NEA
NUCLEAR ENERGY AGENCY

Nuclear Energy: The Future is Now

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Korean Nuclear Society, 18 May 2023

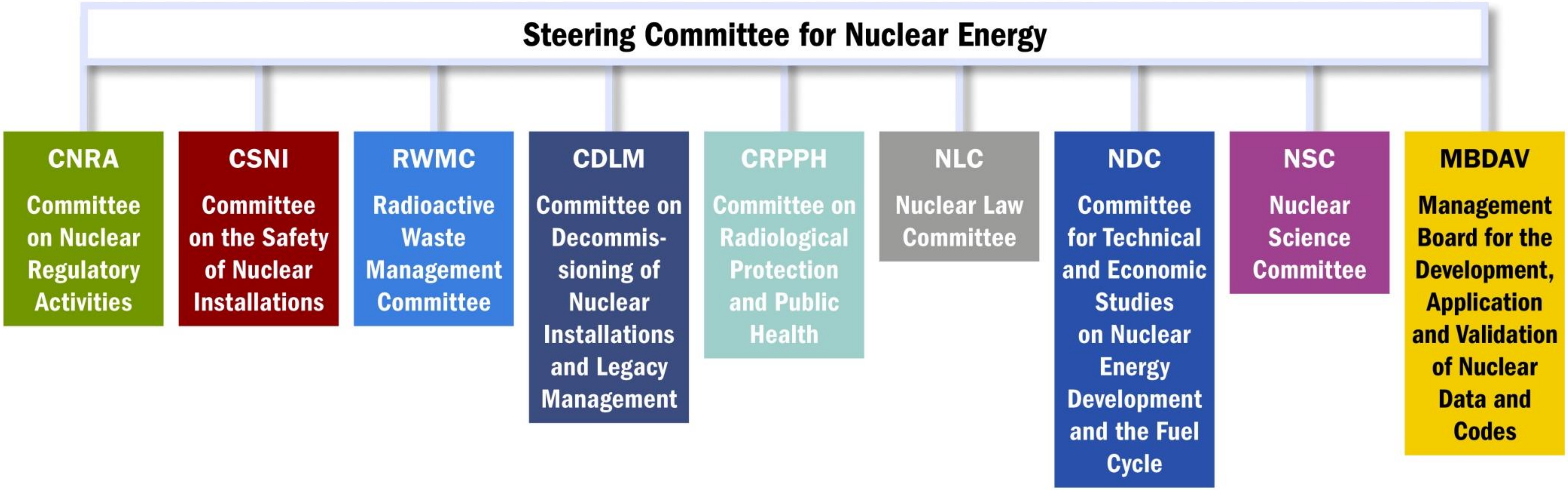
The NEA: 34 Countries Seeking Excellence in Nuclear Safety, Technology, and Policy

- The premier international platform for cooperation in nuclear technology, policy, regulation, research, and education.
- 34 member countries + strategic partners (e.g., China and India).
- 8 standing committees and more than 80 working parties and expert groups.
- Global relationships with industry and universities.

Argentina	Australia	Austria	Belgium
Bulgaria	Canada	Czech Republic	Denmark
Finland	France	Germany	Greece
Hungary	Iceland	Ireland	Italy
Japan	Korea	Luxembourg	Mexico
Netherlands	Norway	Poland	Portugal
Romania	Russia	Slovak Republic	Slovenia
Spain	Sweden	Switzerland	Turkey
United Kingdom	United States		

NEA countries operate about 81% of the world's installed nuclear capacity

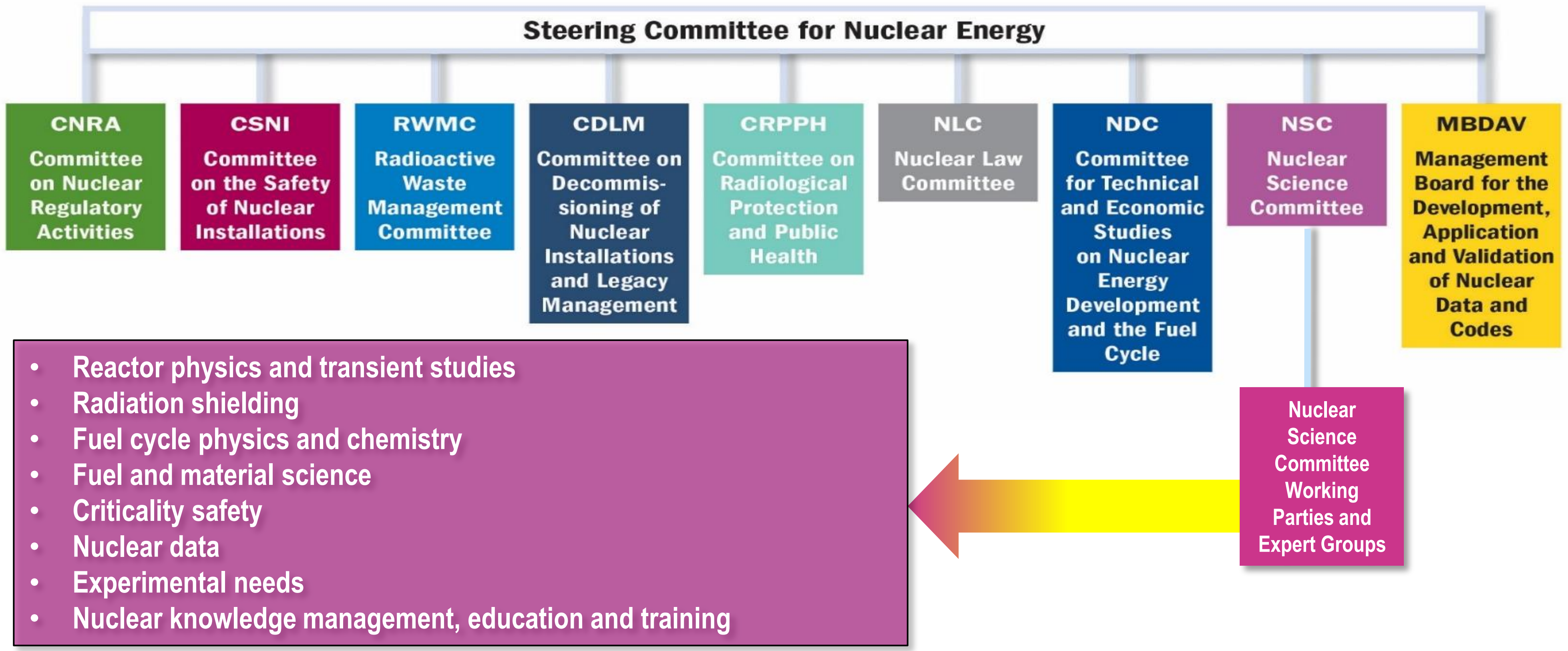
NEA Standing Technical Committees



The NEA's committees bring together top governmental officials and technical specialists from NEA member countries and strategic partners to solve difficult problems, establish best practices and to promote international collaboration.

NEA Standing Technical Committees – Nuclear Science

The NEA Nuclear Science Committee supports member countries to identify, collect, compile, develop, preserve and disseminate the basic scientific and technical knowledge required to ensure the safe, reliable and economic operation of current and next-generation nuclear systems and to promote innovation



NEA Framework for Irradiation Experiments (FIDES) – A Global Platform for Advancing Fuels and Materials

Second Framework for Irradiation Experiments – FIDES-II

- NEA joint undertaking, established pursuant to Article 5 of the NEA Statues in co-ordination with the Nuclear Science Committee (NSC) and the Committee on the Safety of Nuclear Installations (CSNI)
- A stable, sustainable, reliable platform for fuel and material testing using nuclear research reactors (RRs) in NEA member countries
- Generates experimental results and expertise for shared costs
- **FIDES-II Program of Work includes 4 Joint Experimental Programmes (JEEPs) & 3 cross cutting pillars**

P2M
Tests in BR2 & LECA PIE Facility
Belgium & France

INCA
ATF Cladding creep tests in LVR15
Czech Republic

HERA
RIA tests with high burnup fuel in TREAT and NSRR
USA & Japan

INCREASE
Stress-relaxation tests of structural material in ATR
USA

Under Development
Simplified Irradiation of Ad Fuel Concepts

Future experiments using existing RRs to be guided by FIDES-II Strategic Plan

Data Preservation and Quality Assurance

Training and Education

Modelling and Simulation

Participating Countries:

- Belgium
- Czech Republic
- Finland
- France
- Germany
- Hungary
- Japan
- Netherlands
- Spain
- Sweden
- Switzerland
- United States
- European Commission

www.oecd-nea.org/fides-ii

Major International Co-operative Frameworks

NEA Serviced Bodies

- **Generation IV International Forum (GIF)** with the goal to develop new fission technologies with greater sustainability (including effective fuel utilisation and minimisation of waste), economic performance, safety and reliability, proliferation resistance and physical protection.
- **Multinational Design Evaluation Programme (MDEP) -** initiative by national safety authorities to leverage their resources and knowledge for new reactor design reviews (ABWR, AES2006, AP1000, EPR, HPR1000).
- **International Framework for Nuclear Energy Cooperation (IFNEC) –** 65-country forum for multilateral discussion and analyses of a wide array of nuclear topics involving both developed and emerging economies.

