MEETING CLIMATE CHANGE TARGETS

THE ROLE OF NUCLEAR ENERGY

Michel BERTHELEMY
Division of Nuclear Technology Development and Economics
OECD Nuclear Energy Agency

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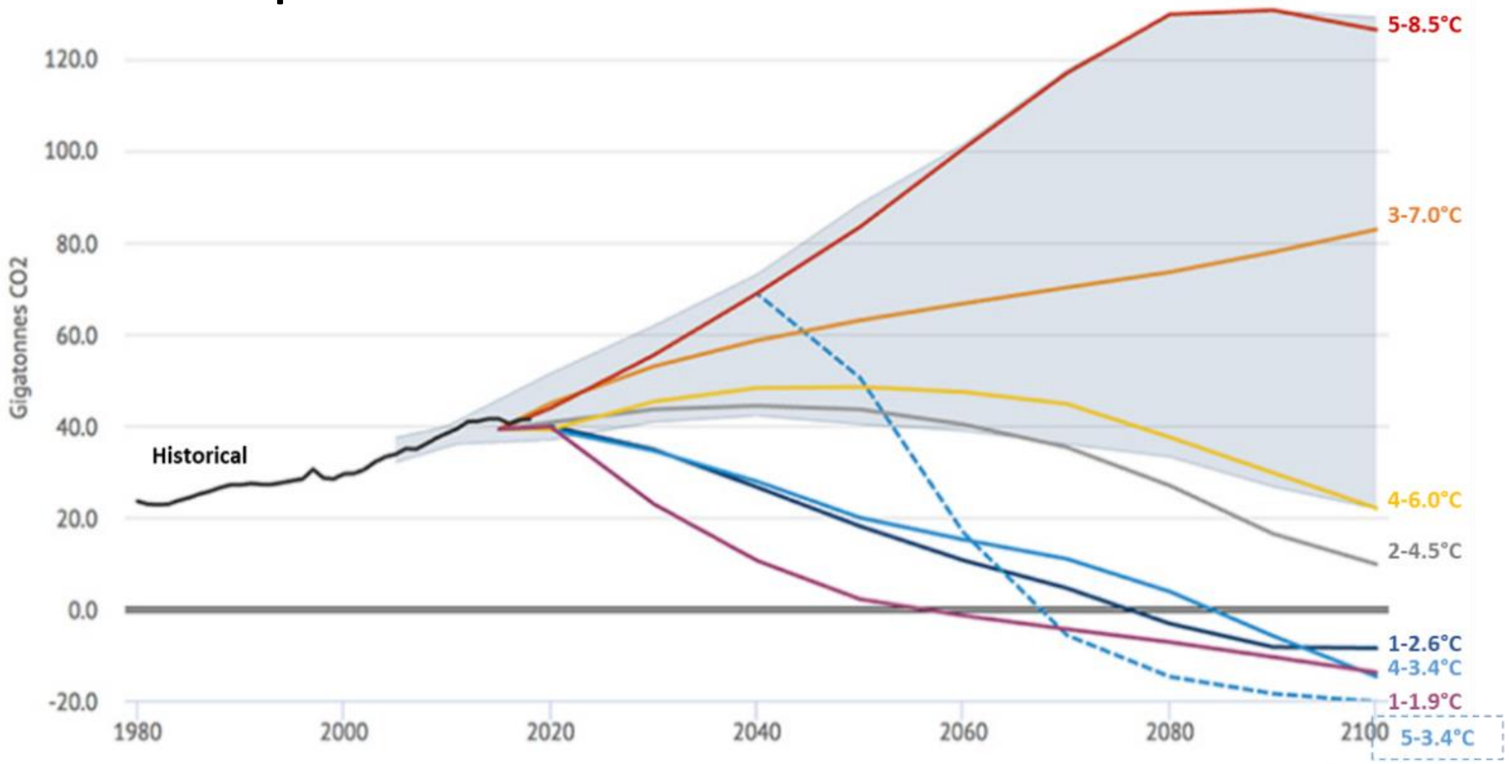
1. Context

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
- None of the published pathways project **aspirational scenarios** for nuclear innovation
- 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 (2021c)	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%**

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

2. The Role of Nuclear Energy

Nuclear Energy Today

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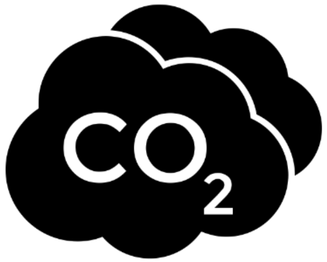


