NEA
NUCLEAR ENERGY AGENCY

MEETING CLIMATE CHANGE TARGETS:

THE ROLE OF NUCLEAR ENERGY

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Outline

1. Context

2. The Role of Nuclear Energy

3. Opportunities and Challenges

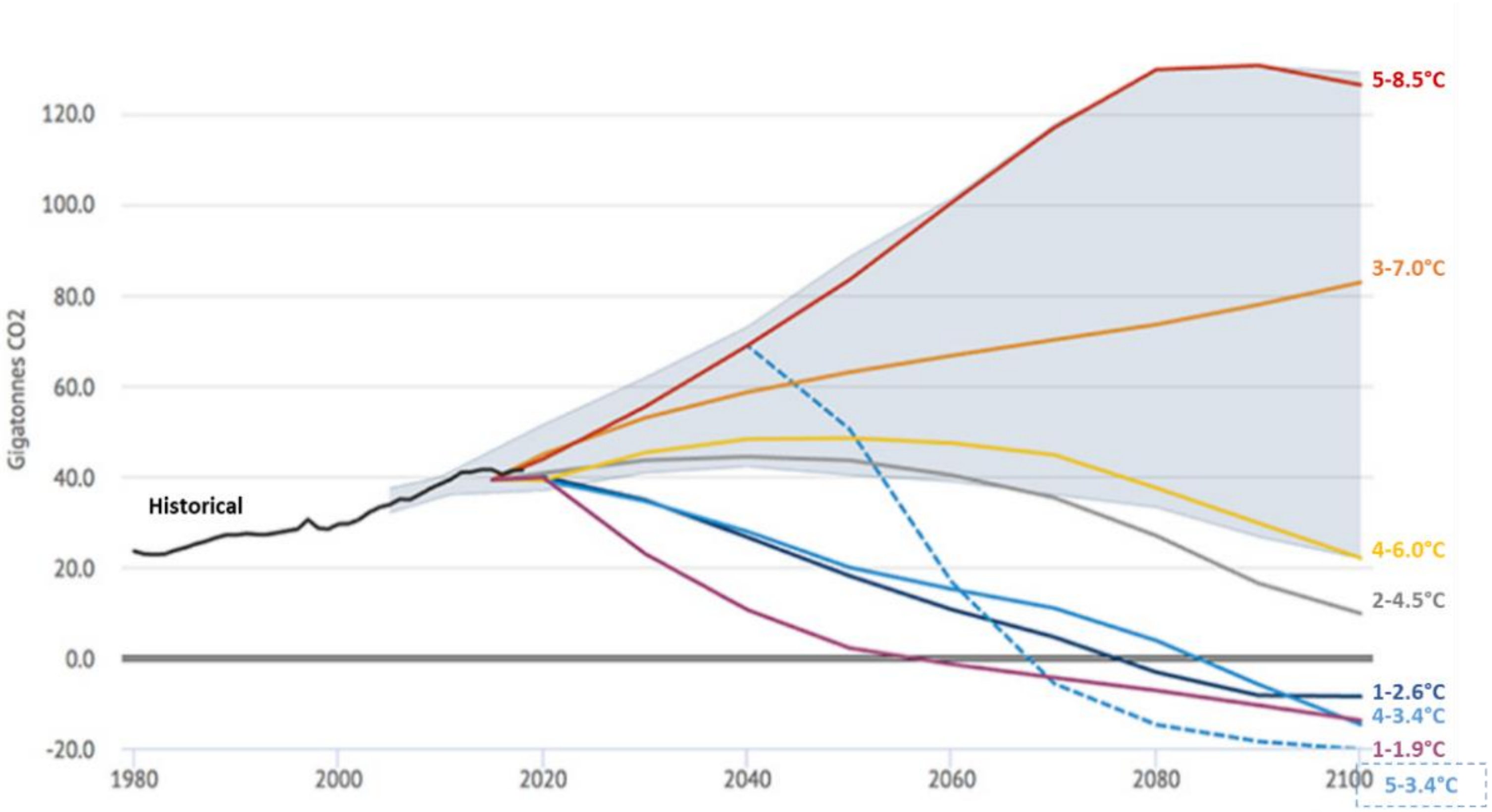
4. Recommendations

1. Nuclear Energy in Today's Energy Policy Context

Global Action Is Urgently Needed

- The magnitude of the challenge should not be underestimated
- The planet has a "carbon budget" of 420 gigatonnes of carbon dioxide emissions for the 1.5°C scenario
- At current levels of emissions, the entire carbon budget would be consumed within 8 years
- Emissions must go to net zero, but the world is not on track

Temperature outcomes for various emissions futures



Source: Carbon Brief (2019).

Pathways to Net Zero Emissions

- Pathways based on the world's carbon budget, emissions reductions targets and timelines have been modelled and published by various organisations.
- All published pathways include levels of nuclear energy deployment based on currently available commercial technologies
- Nuclear innovation does not feature prominently because of a lack of specialised expertise in nuclear technologies among modelling teams

Samples of ambitious and aspirational pathways to net zero

Organisation	Scenario	Parameter	2020	2050	Growth rate (2020-50)
IIASA (2021)	Divergent Net Zero Scenario (1.5°C)	Cost of carbon (USD per tCO_2)	0	1 647	-
		Wind (in GWe)	600	9 371	1461%
		Solar (in GWe)	620	11 428	1743%
IEA (2021)	Net Zero Scenario (1.5°C)	Hydrogen (MtH_2)	90	530	490%
		CCUS ($GtCO_2$)	<0.1	7.6	-
		Energy intensity (MJ per USD)	4.6	1.7	-63%
Bloomberg NEF (2021)	New Energy Outlook Green Scenario (1.5°C)	Wind (in GWe)	603	25 000	4045%
		Solar (in GWe)	623	20 000	3110%

Nuclear in Emissions Reduction Pathways

Organisation	Scenario	Climate target	Nuclear innovation	Description	Role of nuclear energy by 2050	
					Capacity (GW)	Nuclear growth (2020-50)
IAEA (2021b)	High Scenario	2°C	Not included	Conservative projections based on current plans and industry announcements.	792	98%
IEA (2021c)	Net Zero Scenario (NZE)	1.5°C	Not included but HTGR and nuclear heat potential are acknowledged.	Conservative nuclear capacity estimates. NZE projects 100 gigawatts more nuclear energy than the IEA sustainable development scenario.	812	103%
Shell (2021)	Sky 1.5 Scenario	1.5°C	Not specified	Ambitious estimates based on massive investments to boost economic recovery and build resilient energy systems.	1 043	160%
IIASA (2021)	Divergent Net Zero Scenario	1.5°C	Not specified	Ambitious projections required to compensate for delayed actions and divergent climate policies.	1 232	208%
Bloomberg NEF (2021)	New Energy Outlook Red Scenario	1.5°C	Explicit focus on SMRs and nuclear hydrogen	Highly ambitious nuclear pathway with large scale deployment of nuclear innovation.	7 080	1670%

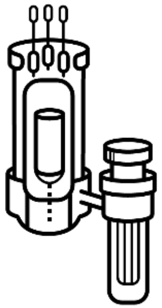
Many pathways require global installed nuclear capacity to grow significantly, often more than doubling by 2050.