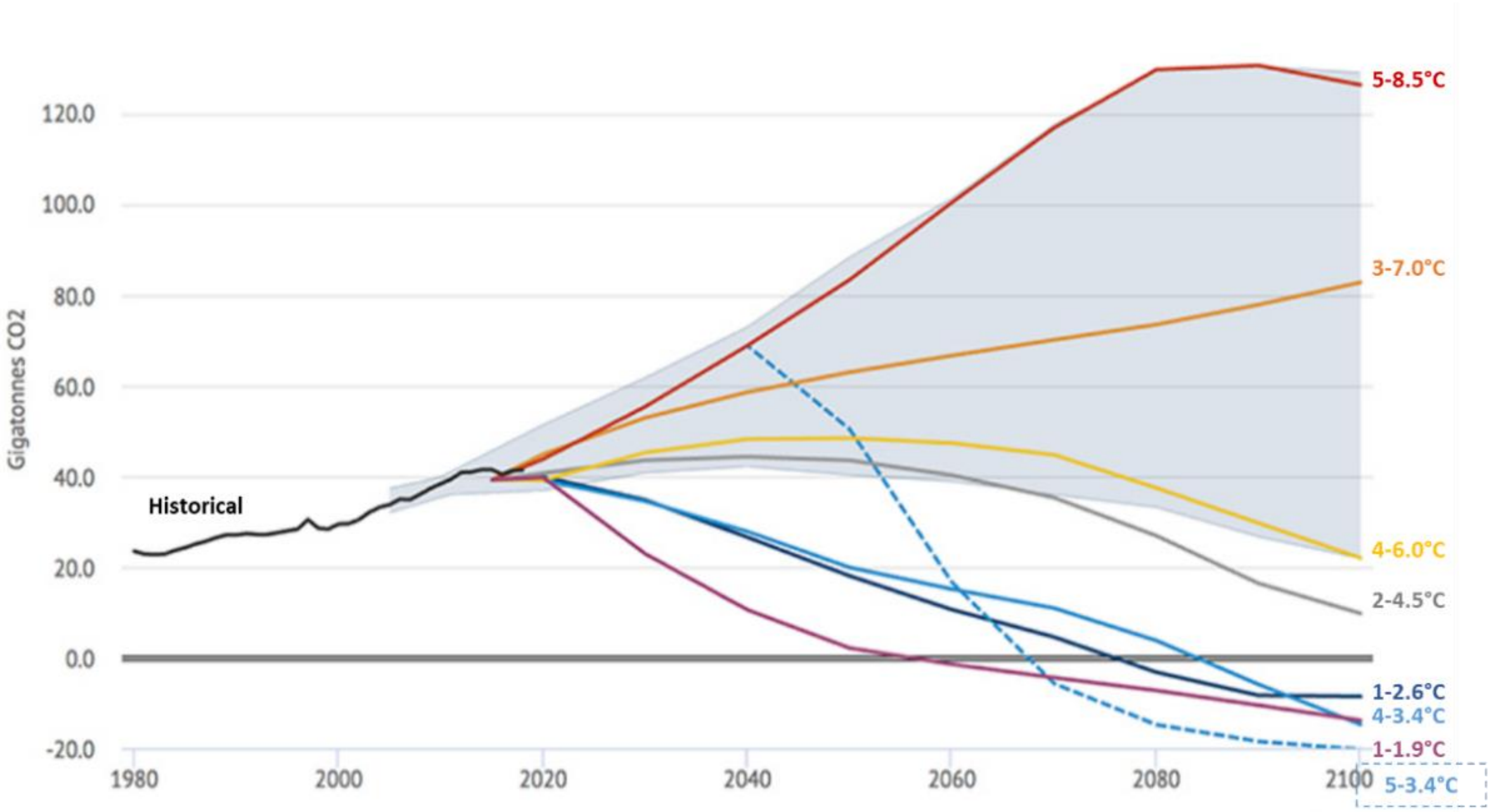
28 Major Joint Projects

- **Nuclear safety research** and experimental data (e.g., thermal-hydraulics, fuel behaviour, severe accidents).
- **Nuclear safety databases** (e.g., fire, common-cause failures).
- **Nuclear science** (e.g., thermodynamics of advanced fuels).
- **Radioactive waste management** (e.g., thermochemical database).
- **Radiological protection** (e.g., occupational exposure).
- **Nuclear Education, Skills and Technology Framework (NEST)** (promoting the development of a new generation of subject matter experts).

Global Action Is Urgently Needed to Meet Climate Targets

- 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).

Key Observations

- **Energy security is now the driving issue in many capitals** as electricity prices rise dramatically around the world and recent geopolitical events create fears of a gas supply crisis in Europe.

- **Coal use is shrinking** as policies, markets, and public perception turn against its use in many countries.

- **Recent focus on 2030 targets for CO_2 reductions** have forced both increased investment in energy and a much larger degree of reality.

- **Particularly in the aftermath of COP26, many OECD and emerging economies view nuclear energy as a key element in their decarbonization strategies.**

Nuclear in Emissions Reduction Pathways

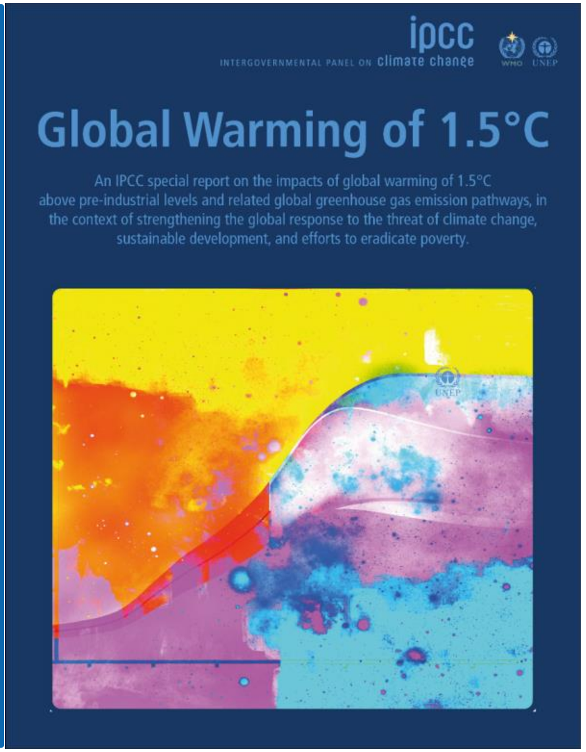
Organisation	Scenario	Climate target	Nuclear innovation	Description	Role of nuclear energy by 2050	
					Capacity (GW)	Nuclear growth (2020-50)
IAEA (2021b)	High Scenario	2°C	Not included	Conservative projections based on current plans and industry announcements.	792	98%
IEA (2021c)	Net Zero Scenario (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

Nuclear Energy Can—and Must—Play a Larger Role In Support of Global Net-Zero Goals

In its 2018 special report, the IPCC reviewed **90 pathways consistent with a 1.5°C scenario** – i.e., pathways with emissions reductions sufficient to limit average global warming to less than 1.5°C.

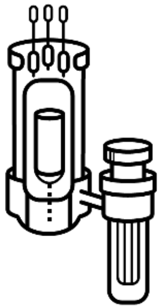
On average, the scenarios reflect the need for global nuclear capacity to **triple by 2050 to 1160 gigawatts**, up from 394 gigawatts in 2020.



The Full Potential of Nuclear Energy to Contribute to Emissions Reductions

Long Term Operation

Large Gen-III Reactors



Small Modular Reactors

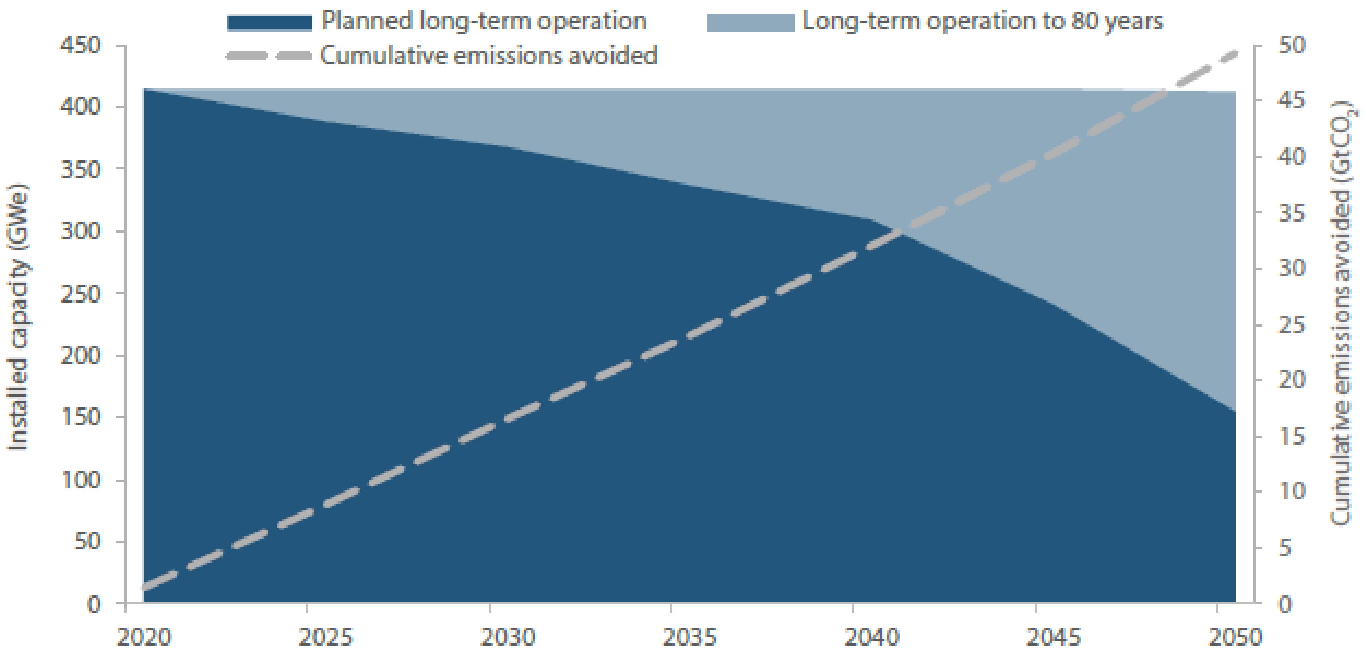
Non-Electrical applications

Complementary nuclear technologies and applications

Long-term Operation of Current Nuclear Plants

- 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
- 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)