Created by ProSymbols
from Noun Project

444
Nuclear reactors in operation globally

30
Countries with nuclear reactors

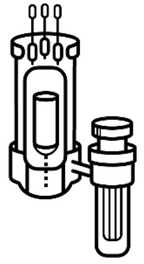
10%
of global electricity

66 GtCO_2
emissions avoided since 1971

The Full Potential of Nuclear Energy to Contribute to Emissions Reductions

Long Term Operation

Gen-III Reactors



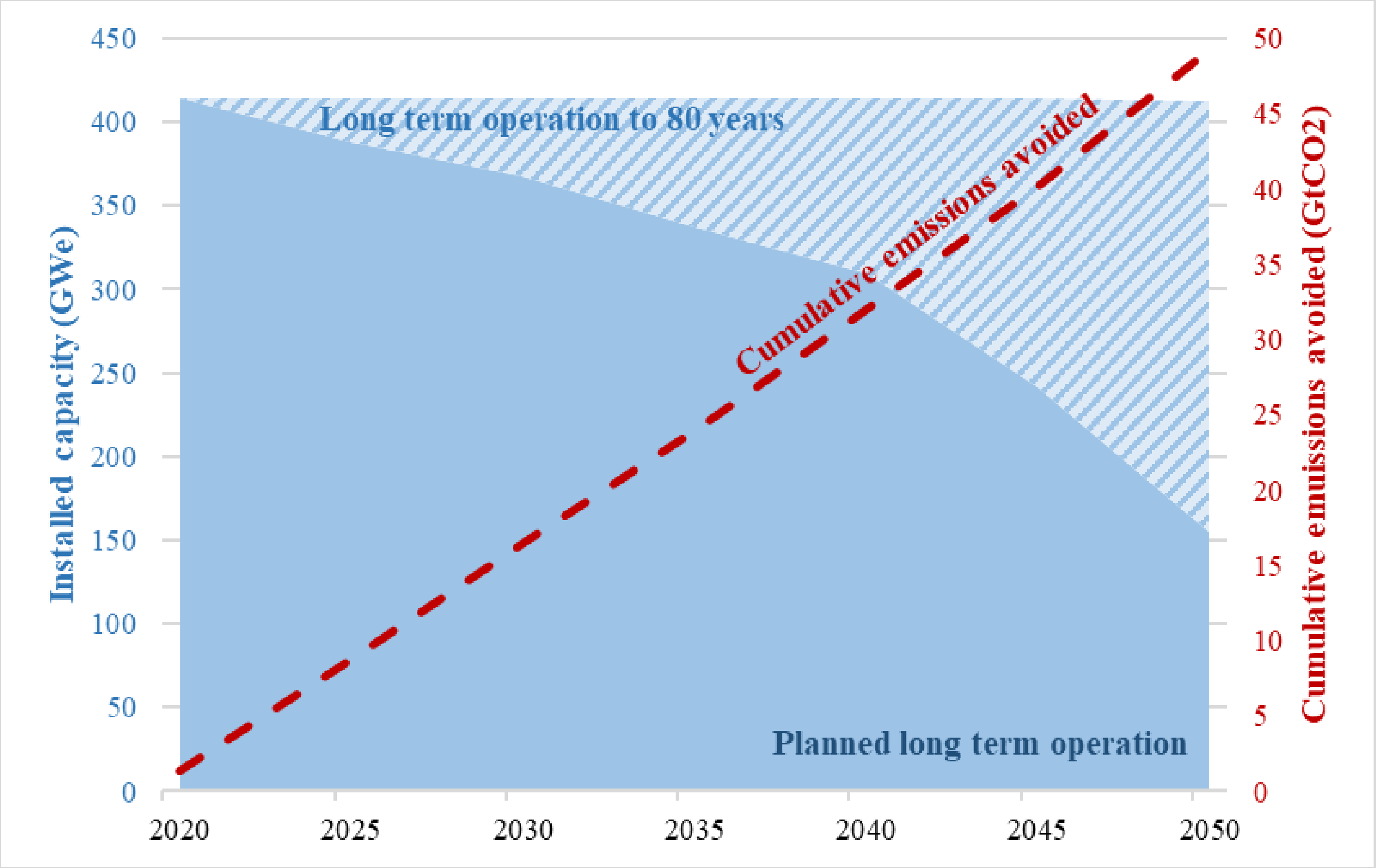
Small Modular Reactors

Non-Electrical 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

Installed Capacity And Cumulative Emissions Avoided

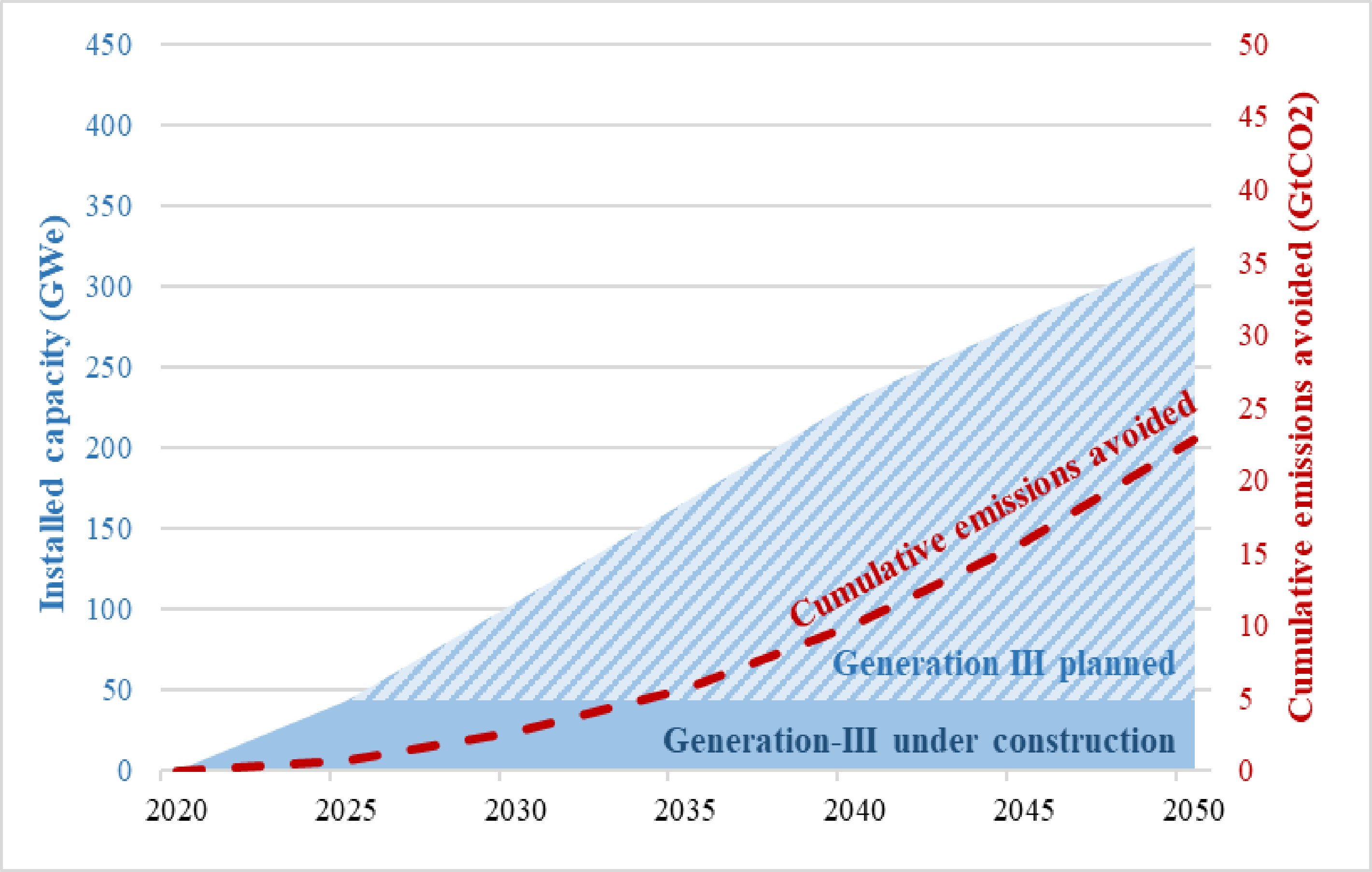


Source: NEA (forthcoming).

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

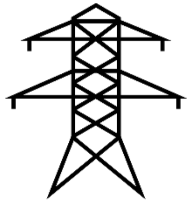
Installed Capacity And Cumulative Emissions Avoided



Source: NEA (forthcoming).

