NEA
NUCLEAR ENERGY AGENCY

Scene-setting: Techno-economics of non-electric applications

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Outline

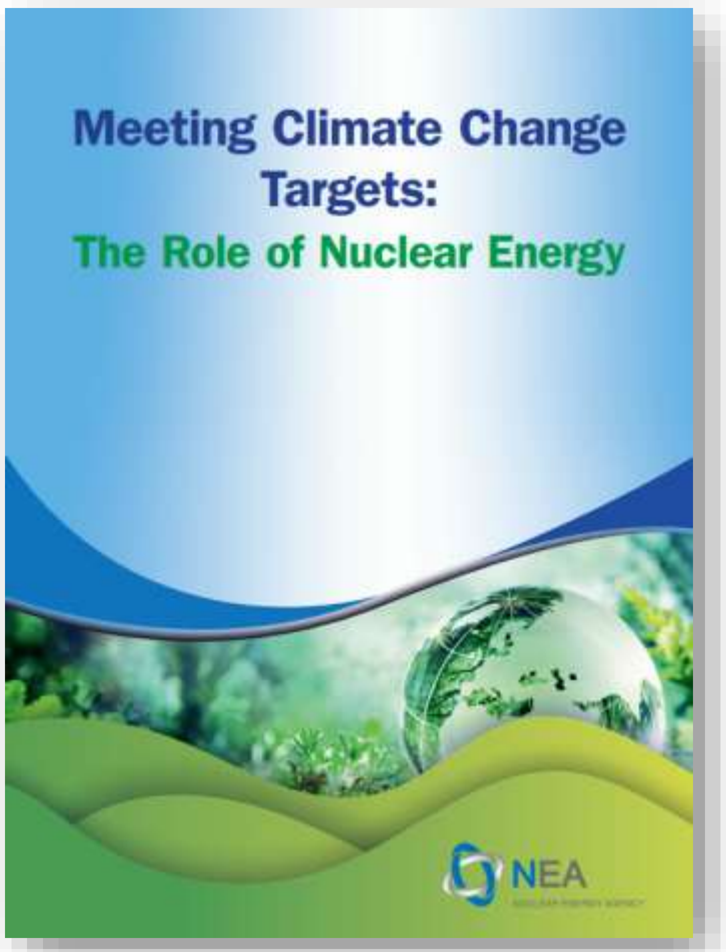
1. **Context: the role of non-electric applications in Net Wero**

2. **Techno-economics of non-electric applications:**
   - Existing experience in nuclear co-generation
   - Opportunities and challenges of nuclear heat for industrial applications
   - Competiveness of nuclear-based hydrogen with advanced nuclear

3. **Key conclusions and recommendations**

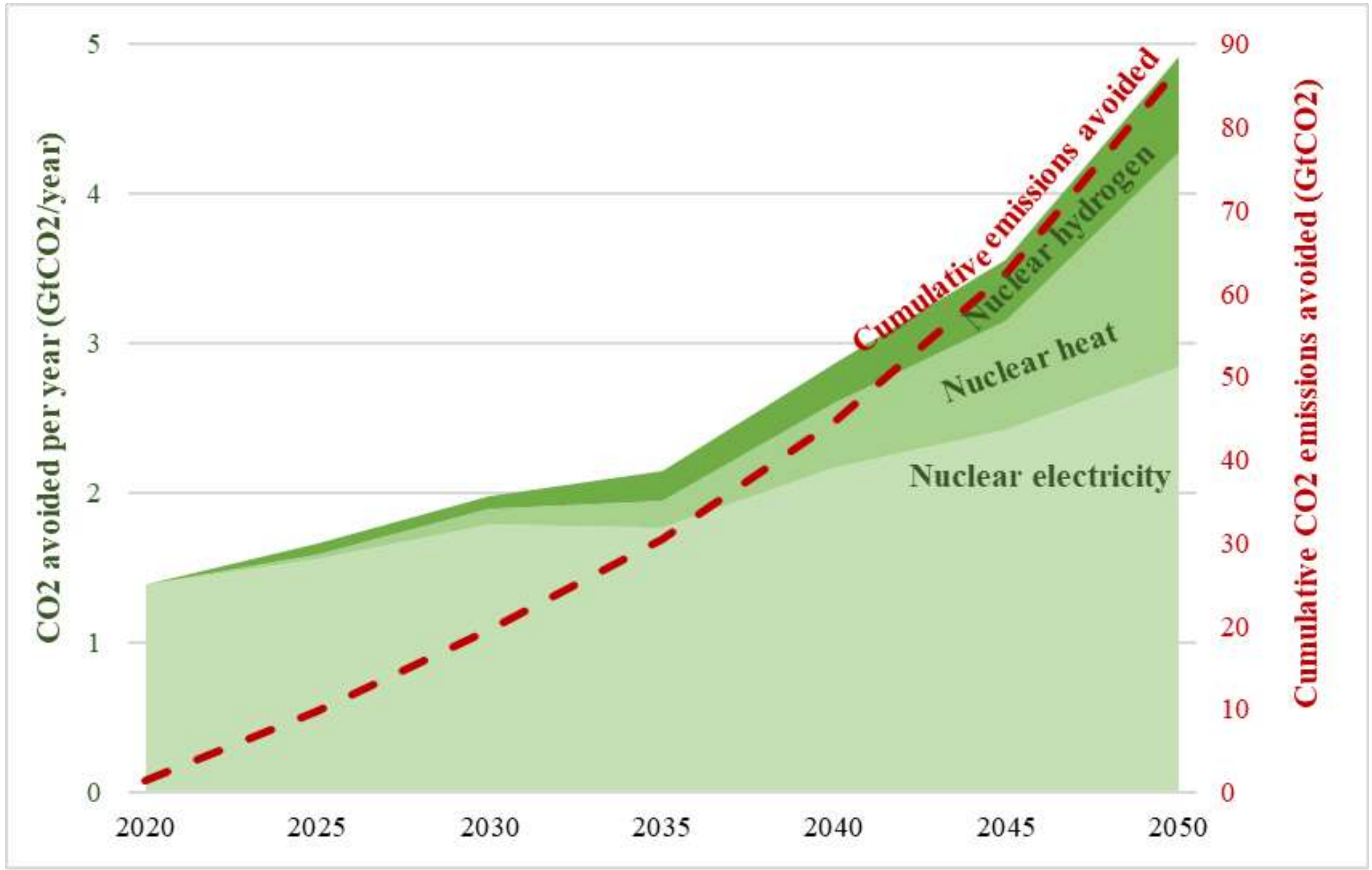
1. Context: The role of non-electric applications in Net Zero

Power and Non-power Applications of Nuclear Energy



https://www.oecd-nea.org/climate_change

Carbon emissions avoided by nuclear power and non-power applications



Source: NEA 2022.