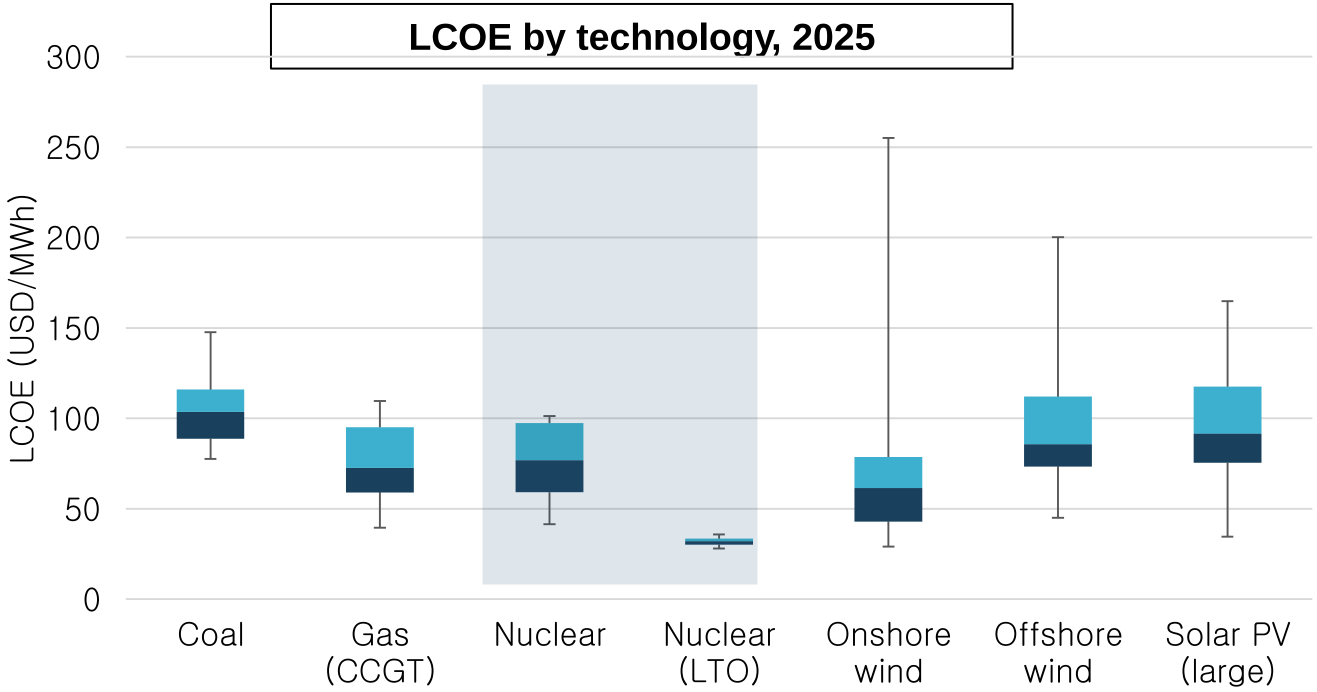


Note: Note: It is assumed that nuclear power (12 gCO_2eq/kWh) is displaced by gas with a carbon footprint of 490 gCO_2eq/kWh (Bruckner, 2014). By 2050, 25% of nuclear reactors are used for nuclear heat applications, also displacing gas. By 2050, nuclear reactors operate with a 90% availability factors 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).

Long-Term Operation is THE Least Cost Option

Challenges to LTO

- **Views of LTO vary around the world due to differing policy and regulatory approaches.** For example in some countries, the 40 year mark is characterized as "plant lifetime."
- Distorted, dysfunctional, and obsolete markets do not recongnise the value of existing nuclear plants to system reliability and carbon reduction.
- Some government policies are leading to the premature shut down of nuclear plants, **placing Net Zero further out of reach.**



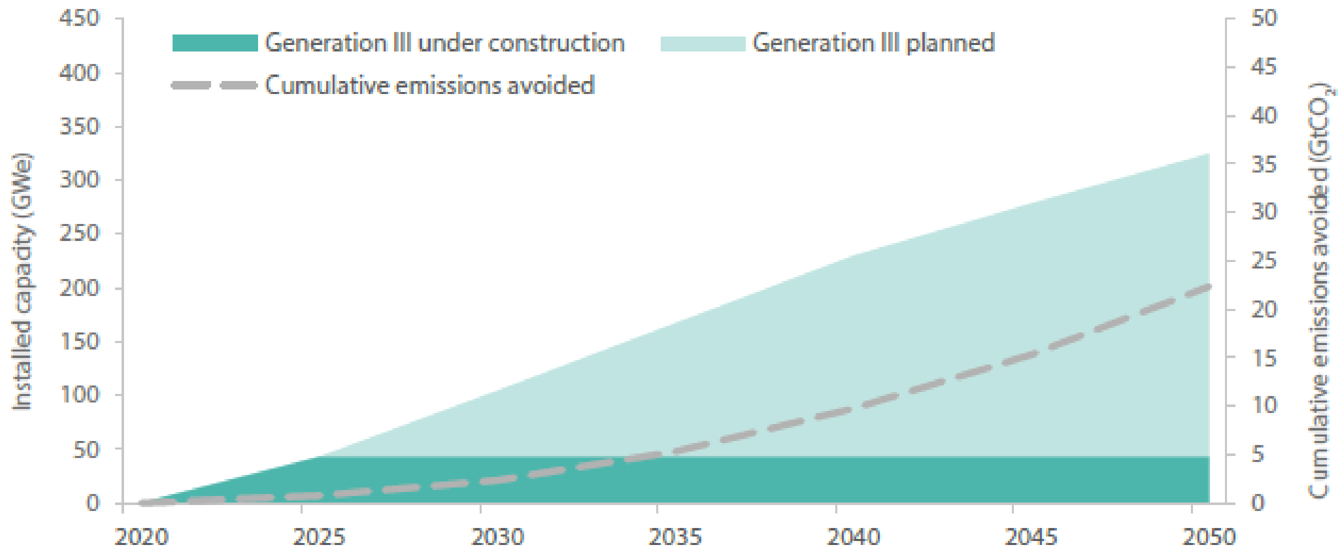
Note: Coal includes lignite plants. Discount rate of 7% and carbon price of USD30/tCO2
Source: IEA/NEA (2020)

Long-term operation could save up to 49 gigatonnes of cumulative emissions between 2020 and 2050.

New Builds of Large Generation III Plants

- 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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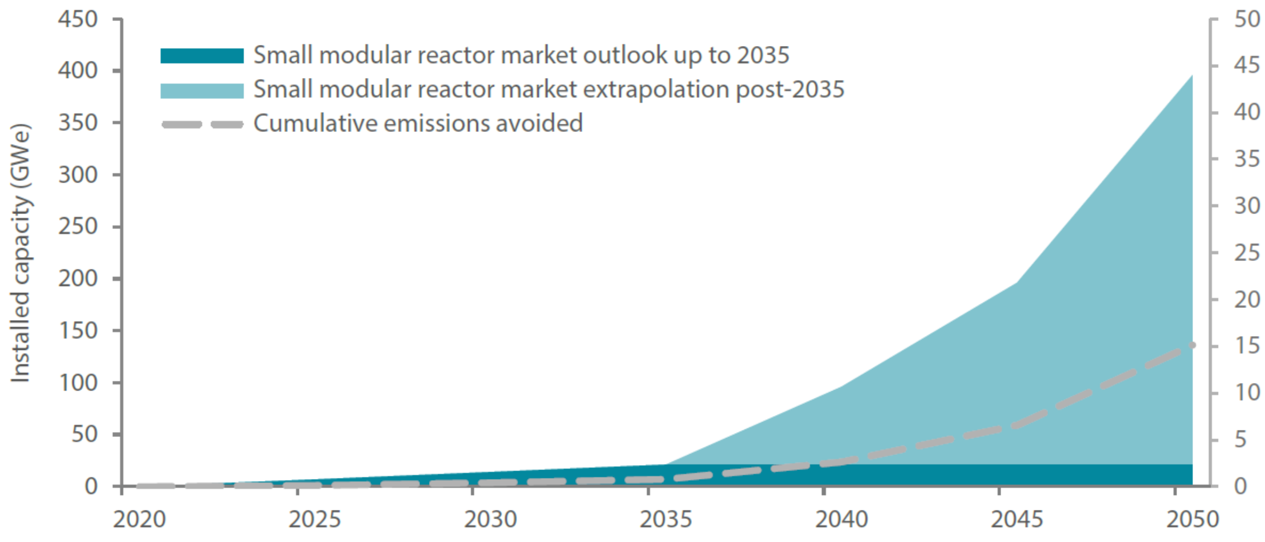
Small Modular Reactors and Generation IV Reactors