2. The Role of Nuclear Energy

The Full Potential of Nuclear Energy to Contribute to Emissions Reductions

Long Term Operation

Large Gen-III Reactors



Small Modular Reactors

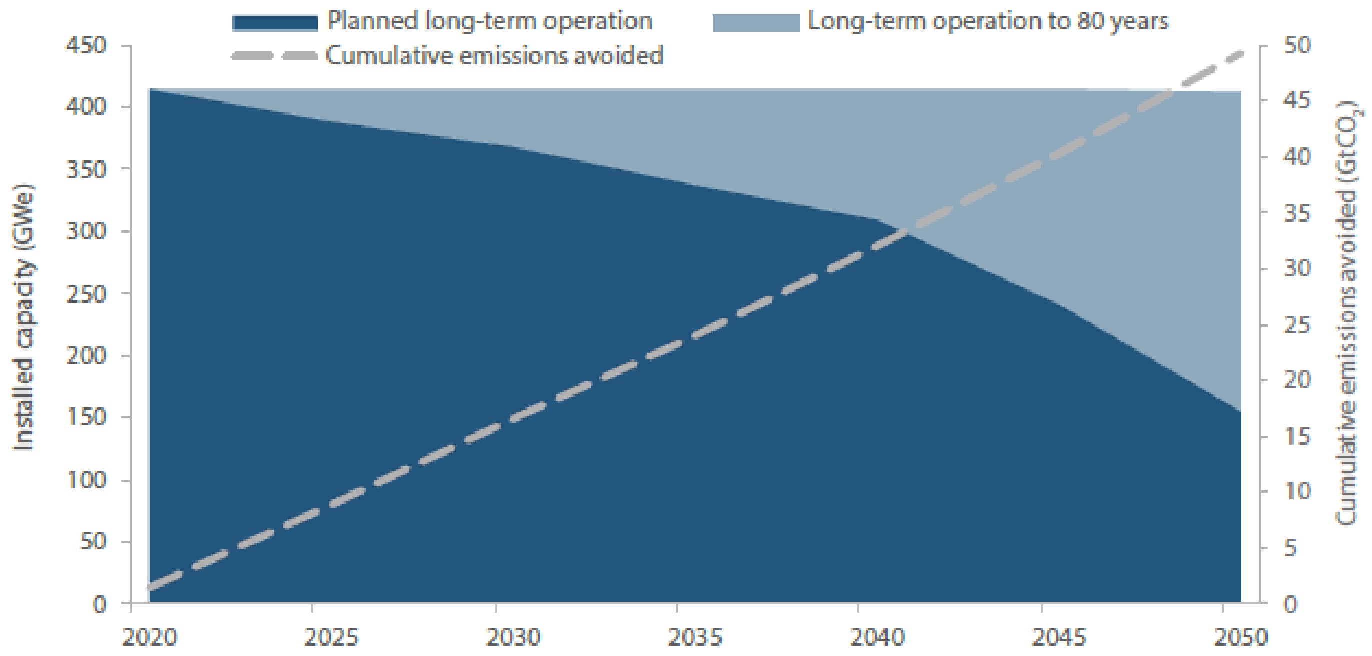
Non-Electrical applications

Complementary nuclear technologies and applications

Long-term Operation

- Presently, the average age of nuclear power plants in OECD countries is 36 years
- The technical potential exists in most cases for long-term operation for several more decades
- Long-term operation is one of the most cost-competitive sources of low-carbon electricity
- Beyond technical feasibility, adequate policy and market are key conditions of success of long-term operation
- Long-term operation could save up to 49 gigatonnes of cumulative emissions between 2020 and 2050

Long-term operation – installed capacity and cumulative emissions avoided (2020-2050)

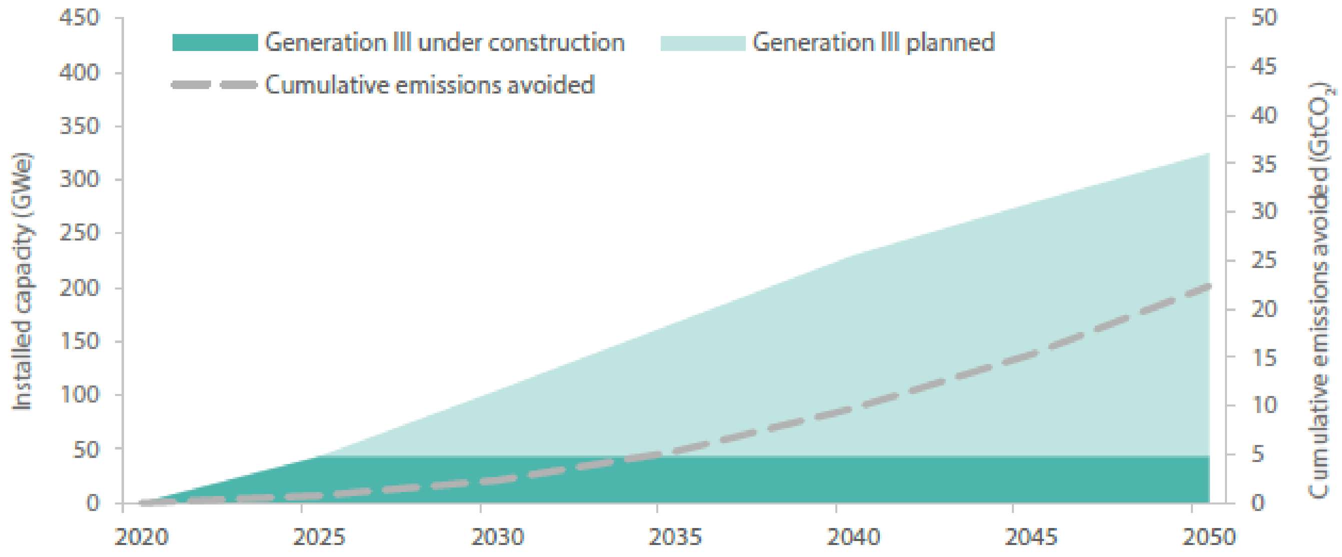


Note: Note: It is assumed that nuclear power (12 gCO_2eq/kWh) is displaced by gas with a carbon footprint of 490 gCO_2eq/kWh (Bruckner, 2014). By 2050, 25% of nuclear reactors are used for nuclear heat applications, also displacing gas. By 2050, nuclear reactors operate with a 90% availability factors with 60% of the power used to supply electricity and 30% to supply hydrogen. Hydrogen produced with nuclear power will displace steam methane reforming (10 kg CO_2 per kg of H_2).