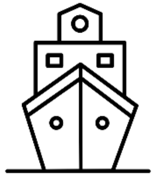
Small Modular Reactors (SMRs) – Applications and Markets

On-Grid



- Larger SMRs (200-300 MWe) are designed primarily for on-grid power generation
- The size of SMRs is especially well-suited to coal power plant replacement

Marine 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

Off-Grid

- 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

- Many SMRs designs will operate at higher temperatures, creating opportunities for decarbonization of hard-to-abate sectors
- High-temperature SMRs could create the first real non-emitting alternative to fossil fuel cogeneration by offering combined heat and power solutions for industrial customers

Small Modular Reactors – Ranges of Sizes and Temperatures

POWER

- SMRs vary in size from 1 to 300 megawatts electric

TEMPERATURE

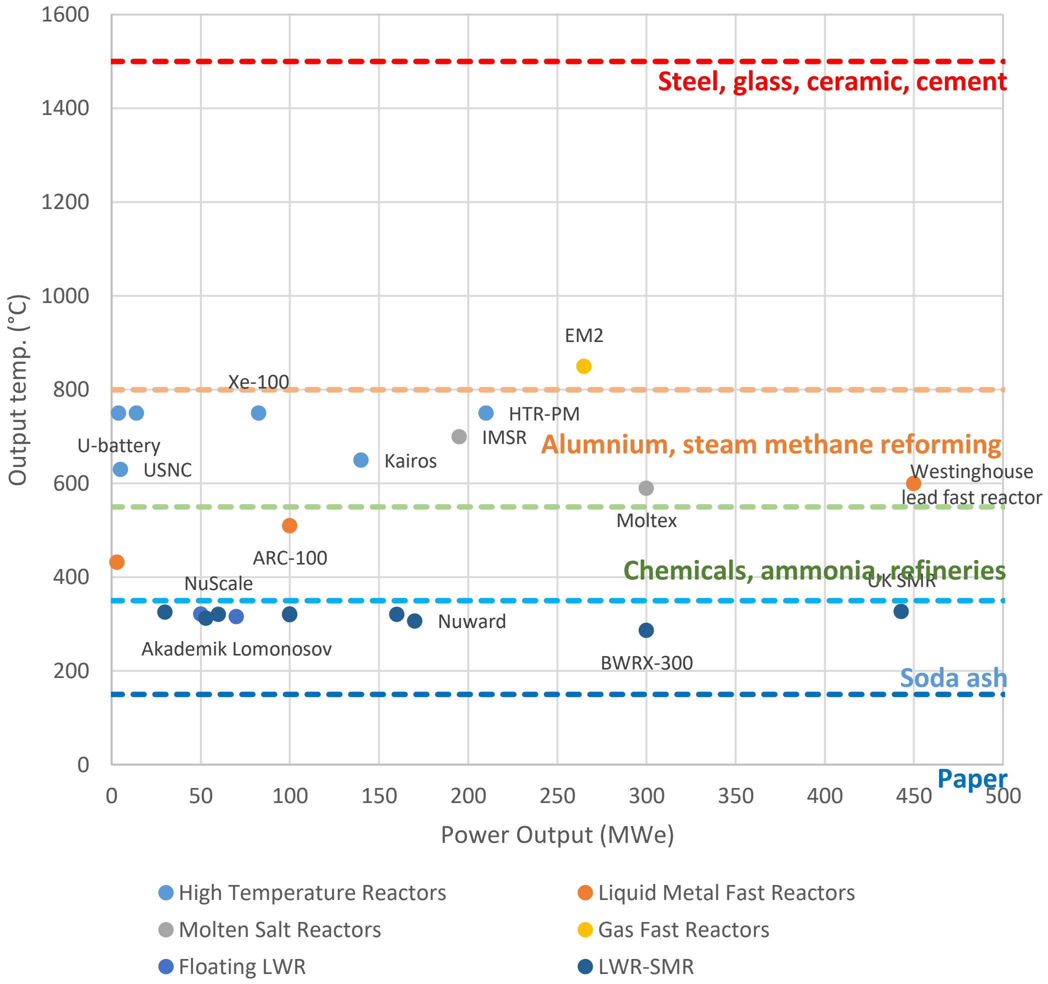
- From 285°C to 850°C in the near-term and up to or over 1,000°C in the future