- 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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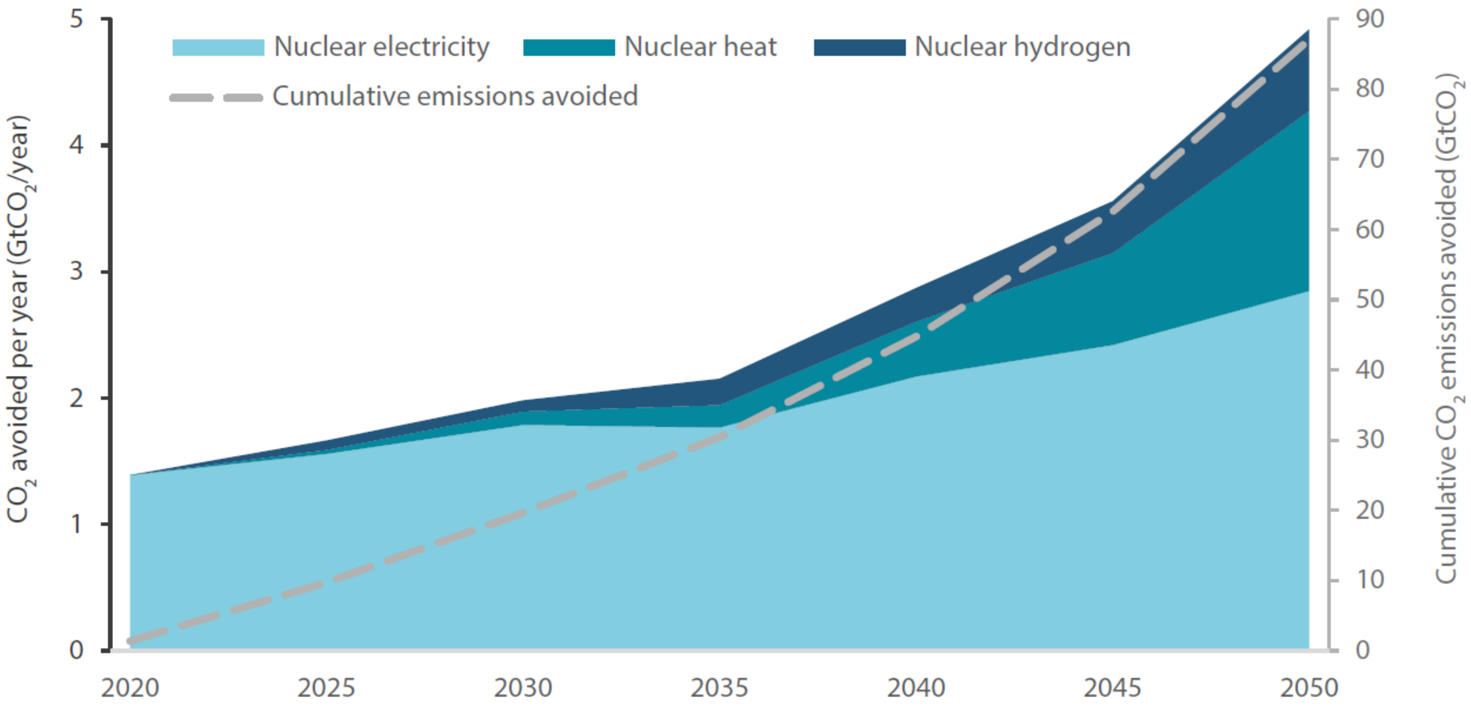
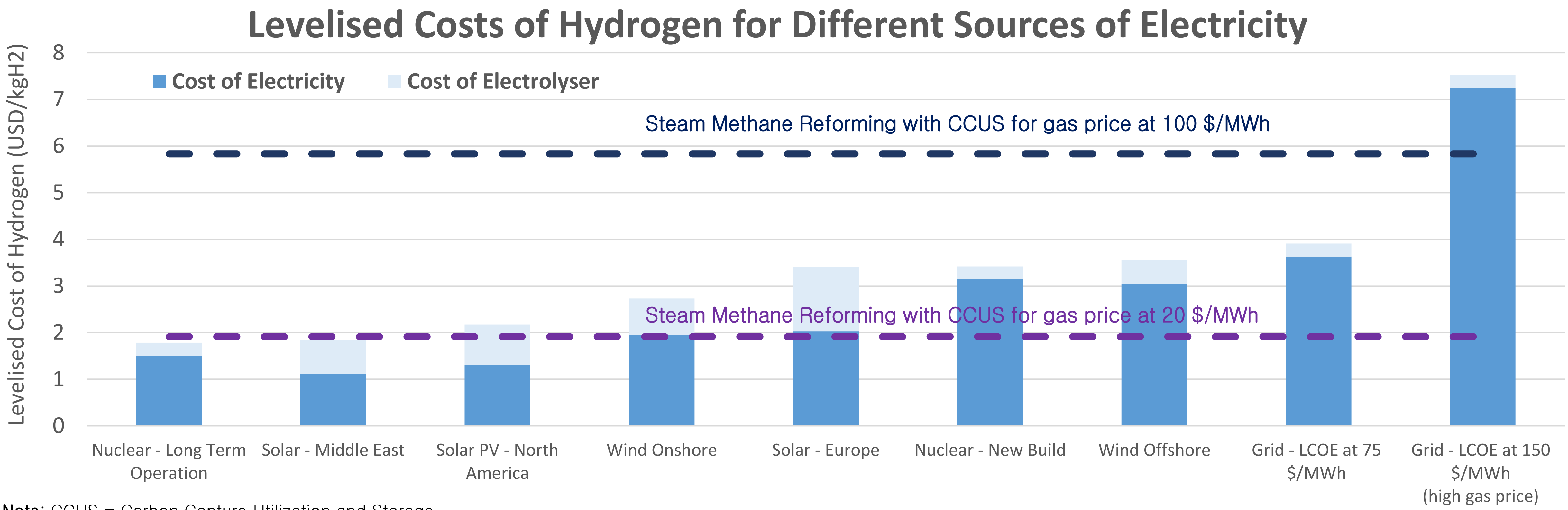
Power and Non-power Applications of Nuclear Energy

- 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



Nuclear is a Competitive Source for Hydrogen Production

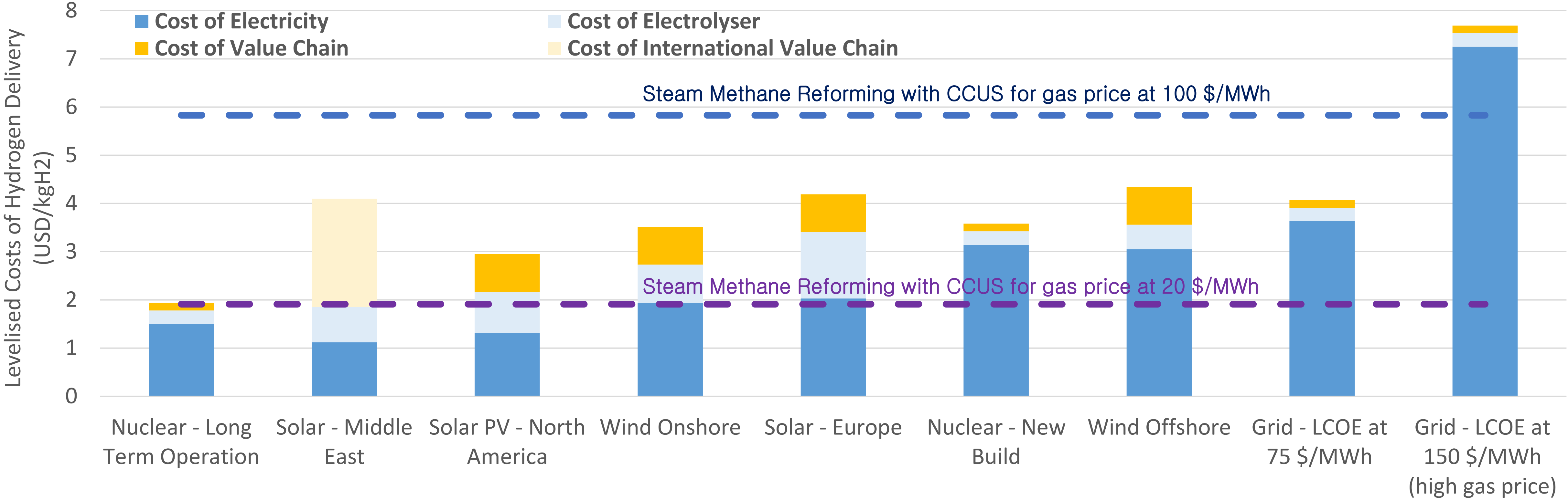


Note: CCUS = Carbon Capture Utilization and Storage

I. The Levelised Cost of Hydrogen (LCOH) is primarily determined by the Levelised Cost of Electricity.
II. Nuclear is a competitive option to produce hydrogen.
III. The competition between water electrolysis and Steam Methane Reforming with CCUS is primarily determined by the price of gas.

Hydrogen Production: Nuclear is Even More Competitive When Taking into Account the Full Value Chain

Levelised Costs of Hydrogen Delivery for Different Sources of Electricity



I. Taking into account value chains costs from hydrogen delivery improves the competitiveness of nuclear power plants and grid-connected electrolysers.
II. By 2030-2035, hydrogen delivery costs is likely to be between 3 and 4 USD/kgH2 in most places of the world.