New builds of large Generation III nuclear technologies

- At the end of 2020, 55 gigawatts of new nuclear capacity in the form of large-scale Generation III reactors were under construction around the world driven largely by new builds outside the current OECD membership
- Taken together, large-scale Generation III reactors that are under construction and planned are expected to reach over 300 gigawatts of installed capacity by 2050, avoiding 23 gigatonnes of cumulative carbon emissions between 2020 and 2050

Generation III new builds – installed capacity and cumulative emissions avoided (2020-2050)



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Even in very high renewable scenarios, there are hard to abate sectors where SMRs can play an important role

Coal replacement for on-grid power

- More than 2 TWe of coal power plants in operation that will have to be phased-out to meet Net Zero objectives
- Larger SMRs (200-300 MWe) are designed primarily for on-grid power generation and is well-suited to coal power plant replacement

Merchant Shipping

SMRs could provide a non-emitting alternative for marine merchant shipping propulsion

- SMRs for marine merchant shipping could yield significant emissions reductions as shipping remains a very hard-to-abate industrial sector

Diesel replacement for off-grid mining

- Smaller SMRs could create an alternative to diesel generation in remote communities and at resource extraction sites
- SMRs could be used to provide power as well as heat for various purposes such as district heating or mine-shaft heating

Heat & hydrogen

- <u>Fossil cogeneration replacement for industries:</u> High-temperature SMRs to unlock non-emitting alternatives for industry
- <u>Fossil replacement for district heating</u> : Most district heating network rely on fossil fuels and lack scalable decarbonization options
- <u>Hydrogen and synthetic fuels:</u> SMRs localization near industrial demand hubs can unlock large-scale production

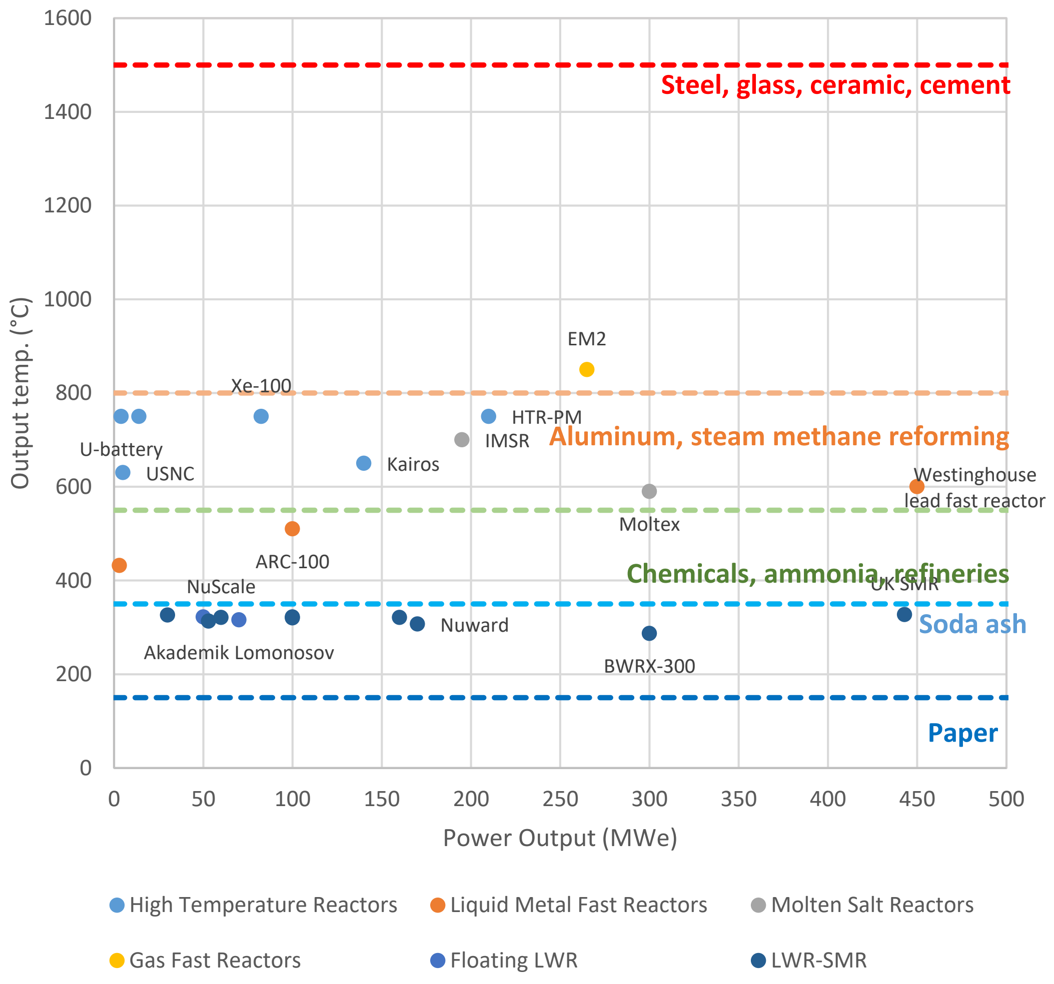
SMRs are expected in a range of sizes and temperatures

POWER
- SMRs vary in size from 1 to 300 megawatts electric

TEMPERATURE
- From 285°C to 850°C in the near-term and up to or over 1,000°C in the future

TECHNOLOGY
- Some SMRs are based on Generation III and Light Water reactor technologies
- Other are based on Generation IV and advanced reactor technologies