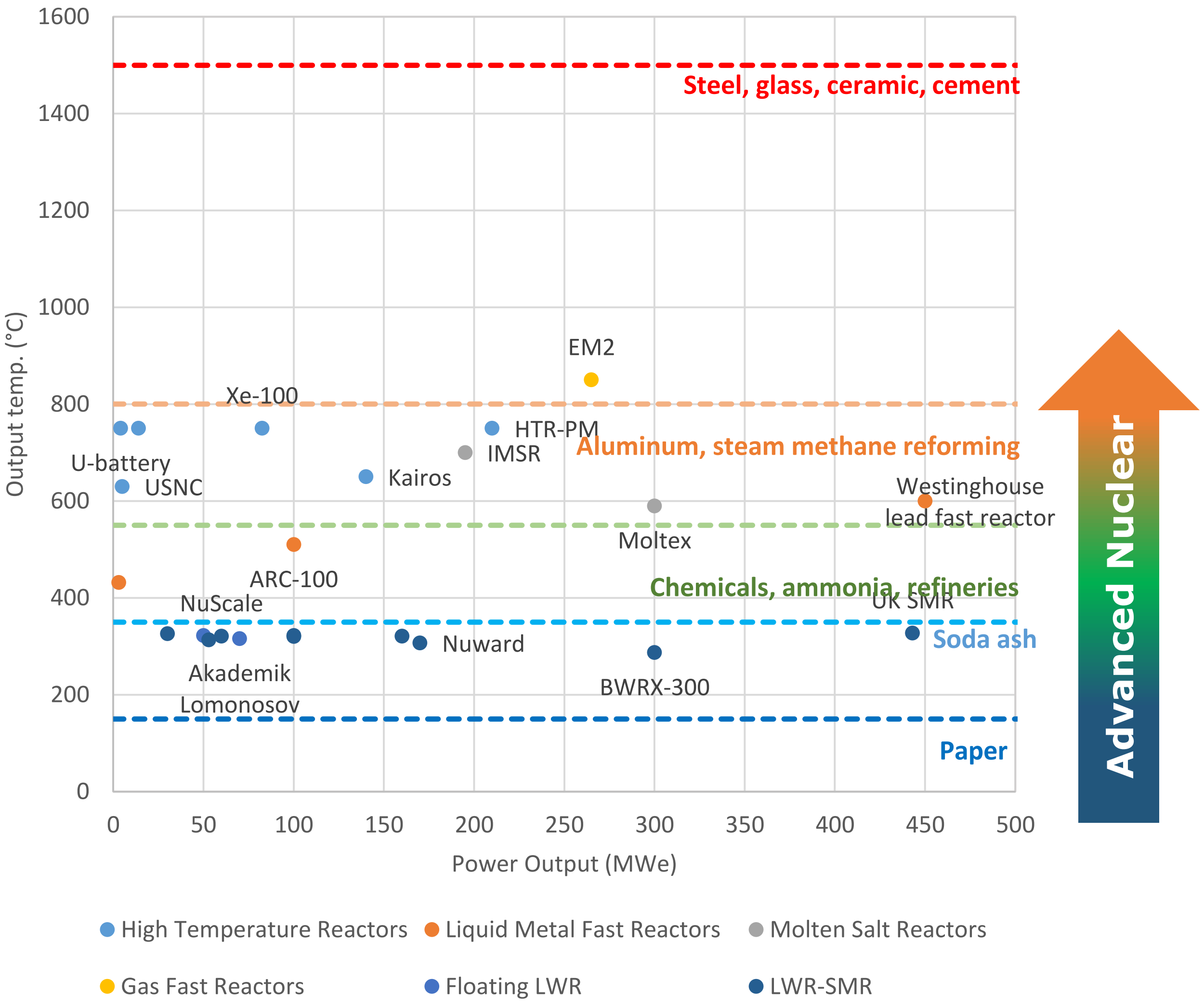
SMRs are expected in a range of sizes and temperatures

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 2022.

2. Techno-economics of non-electric applications

There is already experience in nuclear non-electric applications

- **67 reactors** were used at least partially for non-electric applications such as **district heating** and **water desalination**

