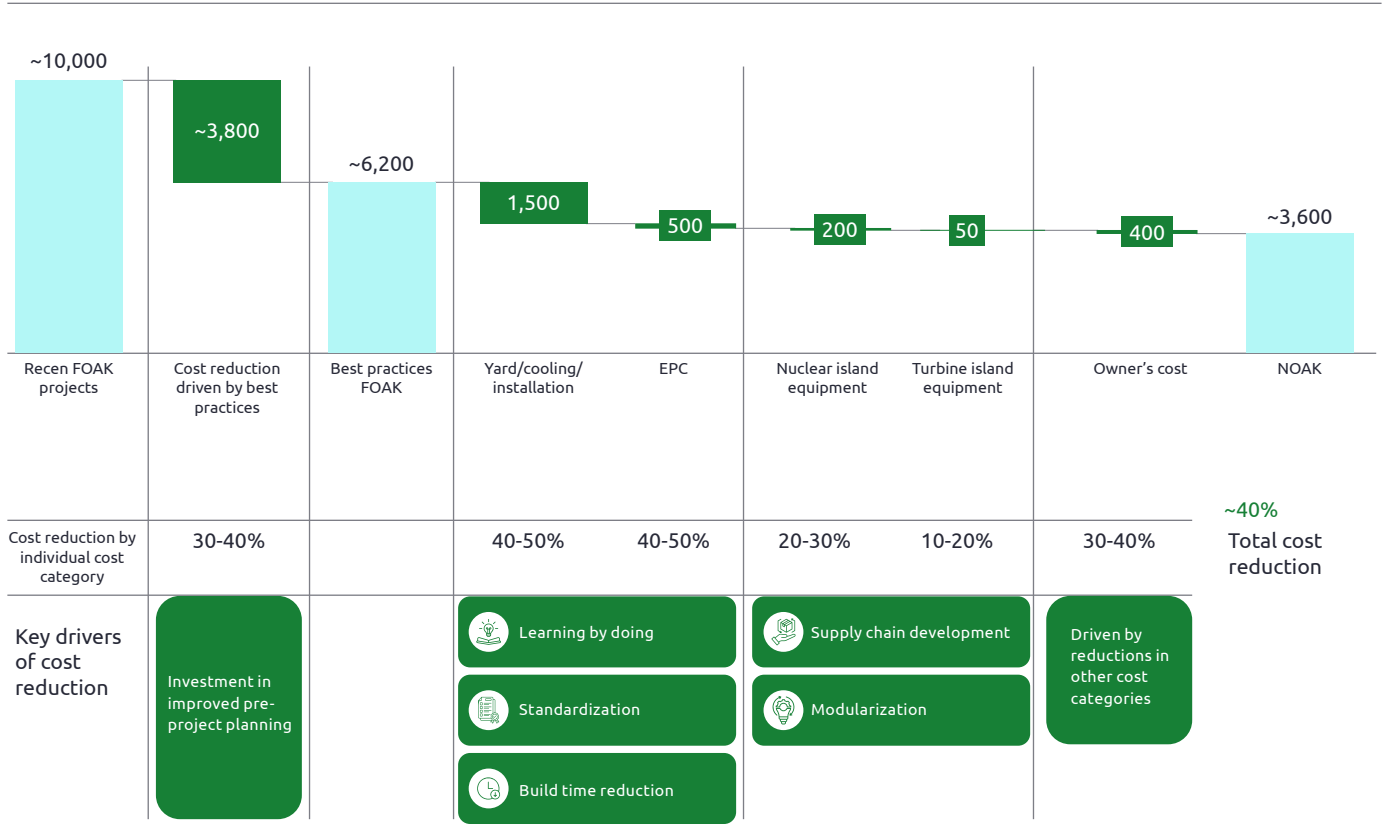
As shown in the U.S. DOE Liftoff report all of the many competing clean technology, necessary to reach net zero, haven't been industrialized to the point of cost competitiveness. However, in nuclear there is a lot of operation experience, and lessons learned, so the roadmap to cost competitiveness is well defined. The DOE anticipates that a minimum order of 10 units will be necessary for the industrialization of a particular platform.

The issue is not competency - it is simply a critical mass of back orders to facilitate investment to industrialize and drive down costs. Much like the model for new airliners – the OEM's design a platform, but don't build until they have a confirmed order book. GE Hitachi, with it's 4 confirmed OPG orders, and significant potential backlog will likely lead this new market. With GE's success the challenge will not be how to get the industry off the ground, but how to meet the demand.

The U.S. DOE's Lift Off report shows a path to drive NOAK costs to a competitive $3,600/KW, yet still above Korea's $2,300/KW over 7 reactors.

FIGURE 5

Potential advanced nuclear FOAK to NOAK overnight capital costs S/kW



Source: https://liftoff.energy.gov/wp-content/uploads/2023/05/20230320-Liftoff-Advanced-Nuclear-vPUB-0329-Update.pdf

Our Convictions

- The support, both from governments and the public, is at an all-time high and increasing. This support is paramount for the industry to succeed.
- Energy demand, primarily for electricity and process heat, is significant, requiring an enormous expansion of current capacity.
- Rapidly growing data center demand is disrupting the current demand landscape and which will necessitate reliable and firm clean energy
- Nuclear is a clear and overwhelming winner for firm, reliable, and dense power that will be required for the massive energy demand to support net zero
- SMRs and AMRs with their multiple technologies and uses cases will support wide-scale adoption for a multitude of clients, breaking free from the utility monopoly and becoming the Key to achieving net zero

About Capgemini

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