FUEL CYCLE
- Some SMRS are based on a once-through fuel cycle
- Other seek to close the fuel cycle by recycling waste streams to produce new useful fuel and minimize waste streams requiring long-term management and disposal

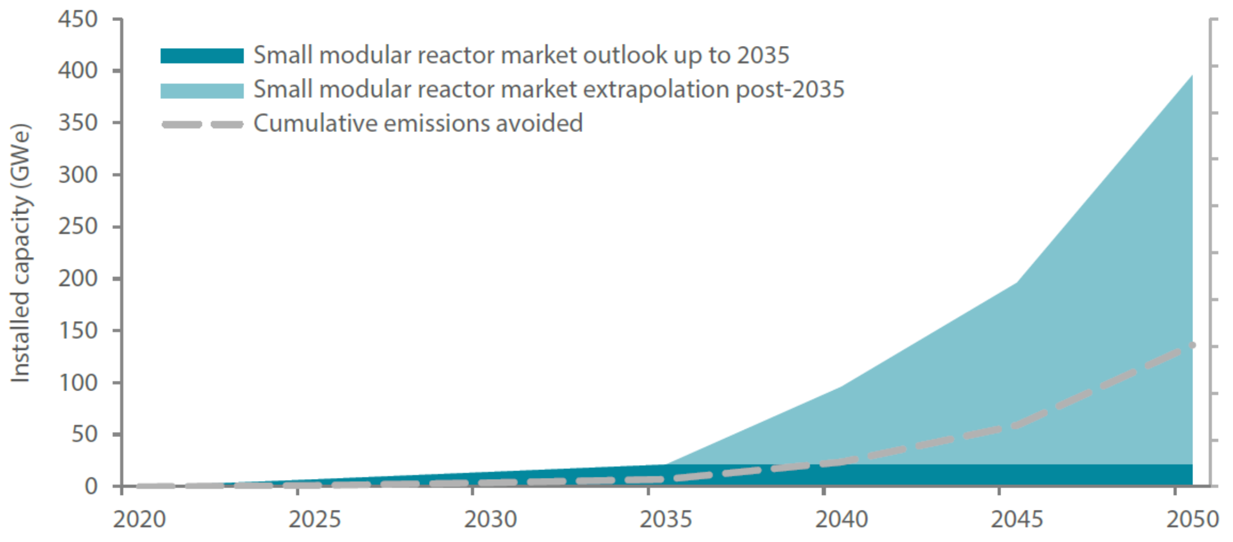


Source: NEA (forthcoming).

Small Modular Reactors

- Several SMR designs are expected to be commercially deployed within 5-10 years and ready to contribute to near-term and medium-term emissions reductions
- SMRs could see rapidly increasing rates of construction in net zero pathways
- Up to 2035, the global SMR market could reach 21 gigawatts
- Thereafter, a rapid increase in build rate can be envisaged with construction between 15 and 150 gigawatts per year

Installed Capacity And Cumulative Emissions Avoided



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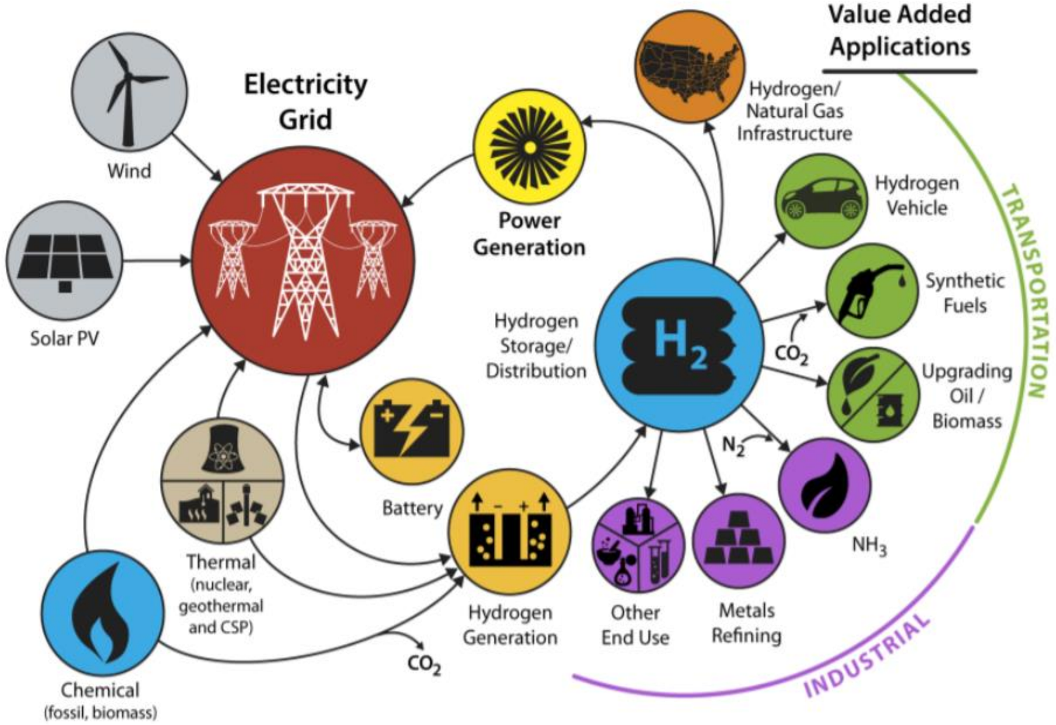
Nuclear energy and SMRs integrate well with variable renewables