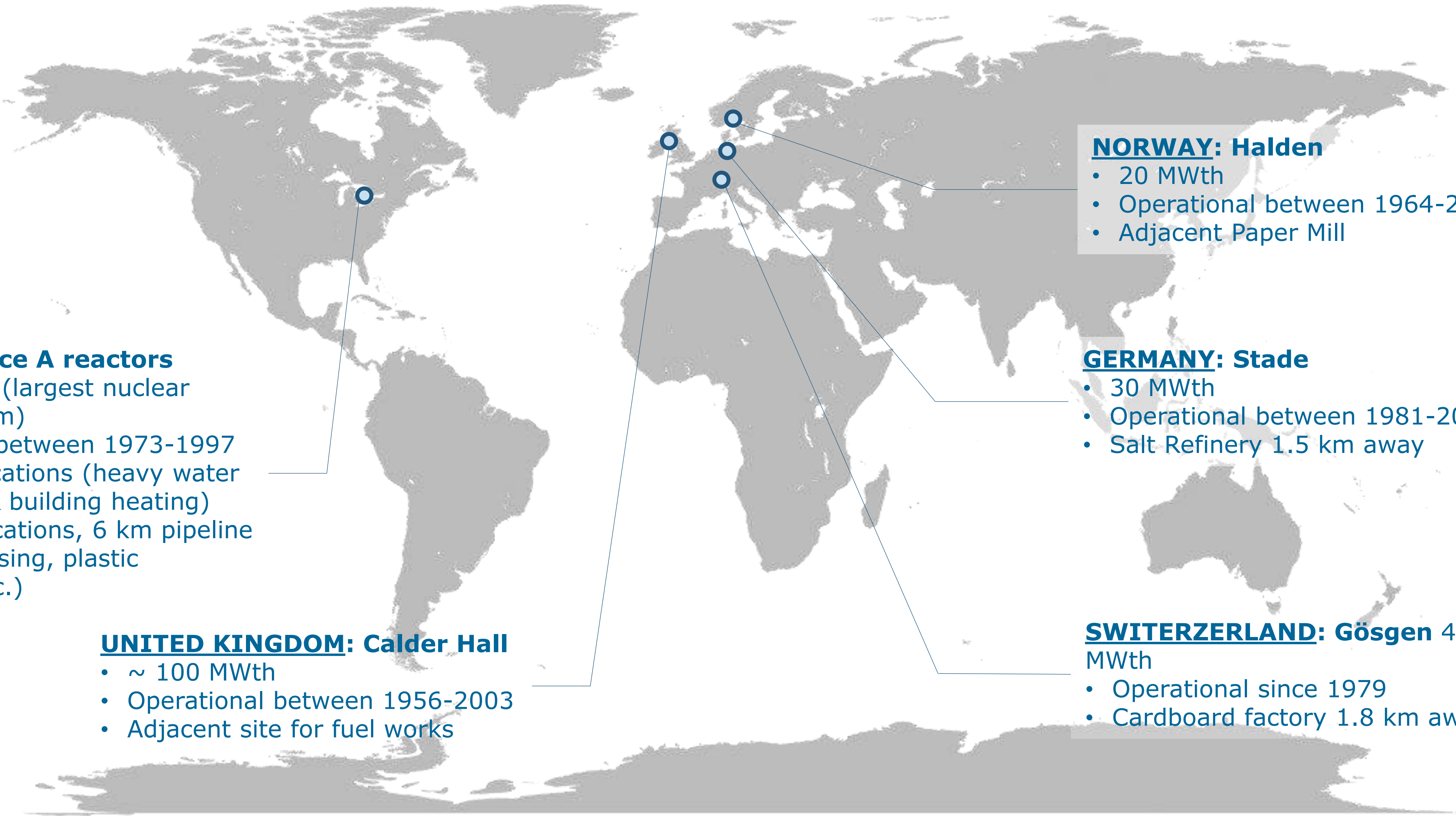
- This is equivalent to about **750 reactor-years** of experience

- Past experiences prove nuclear cogeneration feasibility, with **public acceptance** and **competitiveness as compared with other low-carbon options**

Beznau Nuclear Power Plant

The district heat extraction system was commissioned at the Beznau Nuclear Power Plant in 1984.
Today, the system consists of a 35 km of pipelines and provides 11 local municipalities with up to 150 GWh heat per year.

Beyond District Heating and Desalination, Nuclear Heat Can Also Be Used for Industrial Applications



CANADA: Bruce A reactors
- 5,350 MWth (largest nuclear steam system)
- Operational between 1973-1997
- Onsite applications (heavy water production & building heating)
- Offsite applications, 6 km pipeline (food processing, plastic products, etc.)

UNITED KINGDOM: Calder Hall
- ~ 100 MWth
- Operational between 1956-2003
- Adjacent site for fuel works

NORWAY: Halden
- 20 MWth
- Operational between 1964-2018
- Adjacent Paper Mill

GERMANY: Stade
- 30 MWth
- Operational between 1981-2003
- Salt Refinery 1.5 km away

SWITERZERLAND: Gösgen 45 MWth
- Operational since 1979
- Cardboard factory 1.8 km away

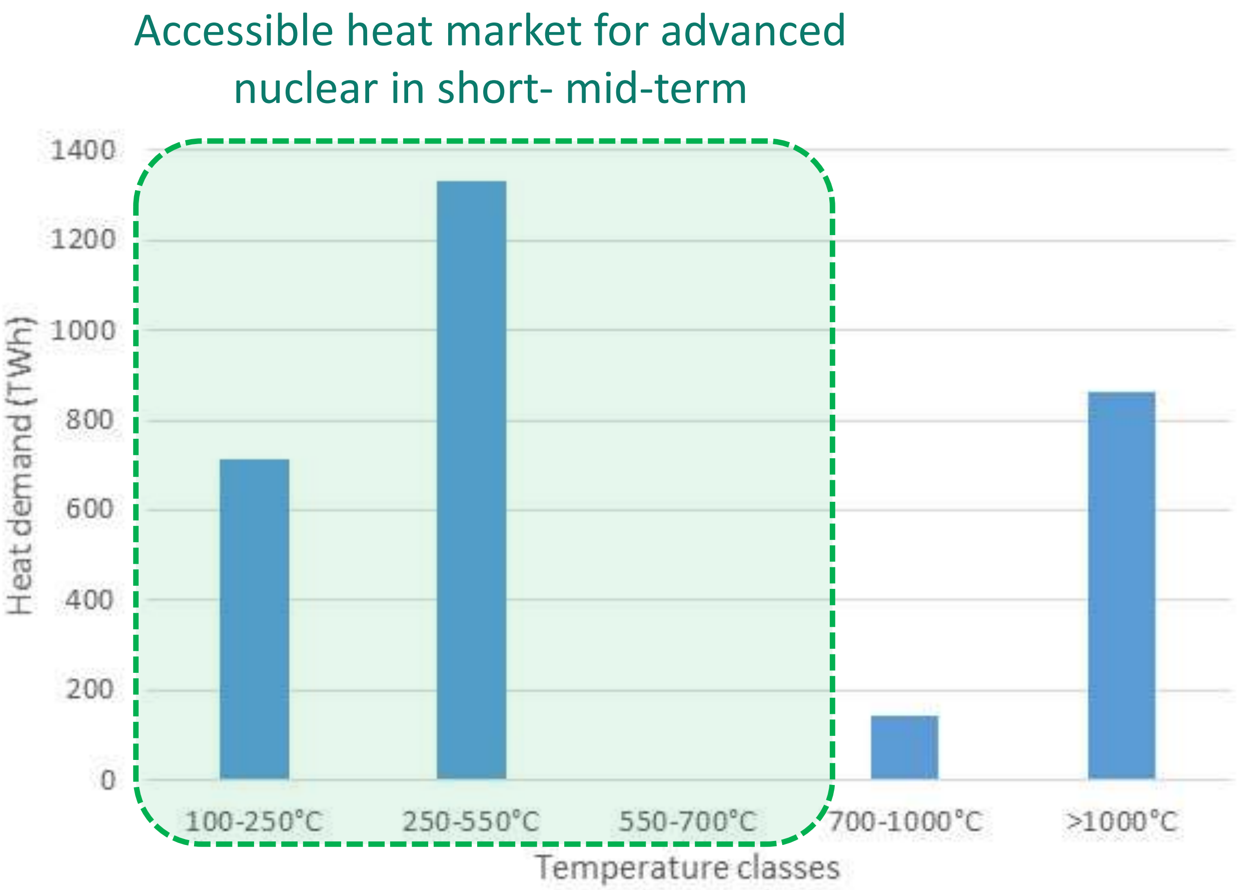
Despite attractive market prospects, the implementation of nuclear heat for industrial applications is not straightforward