Note: CCUS = Carbon Capture Utilization and Storage

Small Modular Reactors and Generation IV Reactors: *Enabling Pathways to Net-Zero*

SMALL MODULAR REACTORS (SMRs)

SMALL
- Smaller output
- Small physical size
- 1–300 MWe

MODULAR
- Factory Production
- Portable
- Scalable

REACTOR
- Nuclear Fission
- Heat
- Electricity

BENEFITS

SIMPLIFIED SAFETY
- Lessons learned from 60 years of operations

FLEXIBILITY
- Adapted to complement variable renewables

APPLICATIONS

ON-GRID
- 200–300 MWe
- Replace coal

MERCHANT SHIPPING
- Marine Production
- Off bunker fuel

OFF-GRID
- Remote sites
- Replace diesel

HEAT
- 285 – 850 °C
- Industrial cogeneration

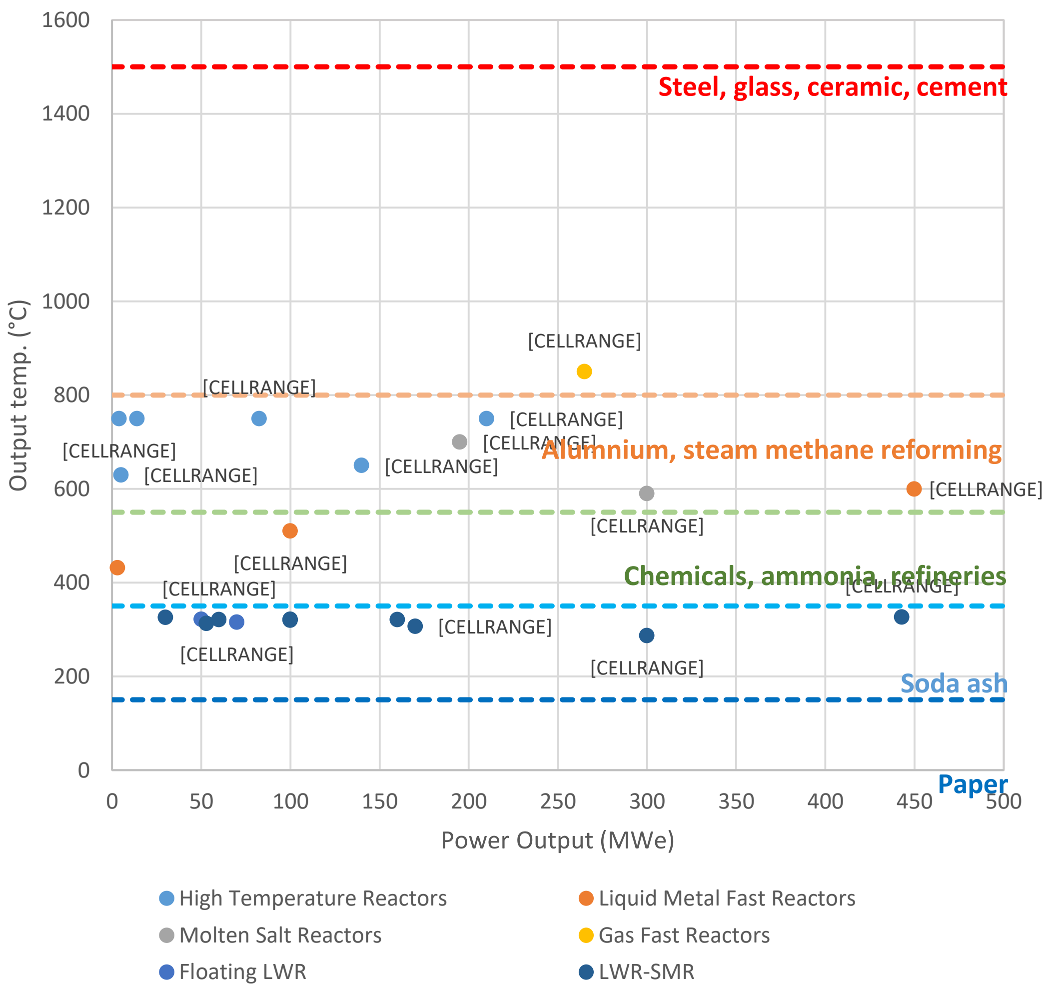
Small Modular Reactors and Generation IV Reactors:
Ranges of Sizes and Temperatures

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

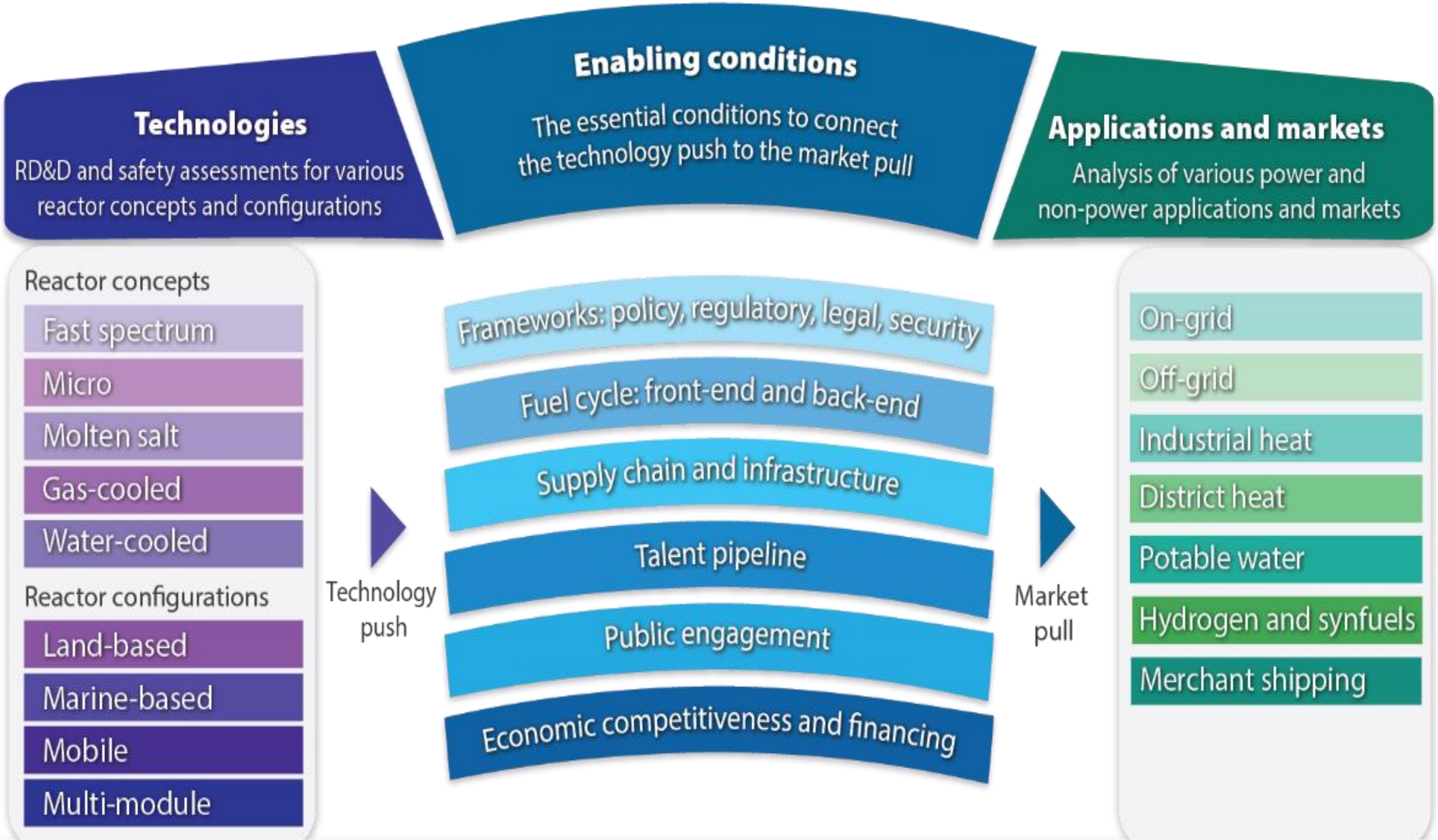
TEMPERATURE
- From 285°C to 850°C in the near-term and up to or over 1,000°C in the future.

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 minimise waste streams requiring long-term management and disposal.