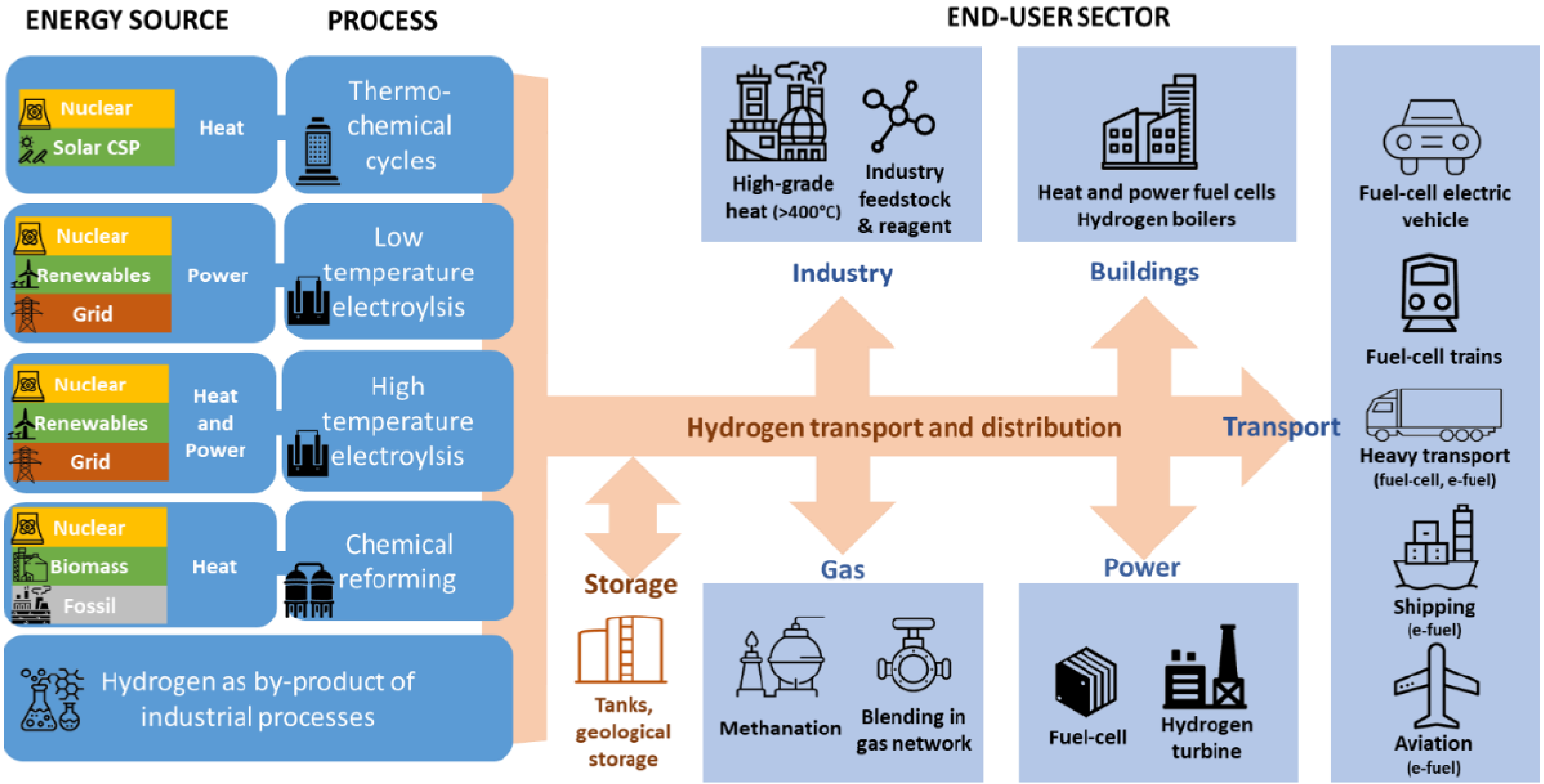
- According to the IEA Net Zero Scenario, nuclear energy will provide an *"essential foundation for Net Zero transitions as a source of dispatchable, secure and increasingly flexible electricity"* and support integration of variable renewables
- Nuclear-renewables complementarities are not limited to the electricity sector. Nuclear, including SMRs, have a central role to play as part of the mix of low carbon solutions:
  - For **hard to abate sectors** where variable renewables will have limitations (e.g. industry, heat, mining)
  - Where low carbon alternatives **have yet to be demonstrated at scale** (e.g. CCUS)

Nuclear-renewable hybrid energy system



Source: INL

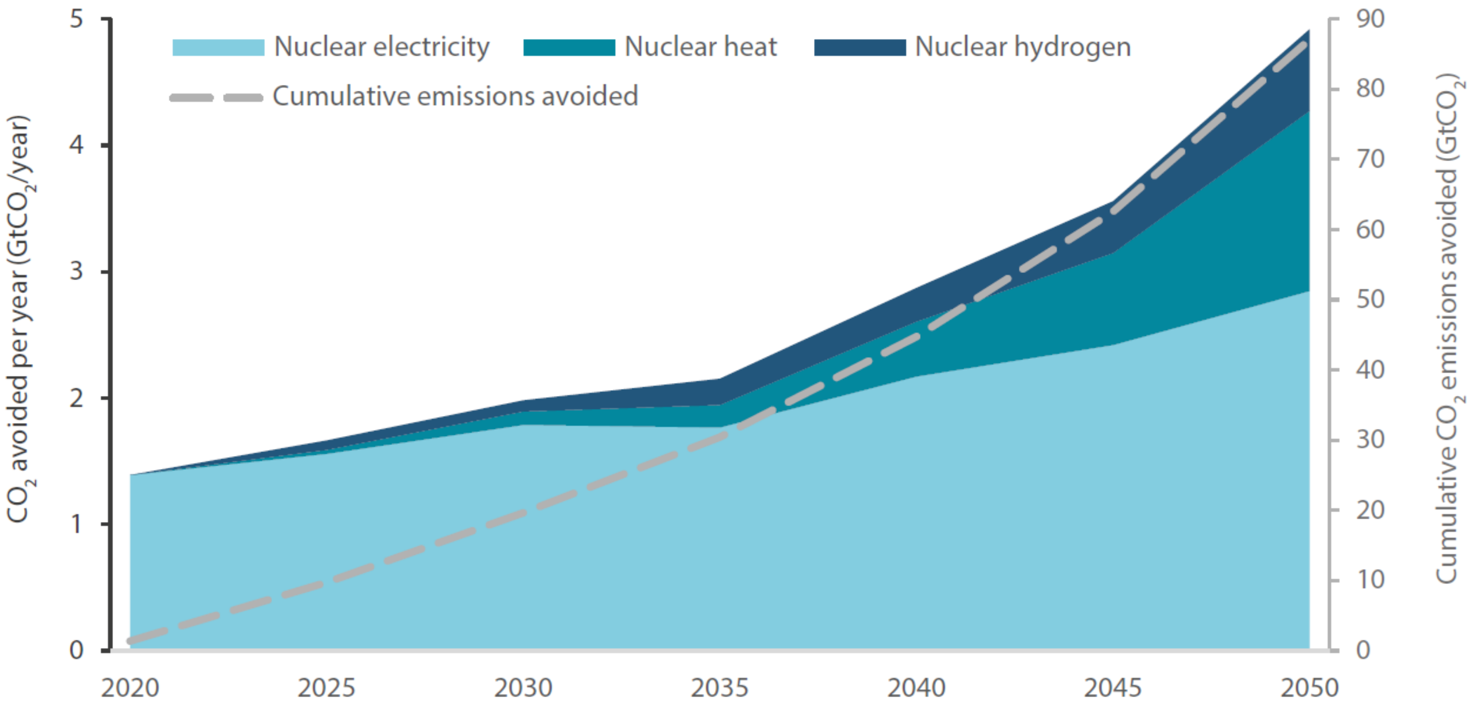
The Hydrogen Economy – sources, production processes, and end-uses