- Technical **solutions to provide nuclear heat beyond up to 500°C already exists** (e.g high temperature reactors), and more could be demonstrated by 2035

- **Ensuring *<u>process compatibility</u>*** is key to access the full market

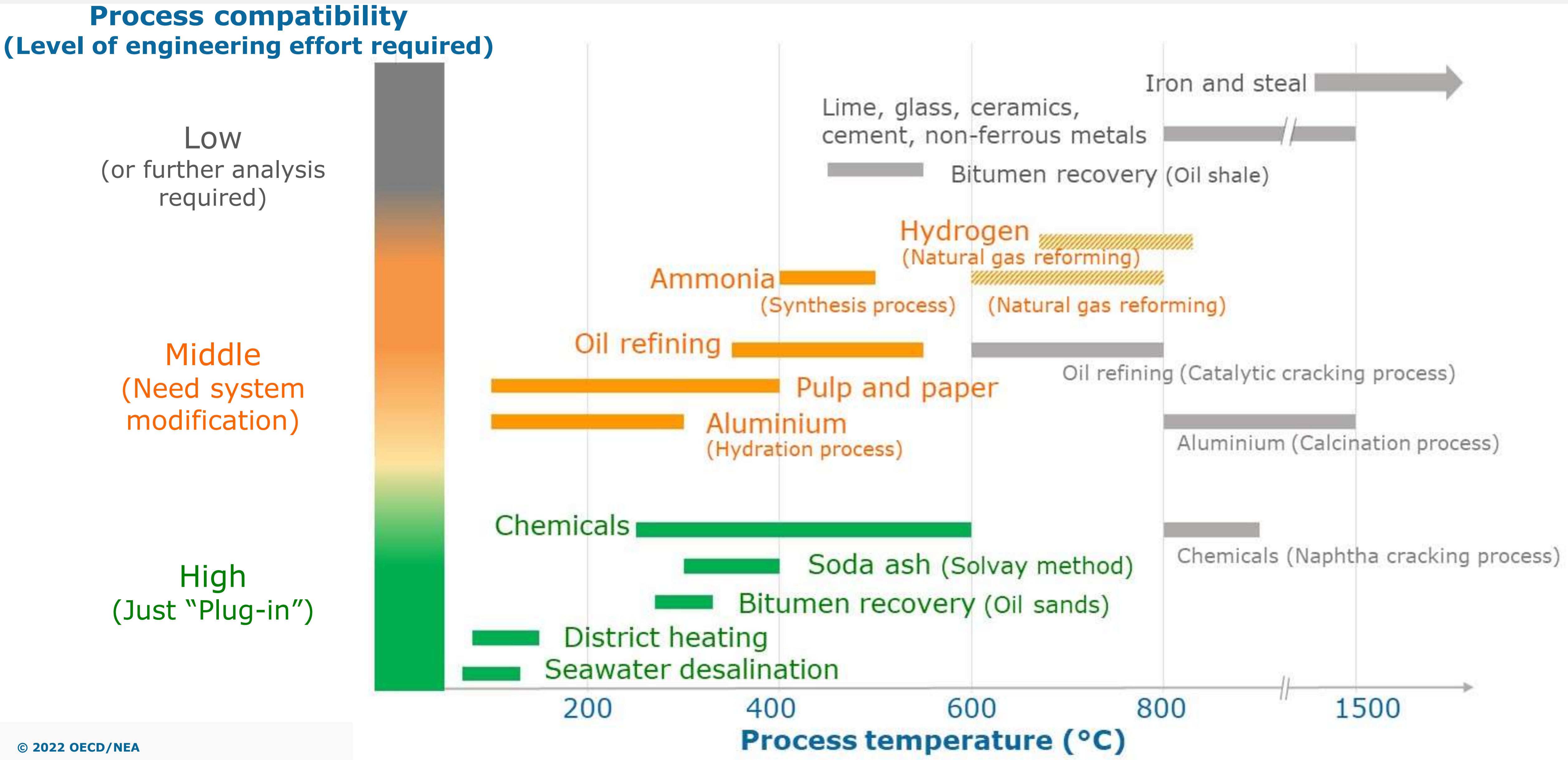
- Key challenges:
  - ***Safety and licensing*** *of coupling and collocation*
  - ***Cost and schedule*** *predictability*