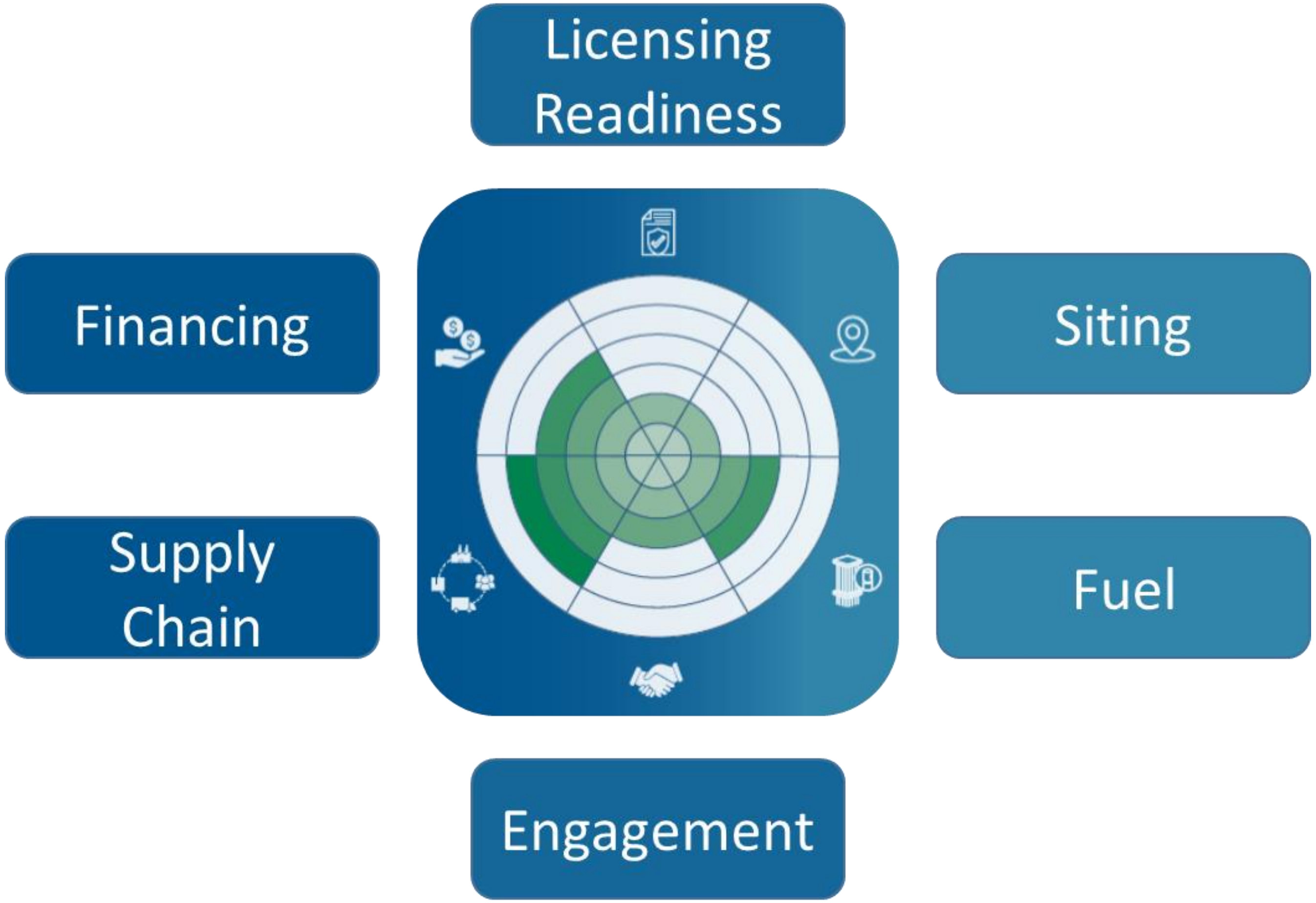
Progress Toward Deployment is Much More than Technical Feasibility

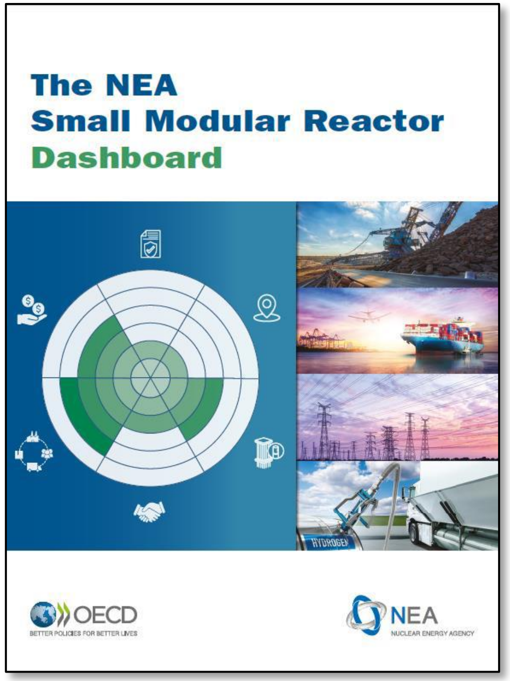


Tracking Progress: *NEA SMR Dashboard*

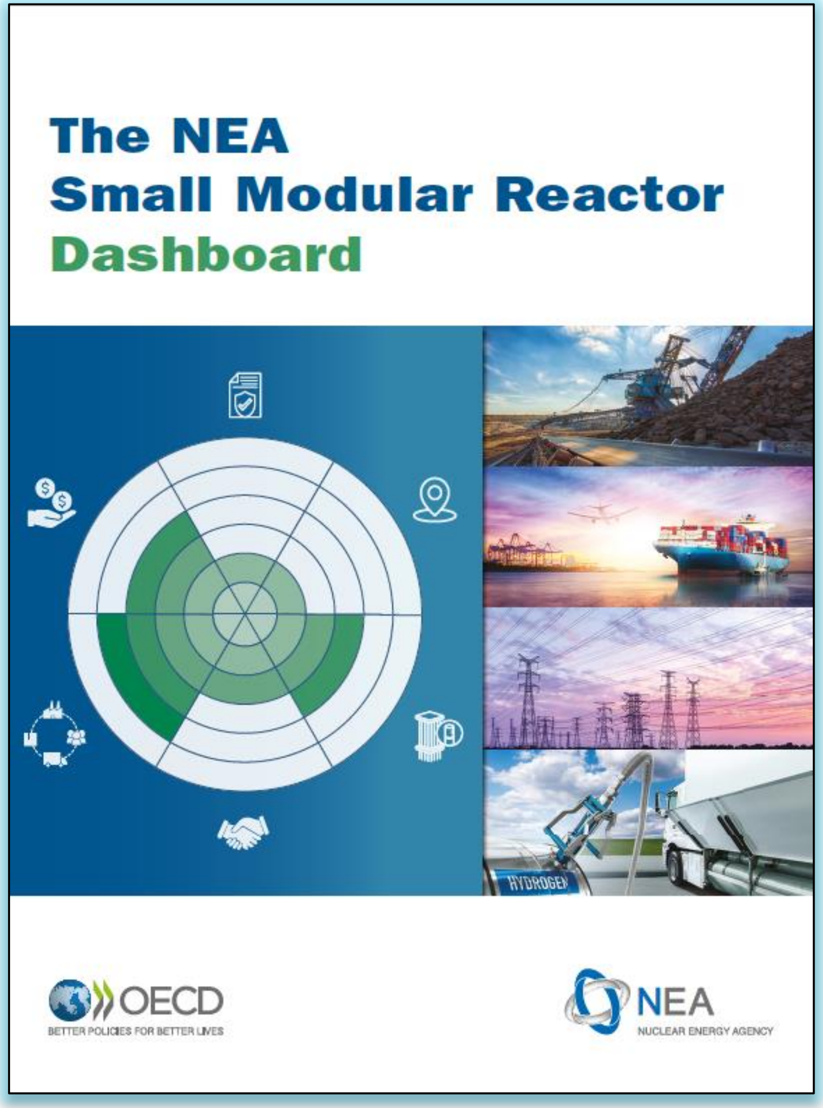
1st edition launched on March 13, 2023

- "Technology readiness level" is useful, but only reveals part of the picture
- **NEA defined six additional indicators of progress**
- With the NEA indicators, the picture becomes clearer





NEA SMR Dashboard: The Next Volume is Coming Soon



- 20-30 SMRs are under consideration for the next volume
- Target launch date July 19th at the Clean Energy Ministerial

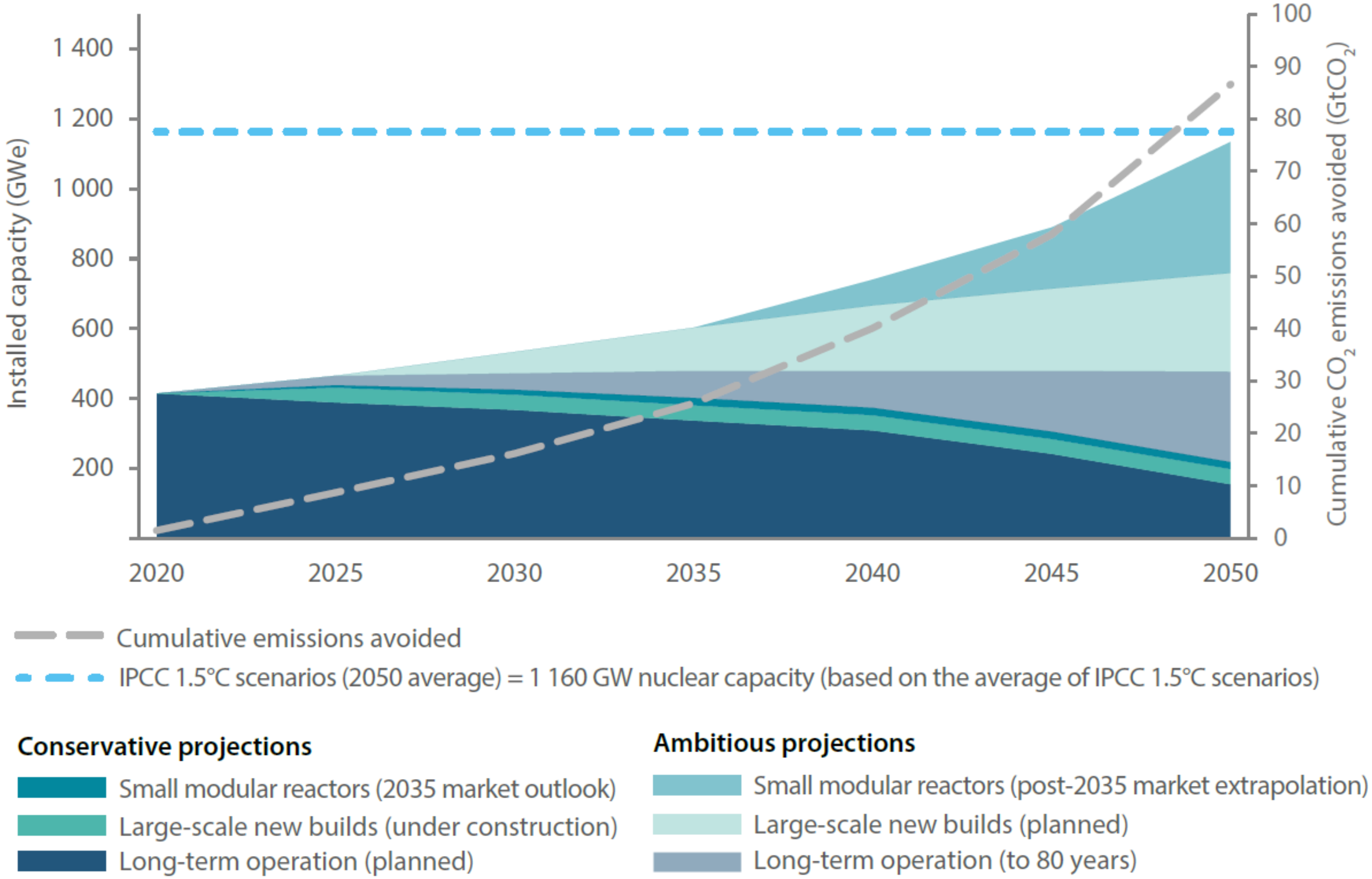
All Vendors are invited to engage with us

NEA.SMR.Dashboard@oecd-nea.org

Innovative Nuclear Technologies Can Play an Important Role in Enabling Net Zero

Reaching the target of 1160 gigawatts of global installed nuclear capacity by 2050 will require a **combination of long-term operation, gigawatt-scale Generation III, SMRs/Gen IV, and non-electric applications** such as nuclear-produced heat and hydrogen.