Power and Non-power Applications of Nuclear Energy

- Taken together, nuclear hybrid systems with non-electric applications including hydrogen can contribute to avoiding nearly 23 gigatonnes of cumulative emissions between 2020 and 2050
- Further, nuclear energy enables more *extensive*, more *rapid*, and more *cost-effective* deployment of variable renewables, by providing much needed flexibility
- The role of nuclear energy in emissions reductions for future energy systems is therefore even greater

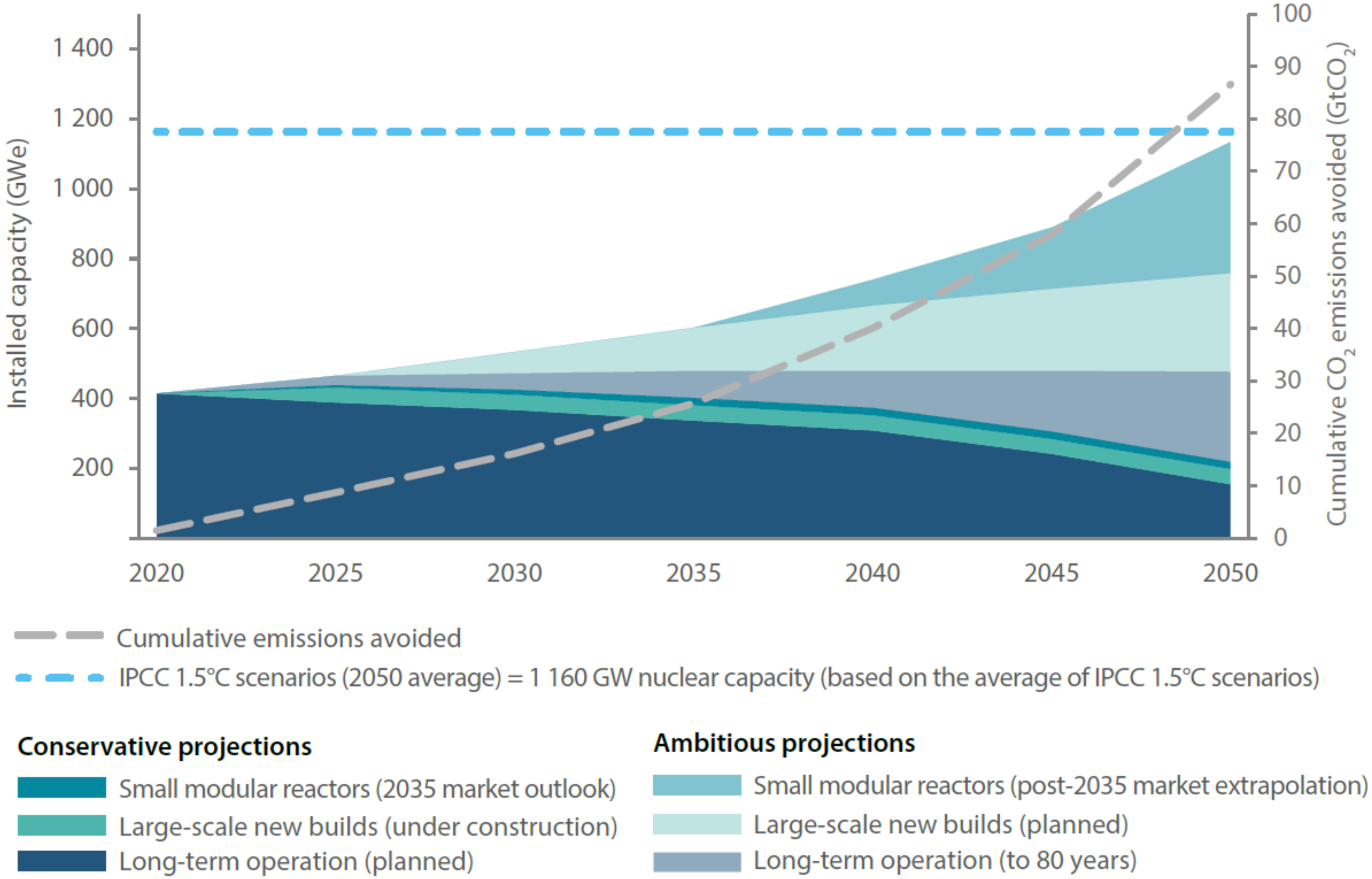
Carbon emissions avoided by nuclear power and non-power applications



SMRs Have an Important Role to Play *Alongside Long-term Operation and New Builds of Large Nuclear Power Plants*