Industrial heat demand by temperature in Europe

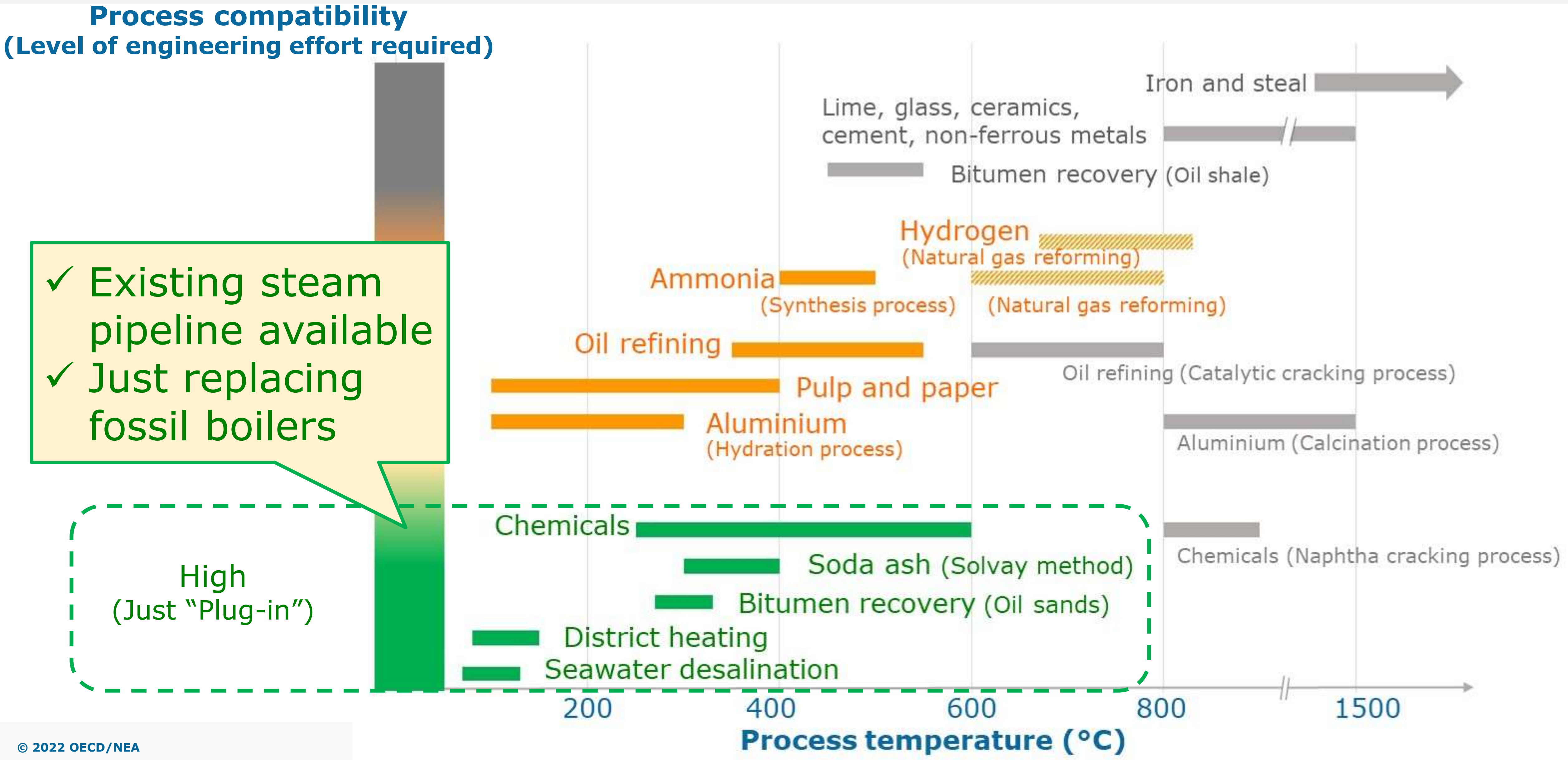


Source: NEA 2022.

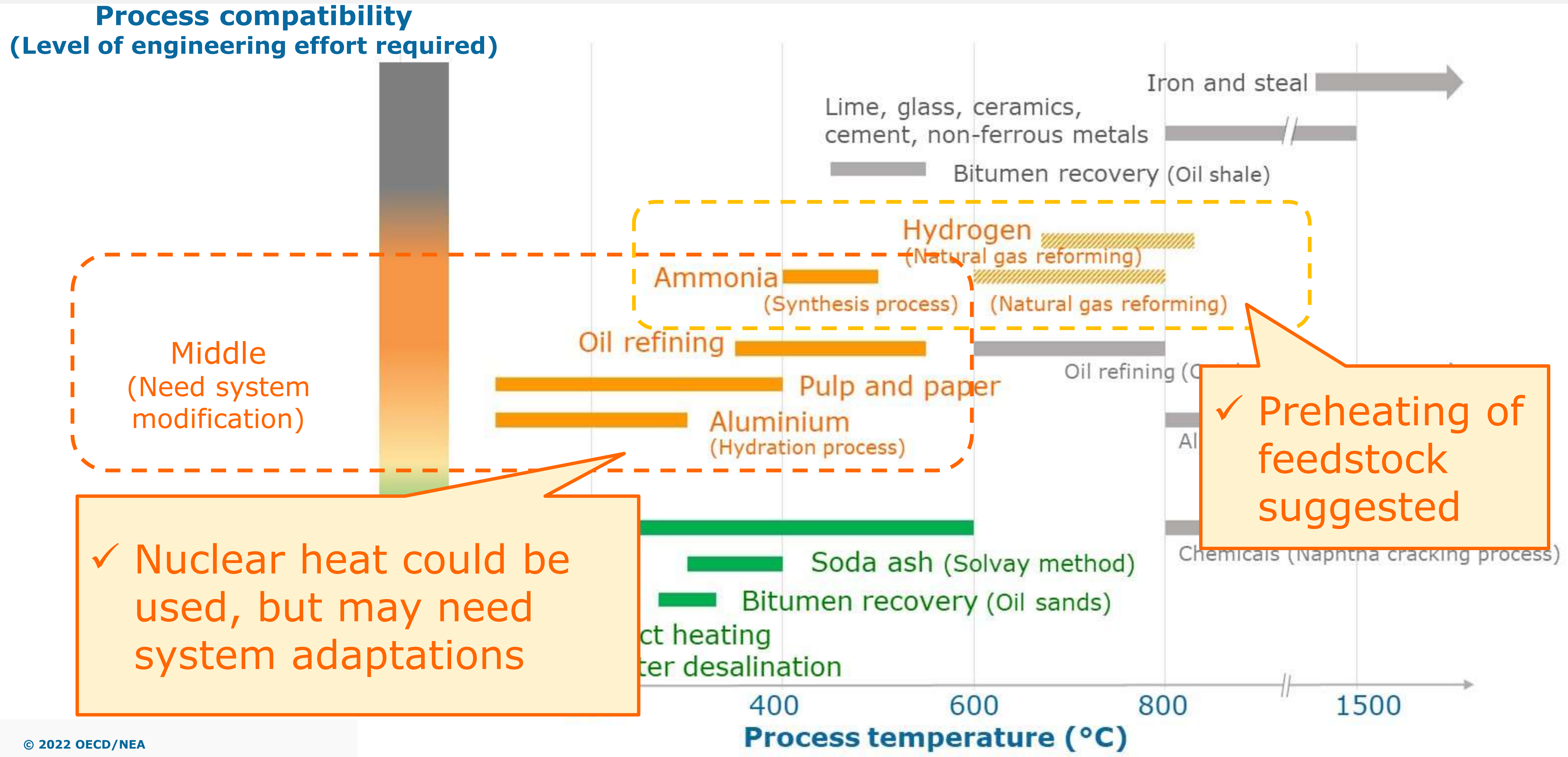
Breaking down process compatibility for nuclear heat applications