TECHNOLOGY

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

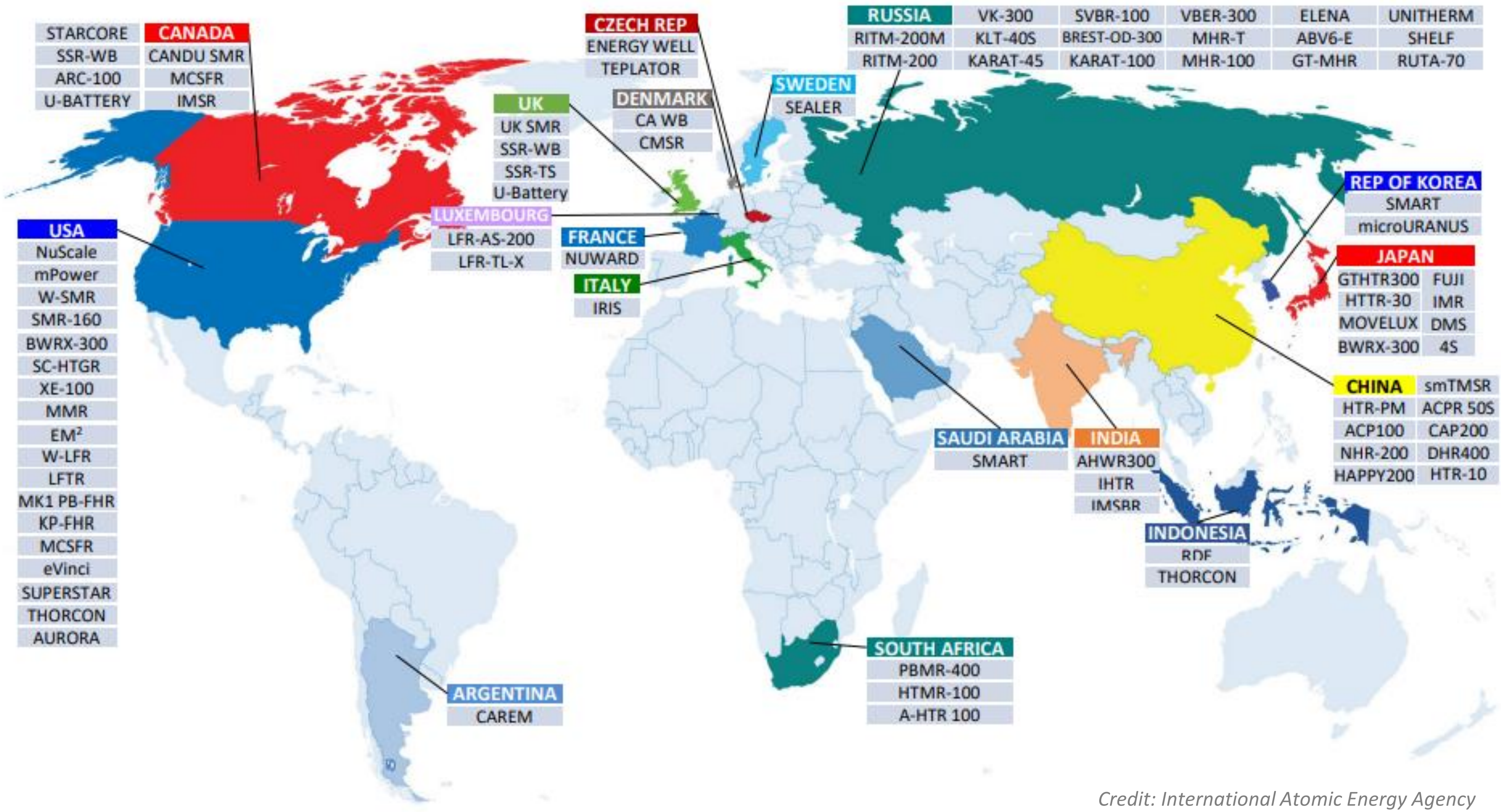
FUEL CYCLE

- 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



Credit: NEA (forthcoming)

The Status of SMR Development Globally

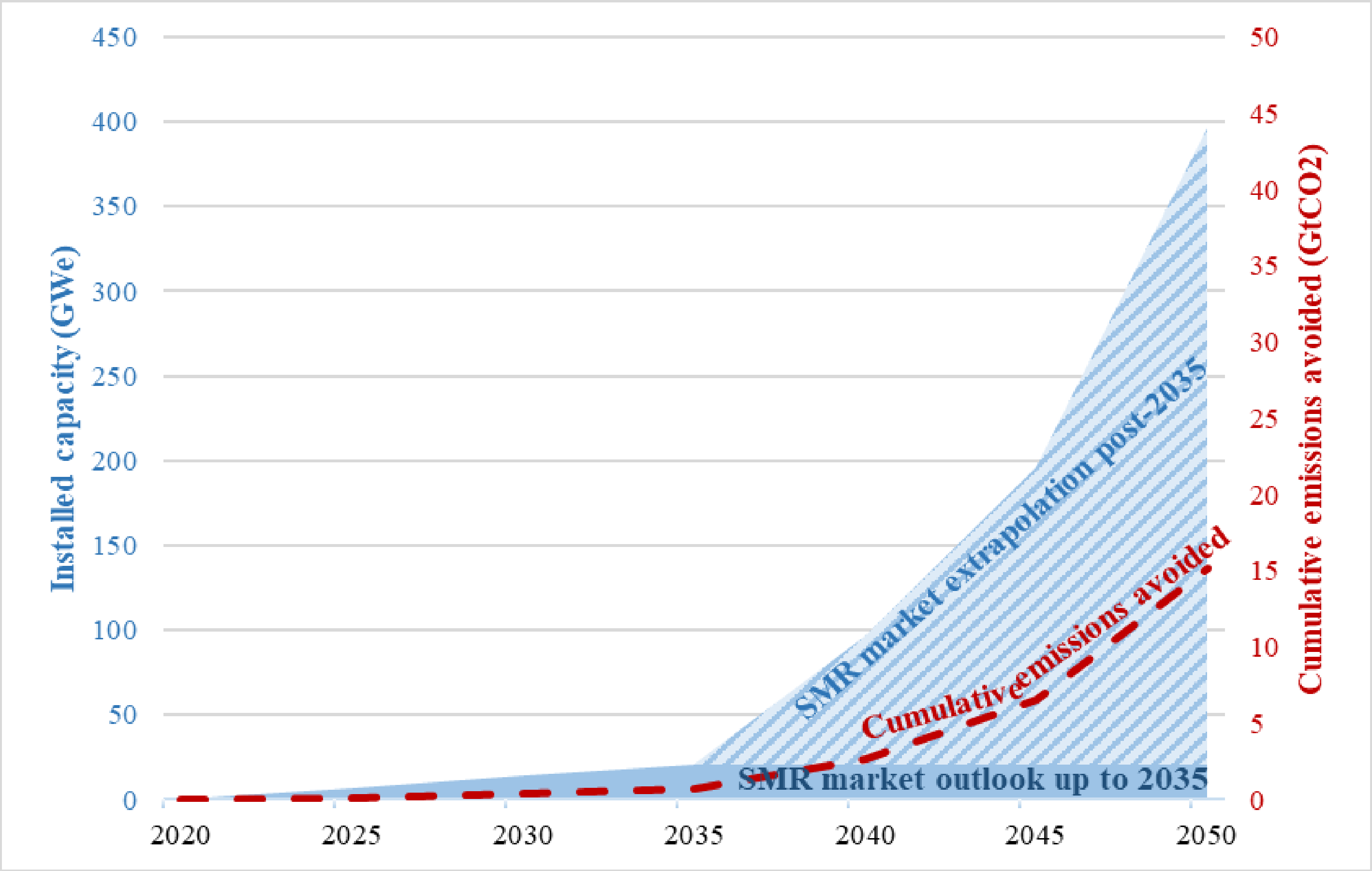


Credit: International Atomic Energy Agency

Small Modular Reactors

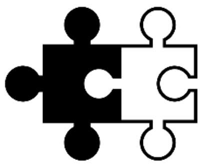
- Several SMR designs are expected to be commercially deployed within 5-10 years and ready to contribute to near-term and medium-term emissions reductions
- SMRs could see rapidly increasing rates of construction in net zero pathways
- Up to 2035, the global SMR market could reach **21 gigawatts**
- Thereafter, a rapid increase in build rate can be envisaged with construction between **50 and 150 gigawatts** per year

Installed Capacity And Cumulative Emissions Avoided

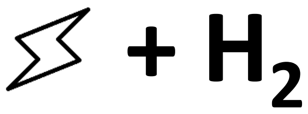


Source: NEA (forthcoming).