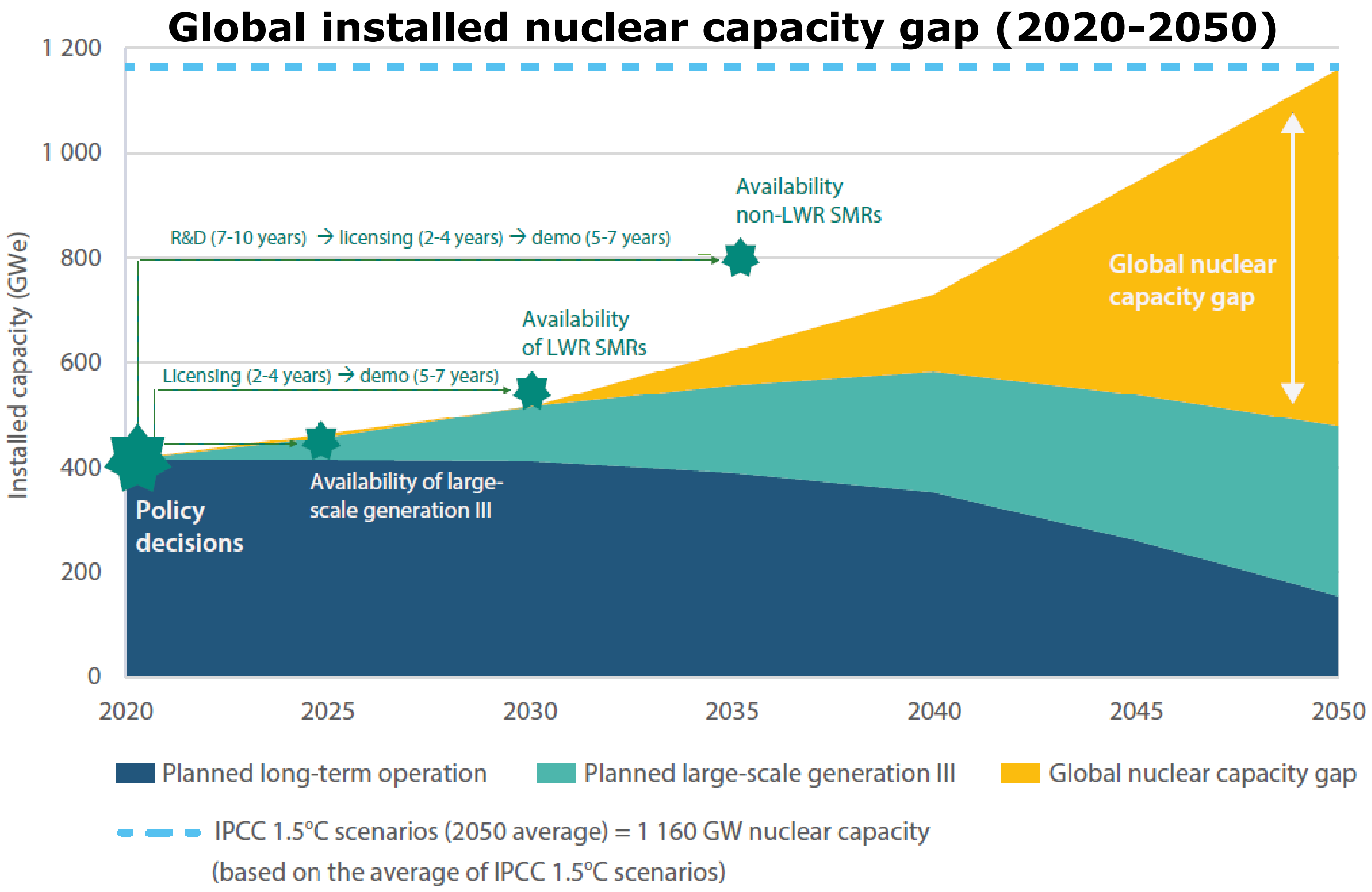
Reaching the target of 1160 gigawatts of global installed nuclear capacity by 2050 will require a **combination of long-term operation, large-scale Generation III, small modular reactors, and non-electric applications** such as nuclear-produced heat and hydrogen.

Full potential of nuclear contributions to Net Zero



Global Installed Nuclear Capacity Gap

- Under current policy trends, nuclear capacity in 2050 is expected to reach **479 gigawatts** – well below the target of 1160 gigawatts of electricity
- Owing to the timelines for nuclear projects, there is an **urgency to action now to close the gap in 2030-2050**