Breaking down process compatibility for nuclear heat applications

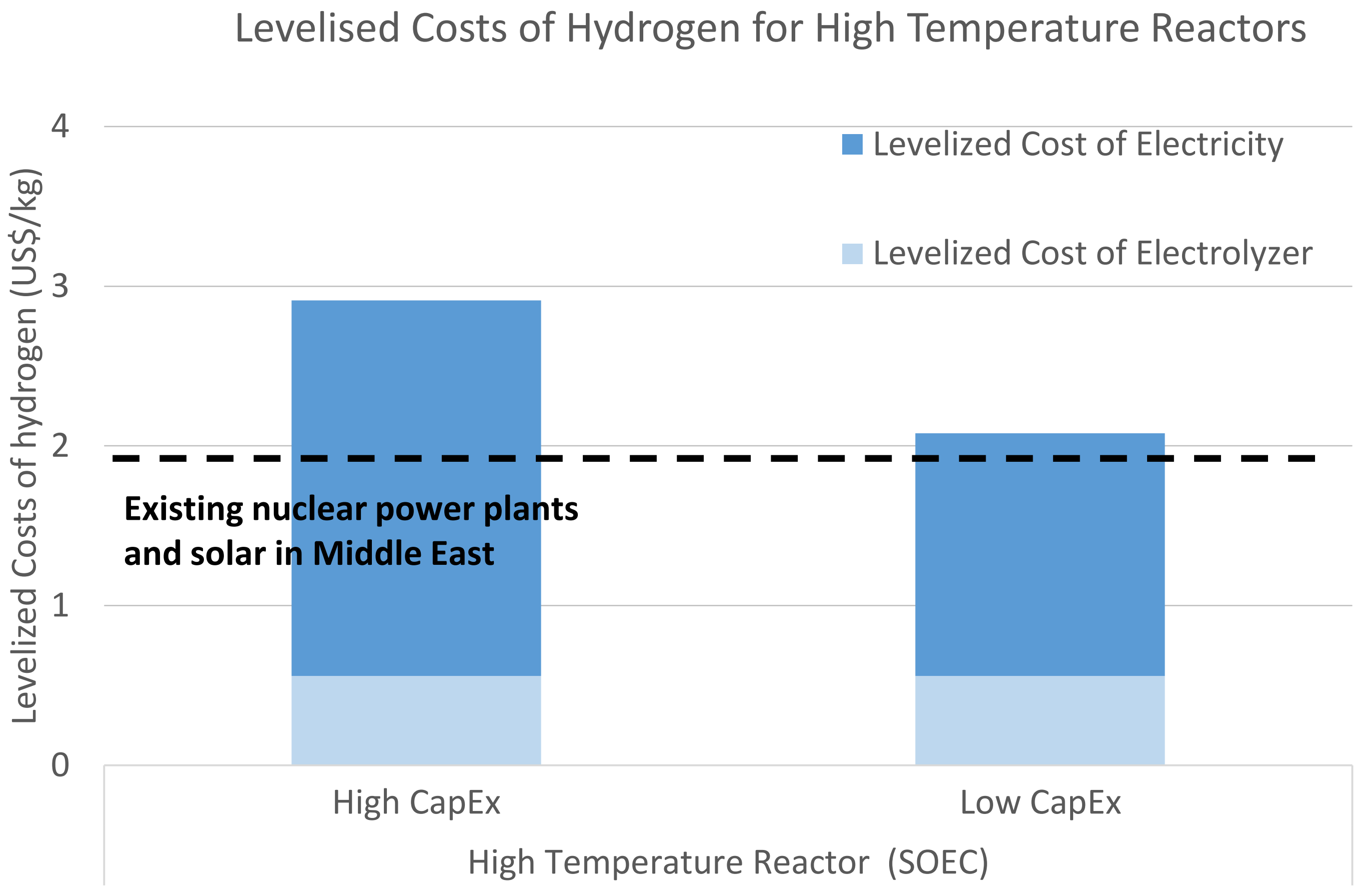


Breaking down process compatibility for nuclear heat applications



Advanced nuclear presents significant opportunities for low carbon hydrogen production at a competitive costs

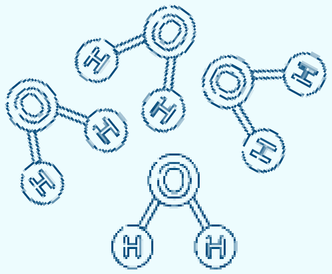
More efficient hydrogen production processes such as **High Temperature Electrolysis** would leverage low-carbon high heat produced from **High Temperature Reactors**. Although important uncertainties remain, **nuclear-hydrogen systems beyond low-temperature water electrolysis offer aspirational opportunities for large scale production of low-carbon hydrogen**.



Note: High CapEx = 4850 USD/kWe ; Low CapEx = 2000 USD/kWe. Hypotheses from IEA/NEA (2020), *Electricity Generation Costs* and Energy Innovation Reform Project (2017), *What Will Advanced Nuclear Power Plants Cost?* respectively.
Source: NEA, 2022

Production costs do not provide the full picture of nuclear-based hydrogen

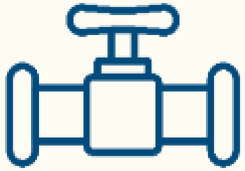
Plant-level Analysis



Hydrogen Production

The costs of hydrogen production cover the costs and load factor of the source of electricity, as well as the costs of electrolysers.

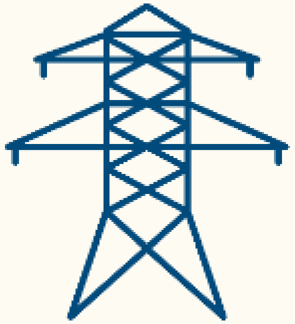
Value Chain Analysis



Hydrogen Delivery

The costs of hydrogen delivery take into account costs for hydrogen storage, transport and distribution. To ensure a cost-efficient infrastructure design, both the production and the consumption characteristics must be taken into account.

System-level Analysis



Hydrogen Integration

Meeting expected demand for hydrogen from electrolysis would lead to significant growth in electricity demand and require to carefully assess how hydrogen can be integrated at the system-level depending on the carbon constraint and the set of available sources of electricity.