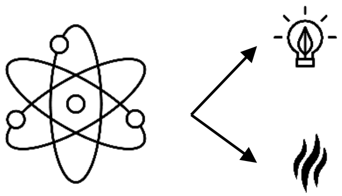
Nuclear hybrid energy systems including heat and hydrogen



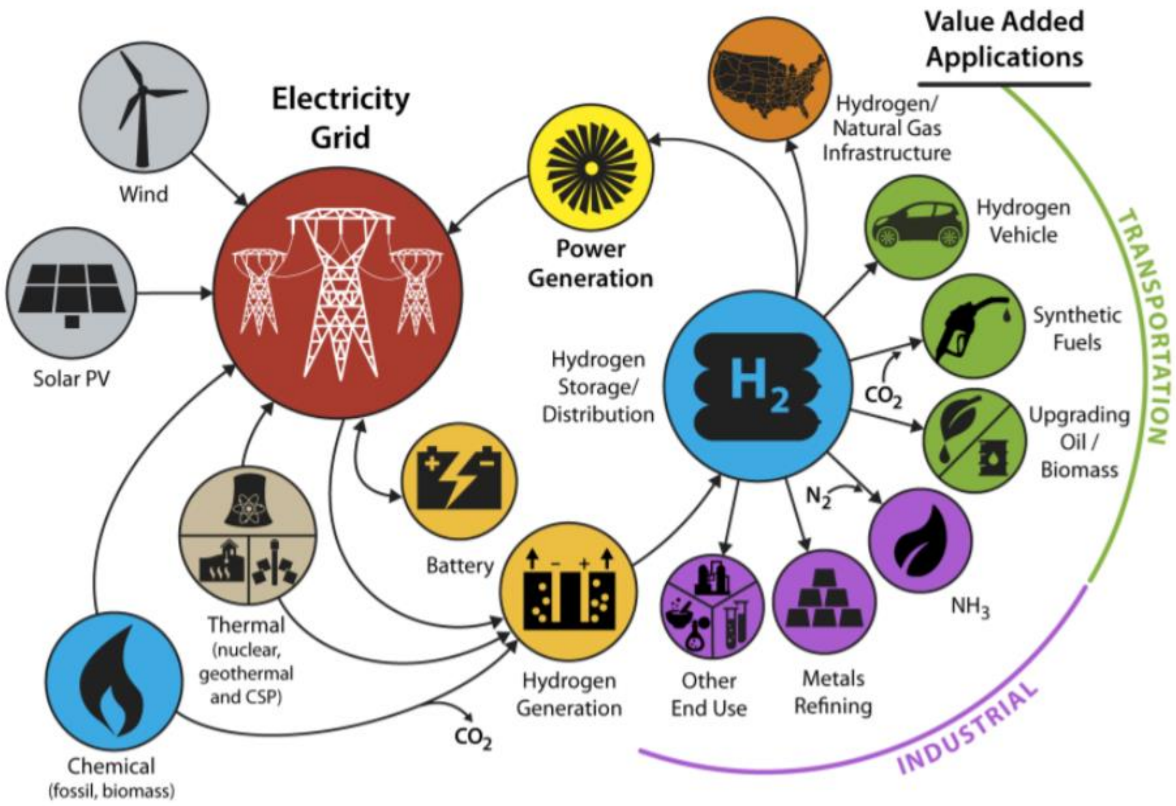
There is **no silver bullet**, all available clean technologies have to contribute to decarbonization



Electricity and clean-hydrogen is the new energy paradigm

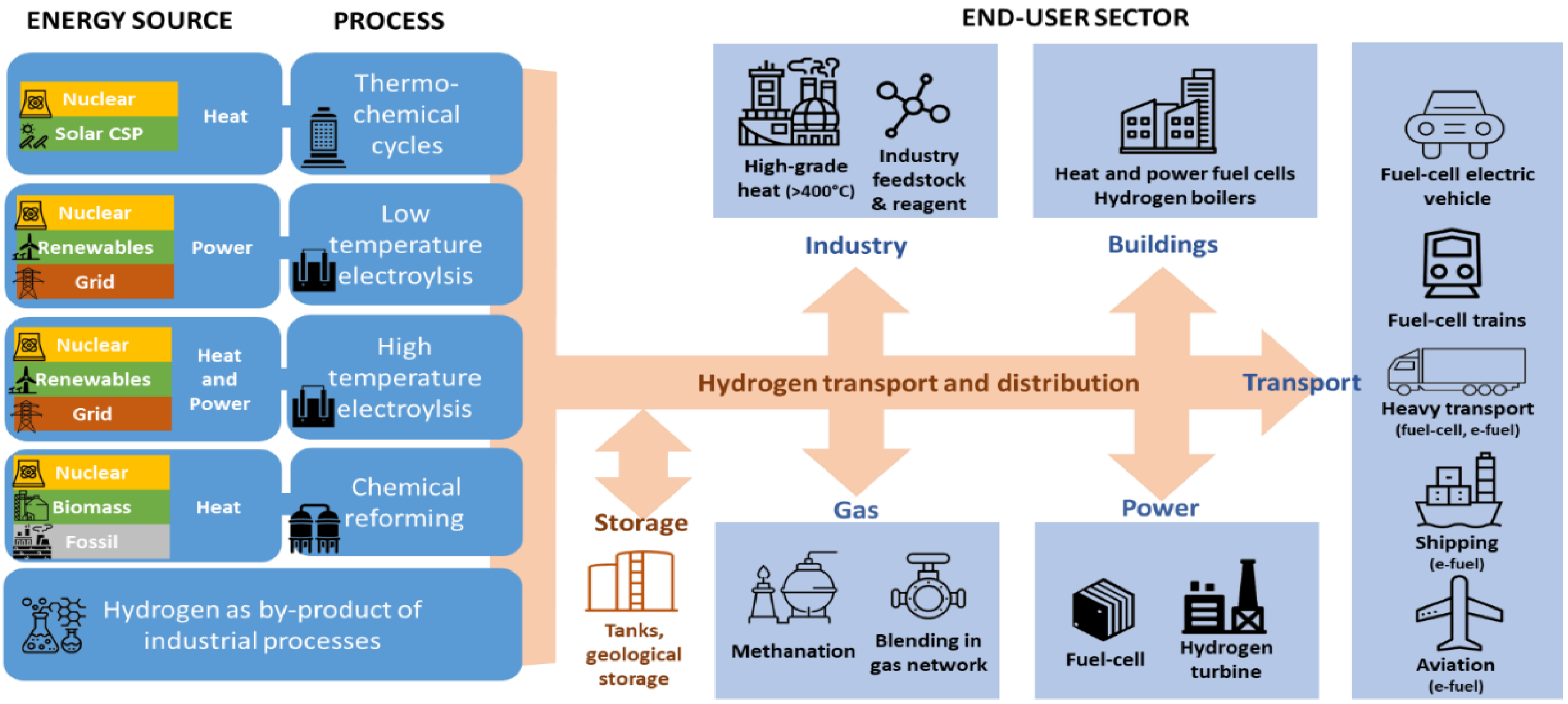


As a **reliable source of clean electricity and high heat**, nuclear is a key pillar of future energy systems