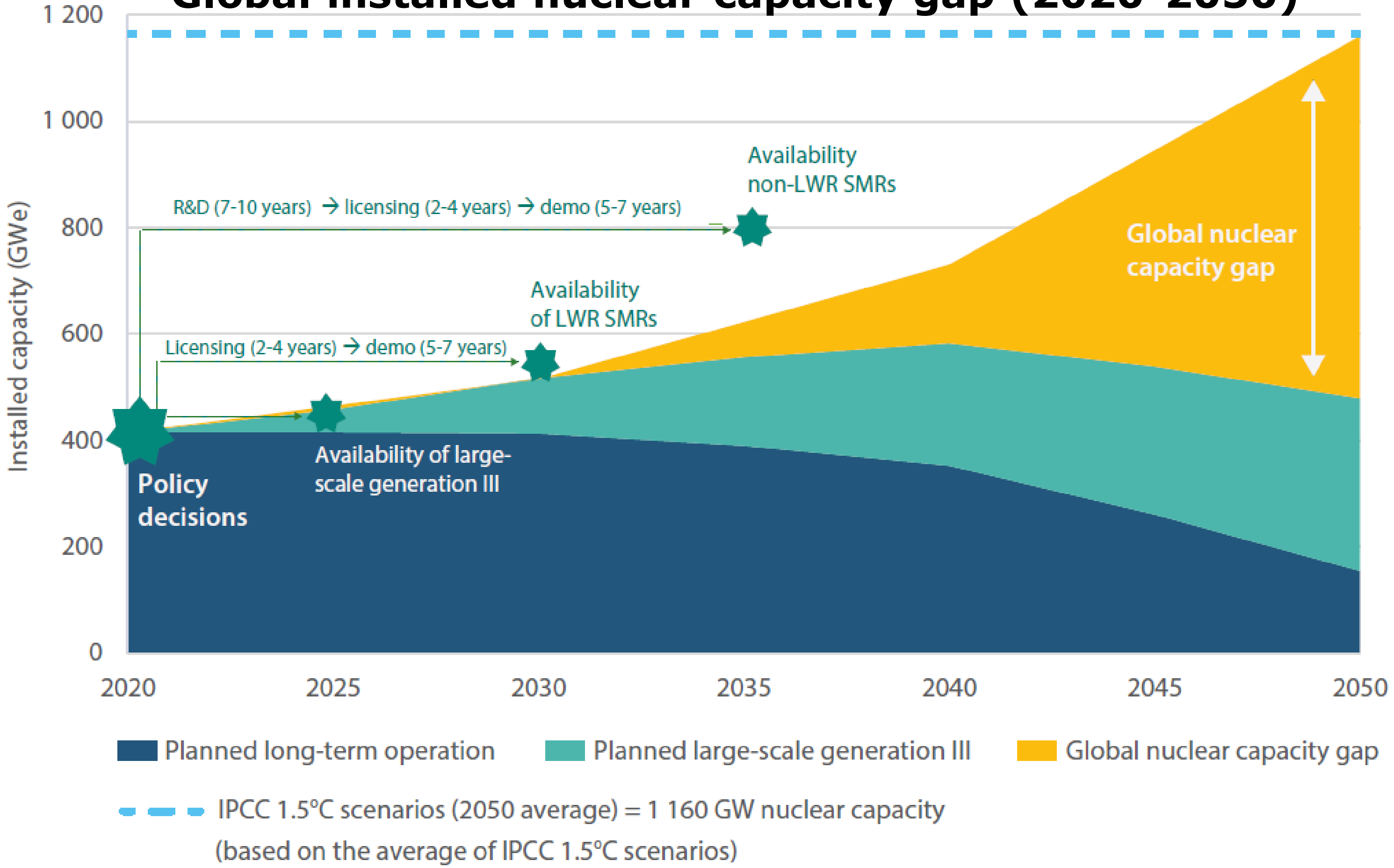
Full potential of nuclear contributions to Net Zero



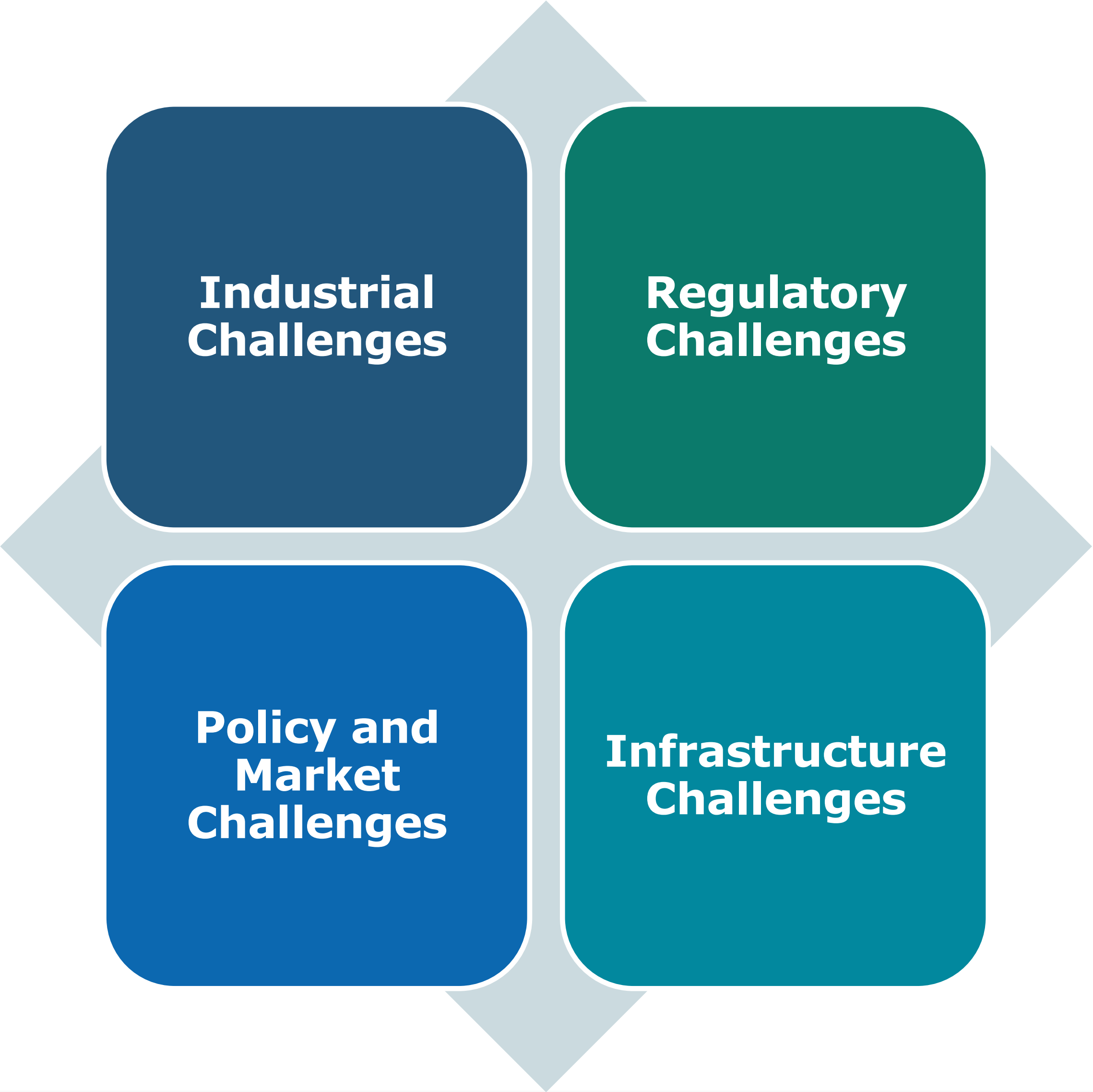
But We are Falling Short of Global Requirements

- 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**

Global installed nuclear capacity gap (2020-2050)



For New Nuclear Energy to be Successful, Key Challenges Must be Addressed



For New Nuclear Energy to be Successful, Key Challenges Must be Addressed

Industrial Challenges

- **Execution**—industry must take breakthrough technologies from the drawing board to commercial reality and deliver projects as promised
- **Operations Models**—industry must present realistic models to operate large numbers of SMRs and microreactors
- **Supply Chain**—past experience demonstrates that the global nuclear supply chain is neither broad nor deep and suppliers are not always as prepared as might be expected