Key conclusions and recommendations

Demonstration: supporting research and development and pilot projects involving industrial players and regulators is key to accelerate the expansion of non-electric applications of nuclear energy

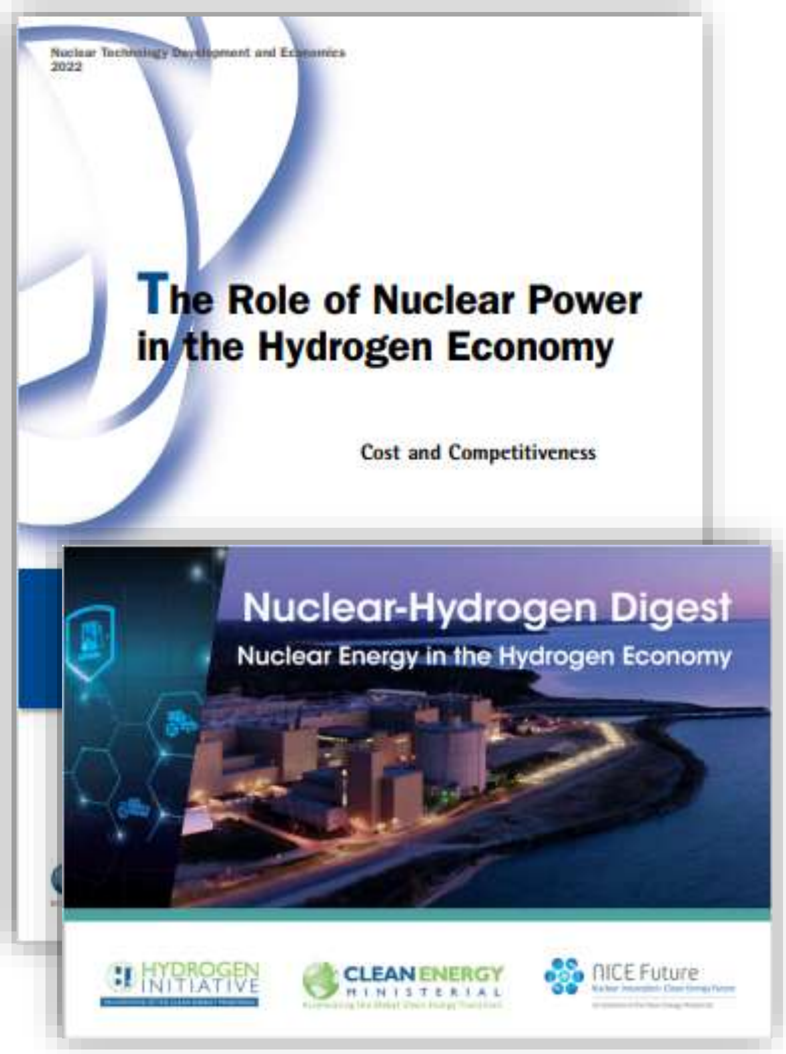
Competiveness: Non-electric applications are likely to develop further if nuclear-based options are more economical than the technical solutions they replace, essentially coal or gas-fired production of heat.

Holistic approach: To succeed, projects should adopt an holistic approach that takes into account end-user requirements as well as the entire value chain beyond the production site.

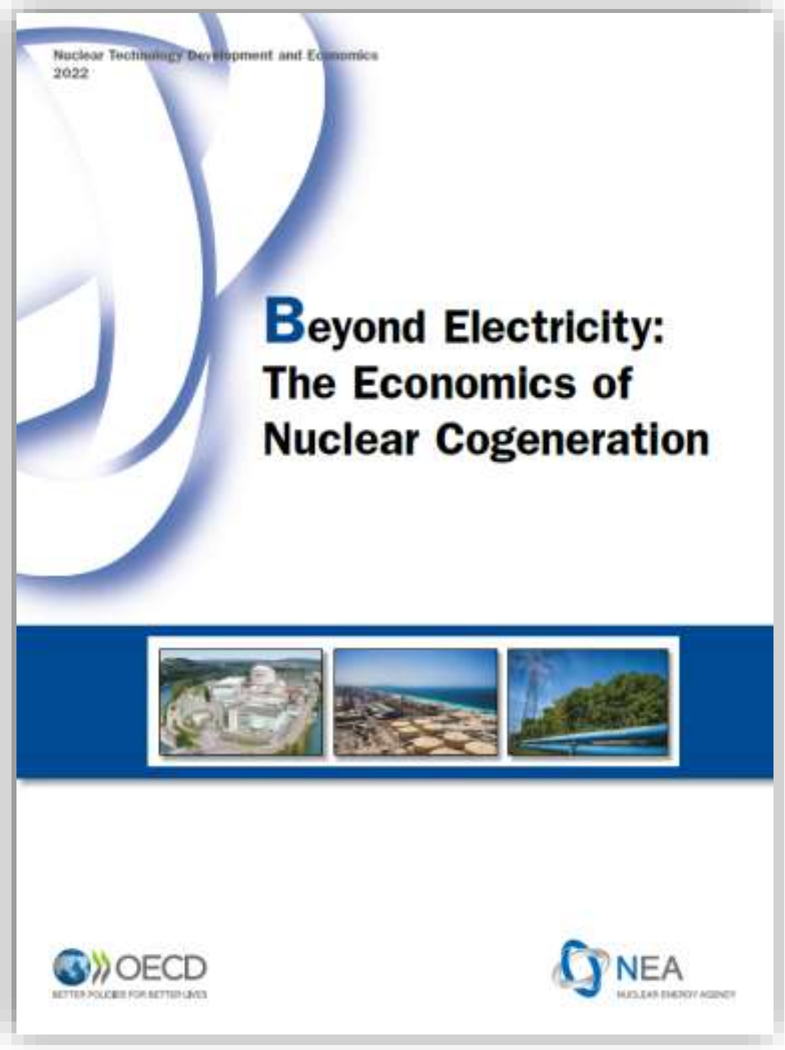
Enabling policy framework: Beyond predictable and technology-neutral polices, non-electric applications also require industrial plans that ensure capacity building and provide adequate economic incentives.

Thank you for your attention!