Credit: US Department of Energy, Idaho National Lab

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

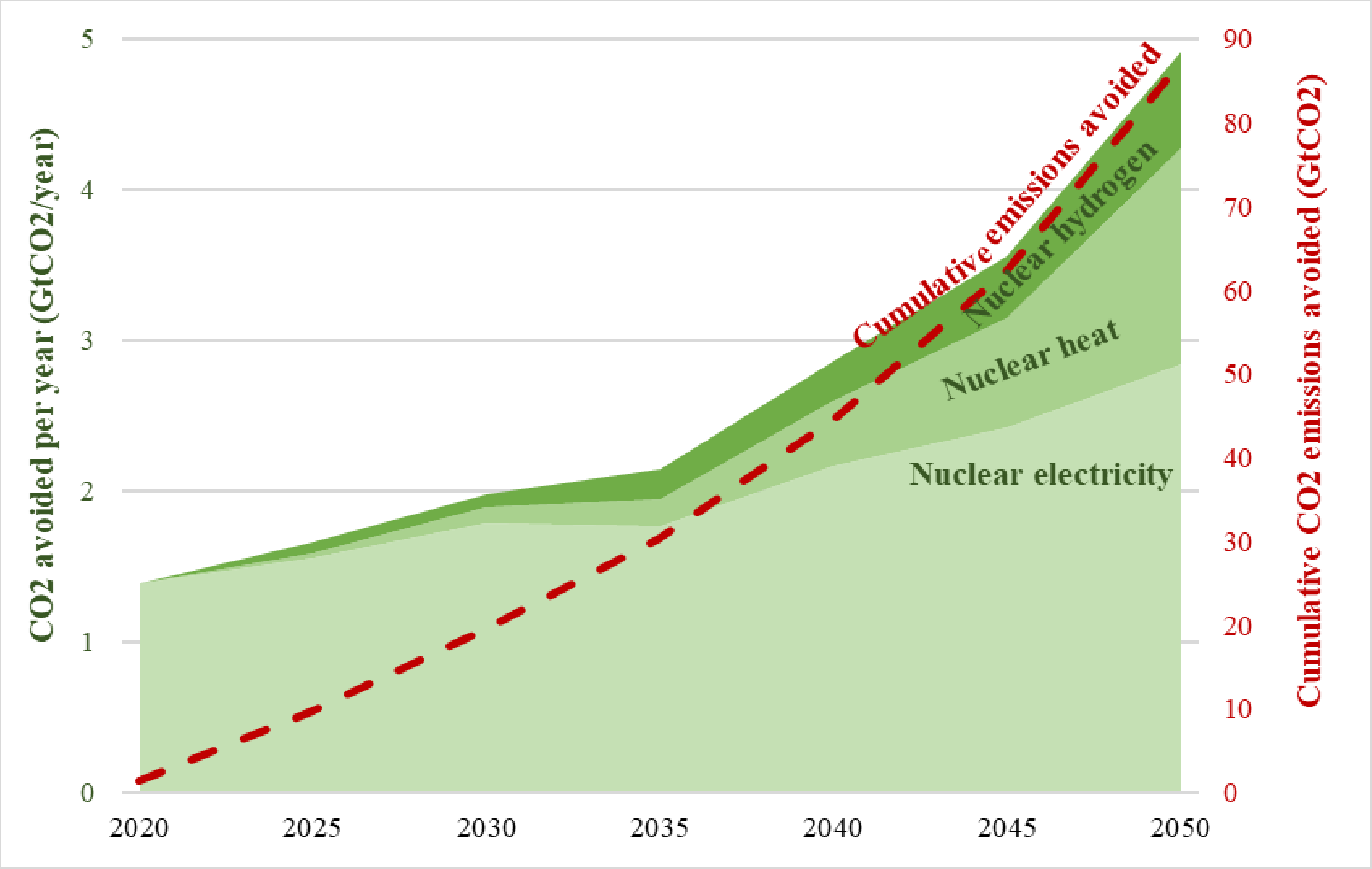


Source: NEA (forthcoming).

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

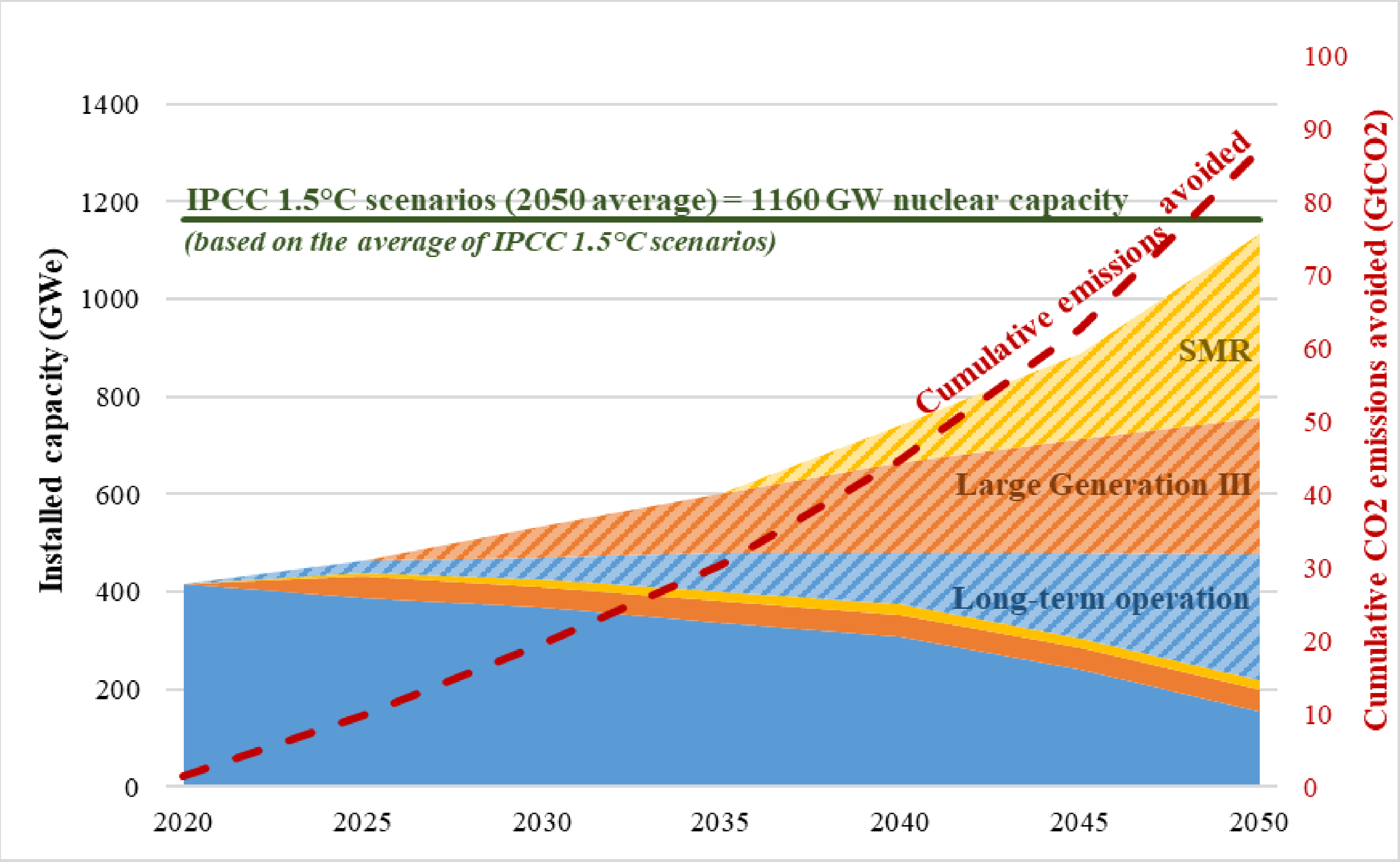
Carbon emissions avoided by nuclear power and non-power applications



Source: NEA (forthcoming).