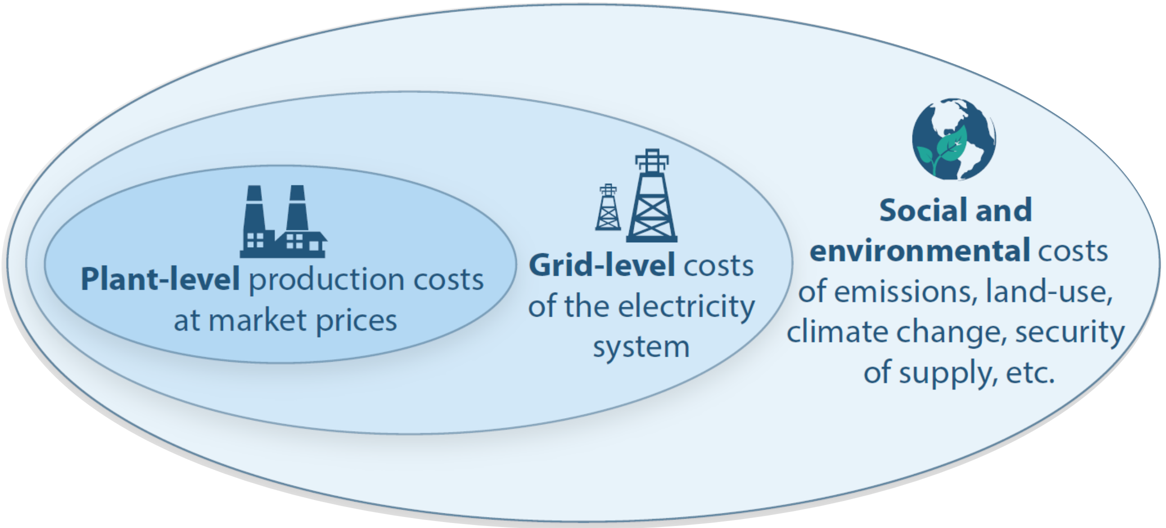


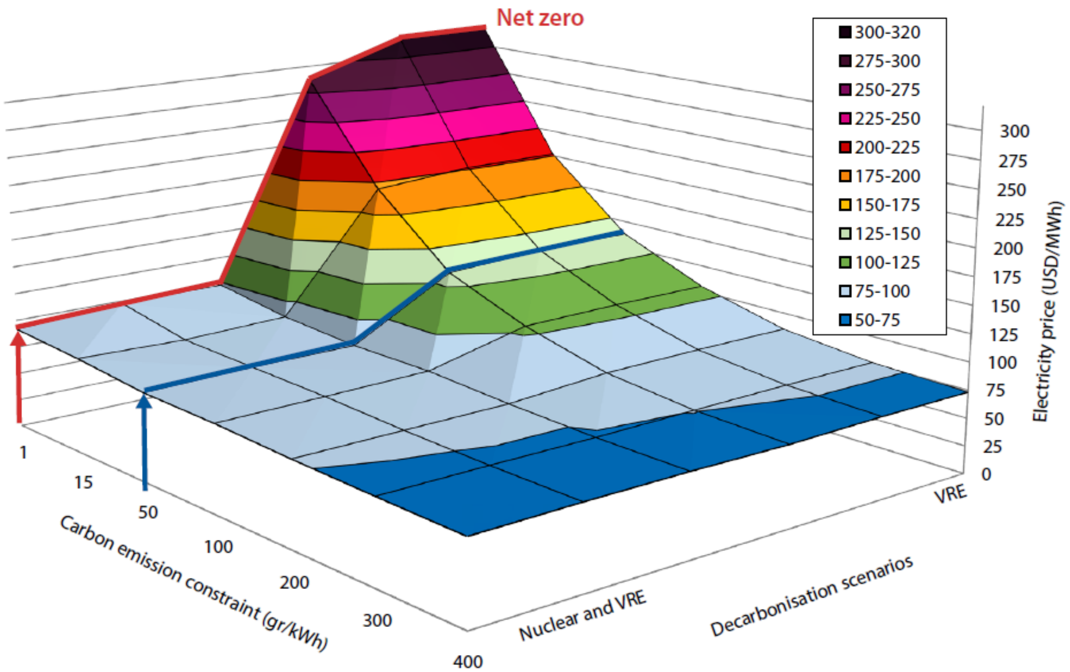
3. Opportunities and Challenges

Nuclear Energy Faces Many Challenges

- **The nuclear sector must move quickly to demonstrate and deploy near-term and medium-term innovations** including advanced and small modular reactors, as well as nuclear hybrid energy systems including hydrogen
- **There are key enabling conditions for success** that the nuclear sector and energy policy-makers more broadly should address in the areas of system costs, project timelines, public confidence and clean energy financing
- **A systems approach is required to understand the full costs of electricity provision**, and to ensure that markets value desired outcomes: low carbon baseload, dispatchability, and reliability
- **Rapid build-out of new nuclear power is possible, but requires a clear vision and plan**
- **Building trust is central to building public confidence** and requires sustained investments in open and transparent engagement as well as science communication. A common mistake is to assume that public confidence is primarily a communication issue
- **Governments have a role to play in all capital intensive infrastructure projects** – including nuclear energy projects. This role can include direct funding, but also enabling policy frameworks that allow an efficient allocation of risks and for nuclear energy projects to compete on their merits on equal footing with other emitting energy projects

Understanding the costs of electricity provision





Understanding system costs of electricity

- To understand the costs of electricity provision requires systems level thinking combining plant-level costs, grid-level systems costs, and full social and environmental costs

Total costs for different mixes of electricity (driving to net-zero)

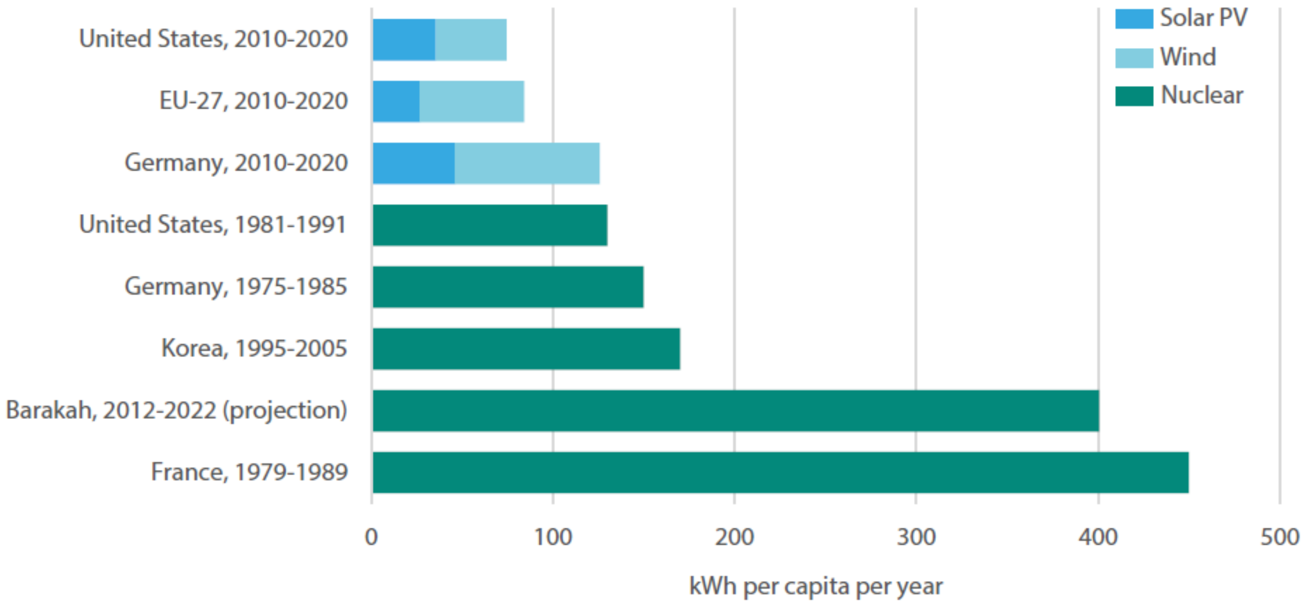
- This 3-dimensional graph shows the effects on total costs as carbon emissions are increasingly constrained. The red line shows what happens to total costs when carbon constraints reach net-zero emissions.

4. Recommendations

Recommendations

1. **Acting now**
   - *Governments* and *industry* should work together on an urgent basis to demonstrate and commercially deploy nuclear energy innovations
2. **Addressing timelines**
   - *Governments* and *industry* should learn from successful examples of rapid deployment of nuclear to decarbonize electricity grids
   - *Regulators* should collaborate to harmonize licensing approaches to enable efficient fleet deployment of nuclear innovations across international boundaries

Average annual increase of low-carbon electricity per capita during decade of peak scale-up



Recommendations (continued)

3. **Understanding and reducing costs**

   - The *nuclear sector* should draw from recommendations made in the NEA (2020) study *Unlocking Reductions in the Construction Costs of Nuclear: A Practical Guide for Stakeholders* to ensure that the sector meets cost objectives

   - *Governments* should take a systems level perspective when developing electricity policies to ensure that markets adequately value key nuclear features such as low carbon baseload, dispatchability, and reliability

4. **Building public confidence**

   - *Governments* and *industry* should engage the citizenry to build trust and public confidence, ensuring that public dialogues about energy options are evidence-based. This involves addressing misinformation and ensuring that a realistic conversation about the pros and cons of various options is facilitated

5. **Financing and investing**

   - *Governments* should make investments in nuclear energy and support a technology neutral approach that includes nuclear energy in taxonomies, climate finance, development finance, and ESG finance

Thank you for your attention