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



www.oecd-nea.org/nuclear-hydrogen



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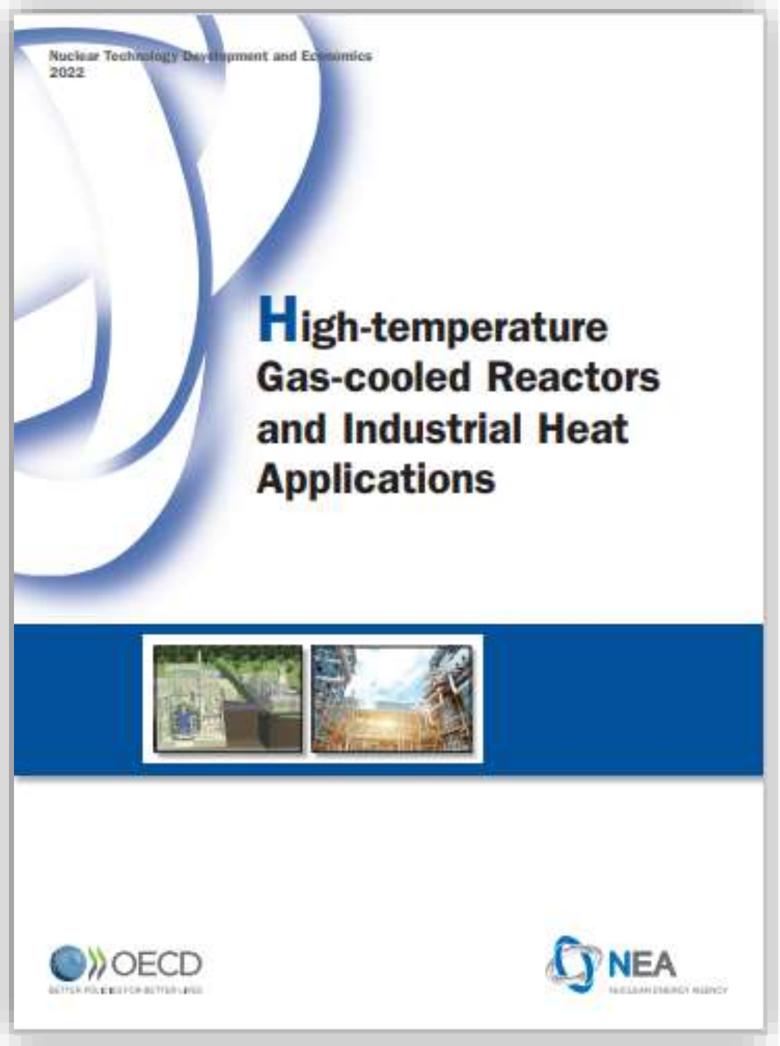


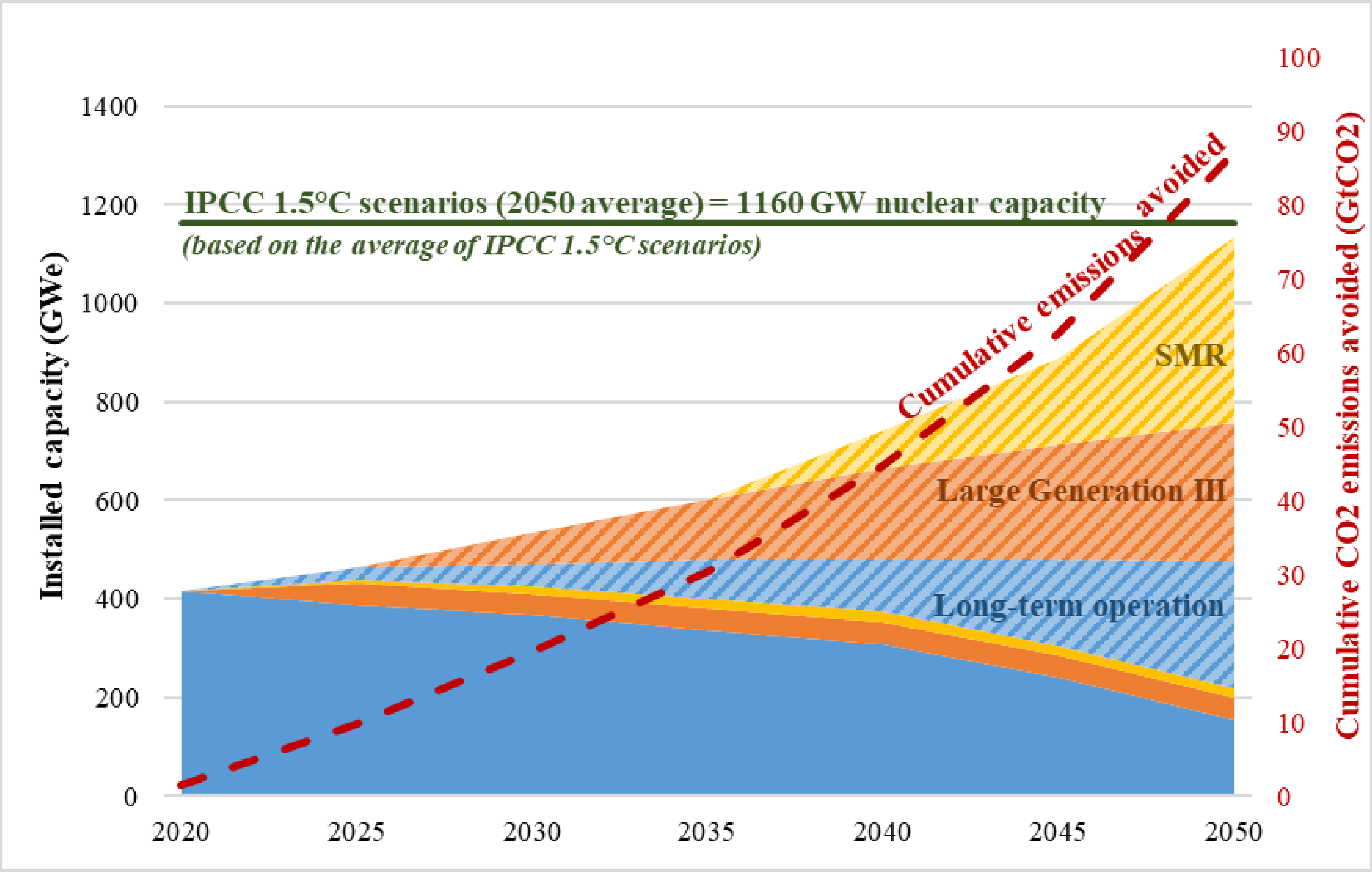
https://www.oecd-nea.org/jcms/htr2022

ANNEX SLIDES

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



Source: NEA 2022.