Full Potential of Nuclear Contributions to Net Zero

- The contributions from long-term operation, new builds of large-scale Generation III nuclear technologies, small modular reactors, nuclear hybrid energy and hydrogen systems project the full potential of nuclear energy to contribute to net-zero
- Reaching the target of **1160 gigawatts** of nuclear by 2050 would avoid **87 gigatonnes** of cumulative emissions between 2020 and 2050, positioning nuclear energy's contribution to preserve 20**% of the world's carbon budget** most likely de to be consistent with a 1.5°C scenario

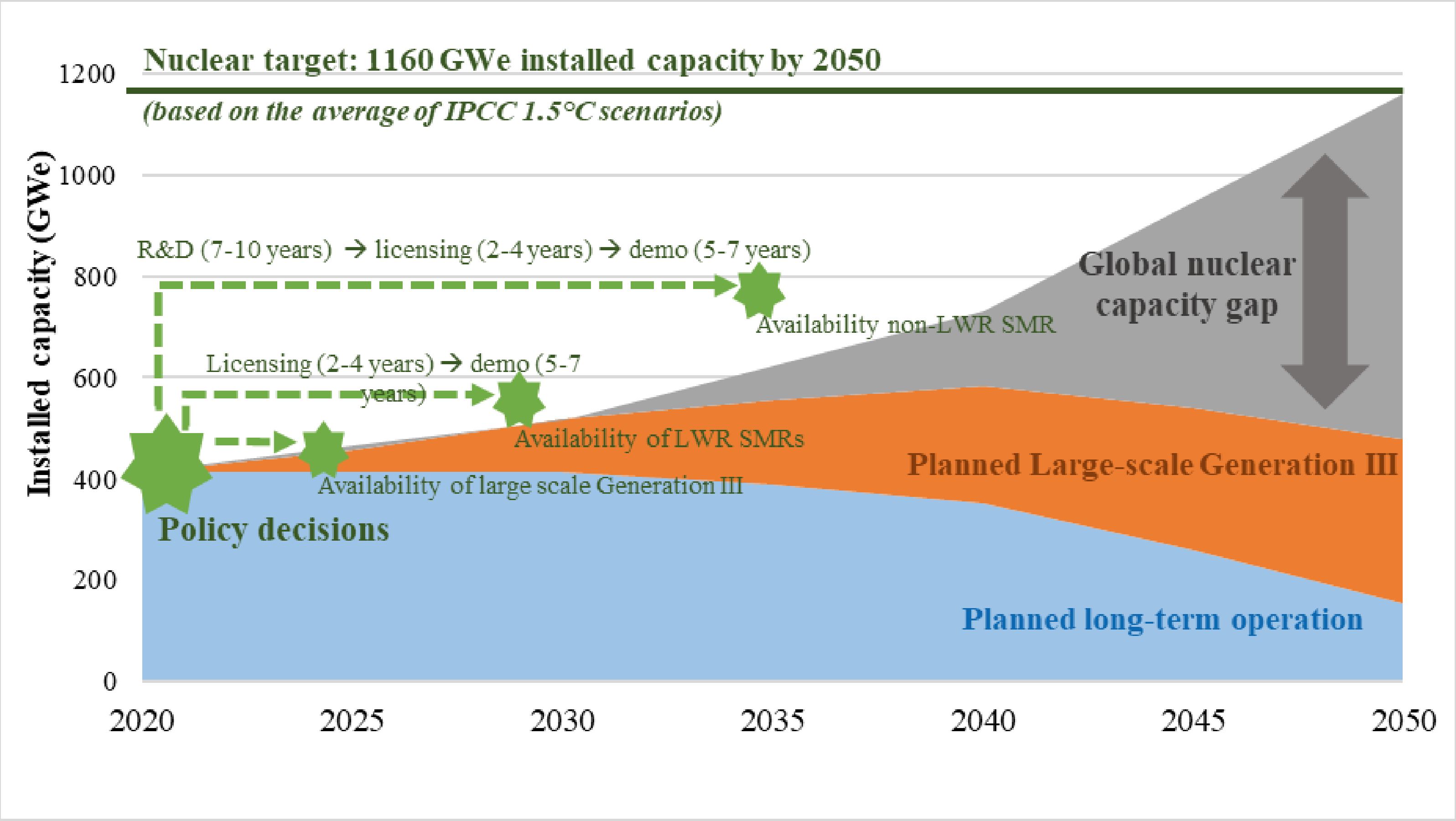


Source: NEA (forthcoming).