For New Nuclear Energy to be Successful, Key Challenges Must be Addressed

Regulatory Challenges

- **Adaptation to New Technologies**—regulators must not view Gen IV technologies through a Gen II lens and must be prepared to address digital technologies
- **Global Thinking**—regulators must act nationally but think globally; otherwise there cannot be a true global market for new technologies
- **Accept New Paradigms**—new technologies may be game-changers in areas such as EP and security, but regulators must be truly risk-informed

For New Nuclear Energy to be Successful, Key Challenges Must be Addressed

Policy and Market Challenges

- **Outdated Electricity Markets—**today’s markets don’t support long-term environmental and energy security goals; dispatchability has value!
- **FOAK—**governments must put policies in place to address FOAK risks; industry cannot/will not absorb all the risks
- **Financing—**government policies are needed to support financing of new nuclear construction and other high-capital investments needed to reach Net-Zero

For New Nuclear Energy to be Successful, Key Challenges Must be Addressed

Infrastructure Challenges

– **HALEU—**the lack of a clear path to provide high assay LEU is already a barrier to new technologies

– **Codes and Standards—**industry, governments, regulators and other stakeholders must commit to strive toward simplified and harmonised nuclear standards

– **Human Resources—**more must be done to promote a new generation of nuclear experts while promoting greater diversity and gender balance

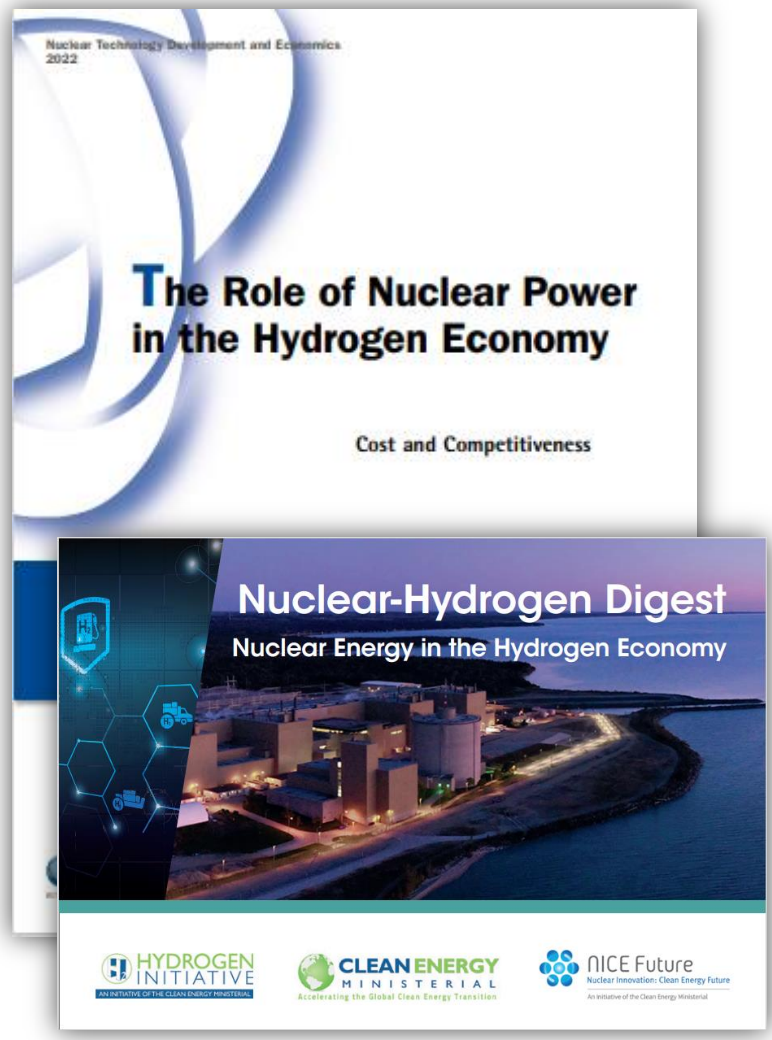
For Climate Action to be Successful, An Enhanced Vision of the Future is Needed

If action on climate is associated with limits to life, economic growth, and freedom, a successful energy transition will be difficult.

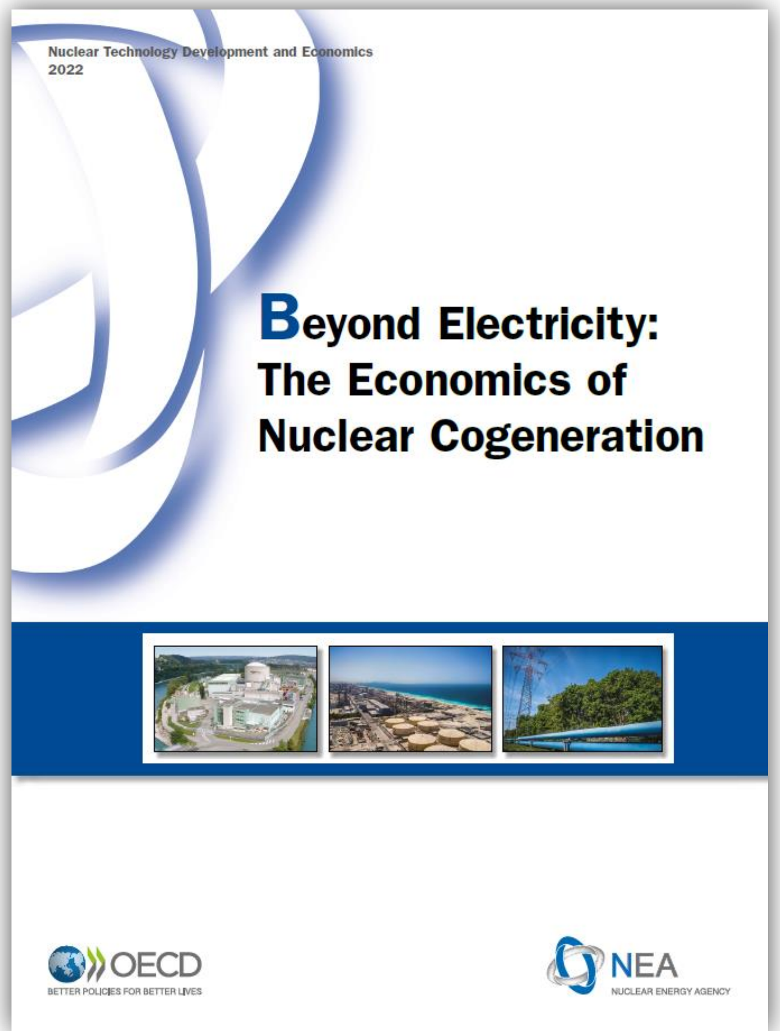
Innovative Nuclear Technologies Help Provide a Solution Set

Thank you for your attention!

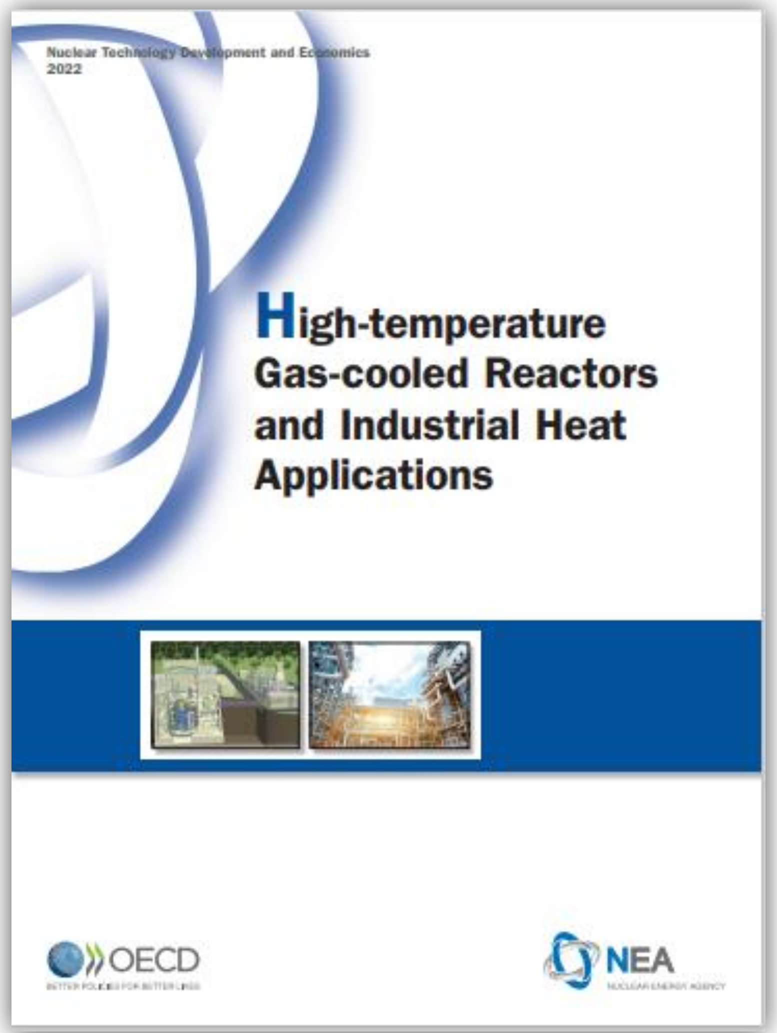
Learn more on: https://oecd-nea.org/



www.oecd-nea.org/nuclear-hydrogen



www.oecd-nea.org/cogen22



www.oecd-nea.org/htgr22