3. Delivering the Full Potential of Nuclear Contributions to Net Zero

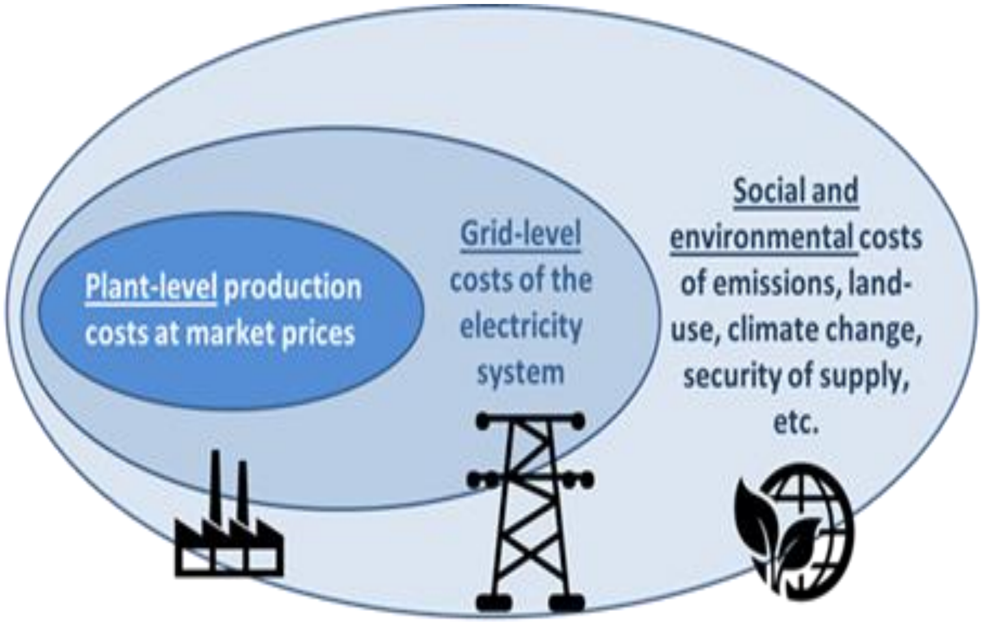
Global Installed Nuclear Capacity Gap

- Under current policy trends, nuclear capacity in 2050 is expected to reach **479 gigawatts** – well below the target of **1,160 gigawatts** of electricity
- There is a projected gap between the *minimum required global installed nuclear capacity* and *planned global nuclear capacity* of **nearly 300 gigawatts by 2050**
- Owing to the timelines for nuclear projects, there is an urgency to action now to close the gap in 2030-2050



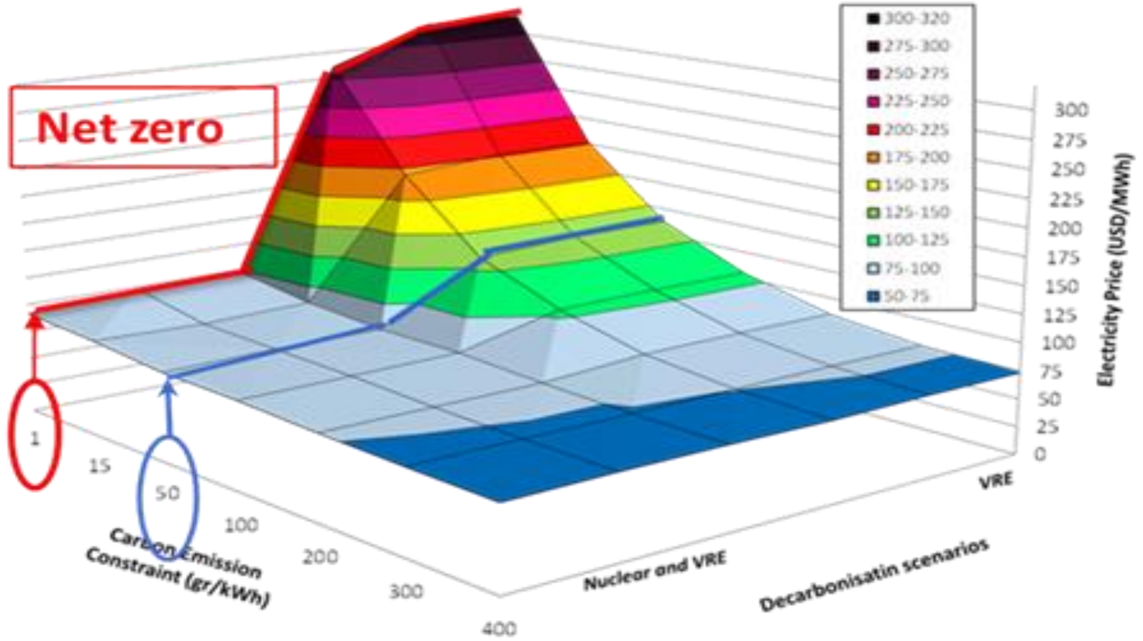
Source: NEA (forthcoming).

Understanding the costs of electricity provision



Understanding system costs of electricity

Source: Adapted from NEA (2012).



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

Source: Based on Sepulveda (2016).

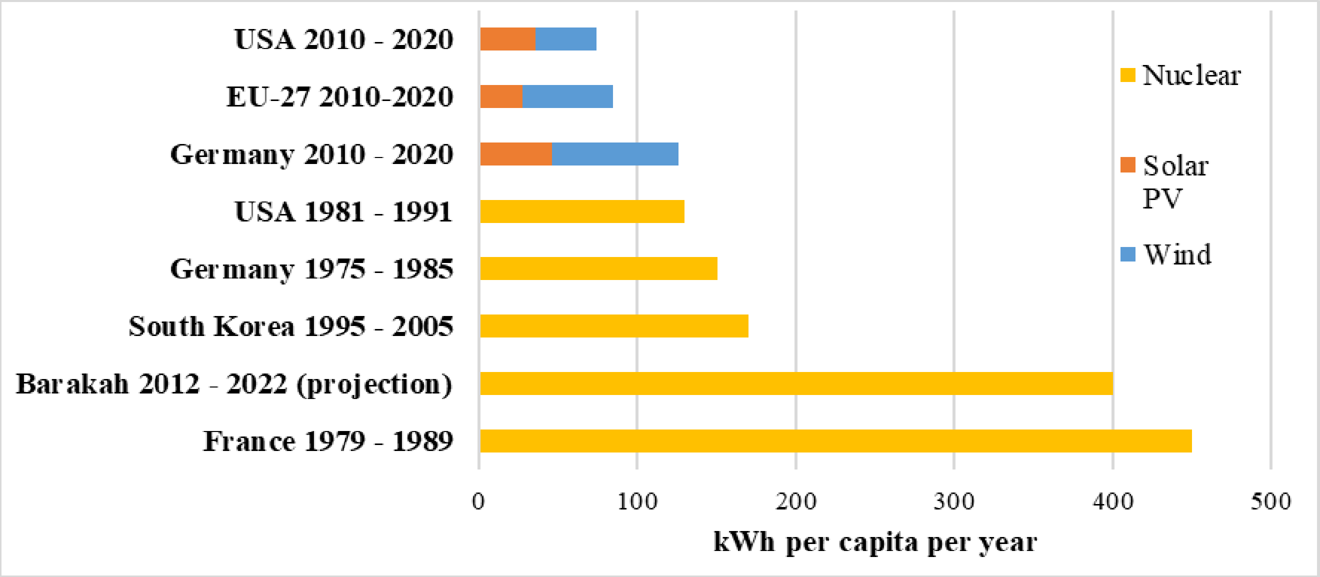
- To understand the costs of electricity provision requires systems level thinking combining plant-level costs, grid-level systems costs, and full social and environmental costs
- This 3-dimensional graph shows the effects on total costs as carbon emissions are increasingly constrained. The red line shows what happens to total costs when carbon constraints reach net-zero emissions.

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 decarbonise electricity grids
   - *Regulators* should collaborate to harmonise 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



Source: NEA (forthcoming).

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

Nuclear Reimagined

Credit: ThirdWay

Thank you for your attention