The competitiveness and necessity of SMRs
The diversified NextGen Nuclear Power

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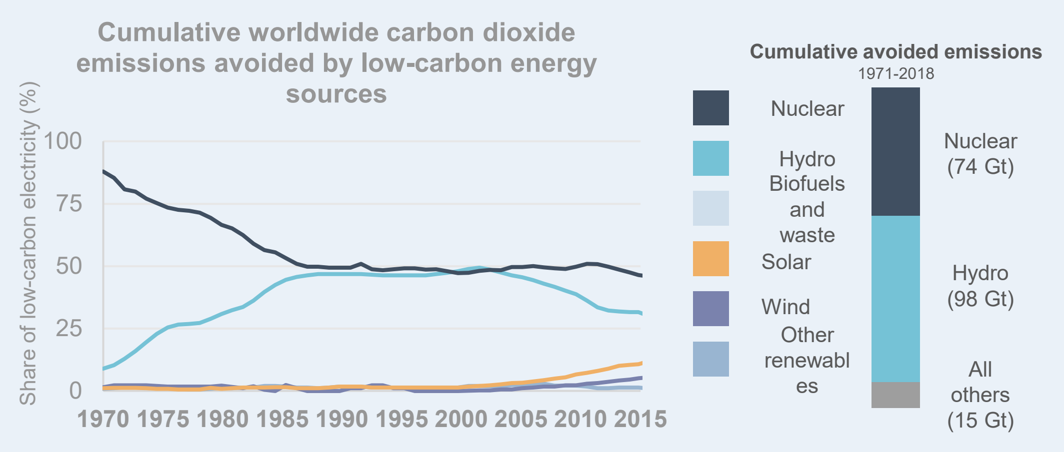
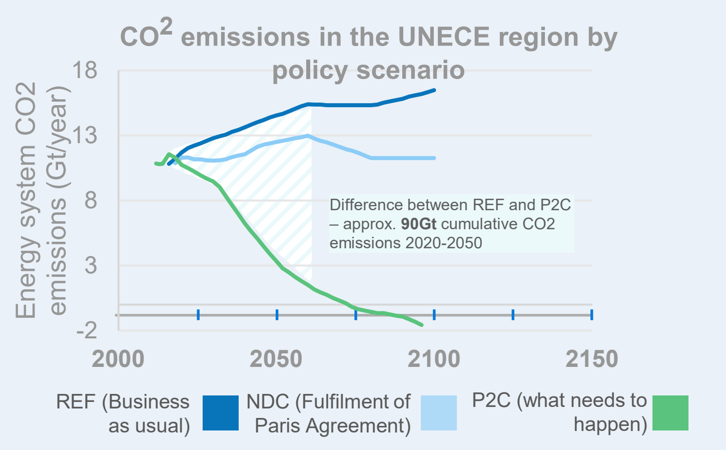
The world stands before a massive challenge. Decarbonization needs to happen fast, at scale.

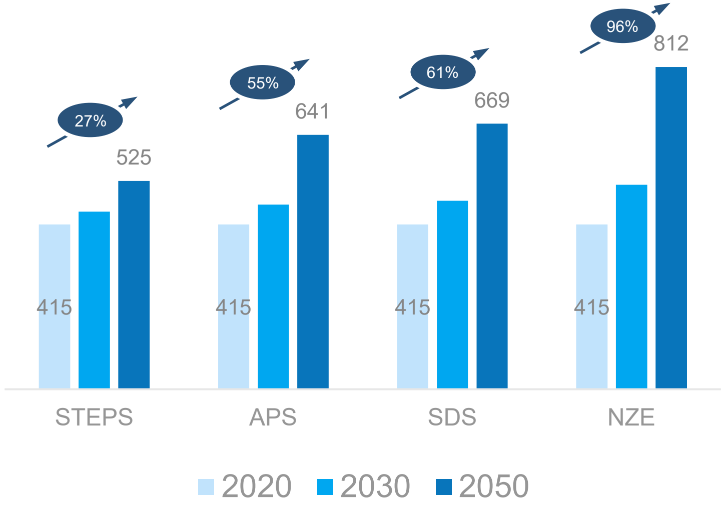




Source: UNECE, Climate Change and Nuclear Power (2020)

All IEA energy climate scenarios projects nuclear capacity growth will be needed by 2050

Ranging from 8–24% capacity increase by 2030, and 27-96% by 2050 depending on climate ambition achievement scenarios



STEPS

Assumes no additional policy implementation beyond existing policies and under development measures
→ **Capacity of nuclear almost stagnates, mainly growing solely in Asia**

APS

Assumes government climate commitments will be met and on time. Gap remains towards 2050 according to Paris agreement 2015.
→ **Capacity of nuclear increases by 12% and 55% respectively**

SDS

Represents a "well below 2 °C" pathway and a gateway to achieving the outcomes targeted by the Paris Agreement, and all energy related SDGs[1]. Adv. Economies reach net zero by '50, China in '60 → **quite positive scenario for nuclear power**

NZE

Presents the narrow yet achievable pathway towards net zero CO2 emissions by 2050. SDGs are also achieved, and global temperature rises to max 1.5°
→**extraordinary scenario for Nuclear power, which almost doubles**

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1. United Nations Sustainable Development Goals. Note: forecasted emissions in 2050 are 33,903 Mt CO2 (STEPS), 20,726 Mt CO2 (APS), 8,170 Mt CO2 (SDS) and 0 Mt CO2 (NZE)
Source: IEA World Energy Outlook 2021

Today, nuclear capacity is concentrated in the northern hemisphere, with a large share in the power generation

North America
CA, MX, US

# reactors	Share of power gen [1]	Capacity GW
114	13%	111

Europe
BE, BG, CZ, DE, FI, FR, HU, NL, RO, SL, SK, ES, SE, CH, UK

# reactors	Share of power gen [1]	Capacity GW
118	38%	110

Near & Russia
BY, RU, UKR

# reactors	Share of power gen [1]	Capacity GW
53	24%	42

Asia[4]
CN, JP, KR

# reactors	Share of power gen [1]	Capacity GW
110	13%	106

South America
AR, BR

# reactors	Share of power gen [1]	Capacity GW
5	5%	3.5

Africa[2]
SA

# reactors	Share of power gen [1]	Capacity GW
2	6%	1.8

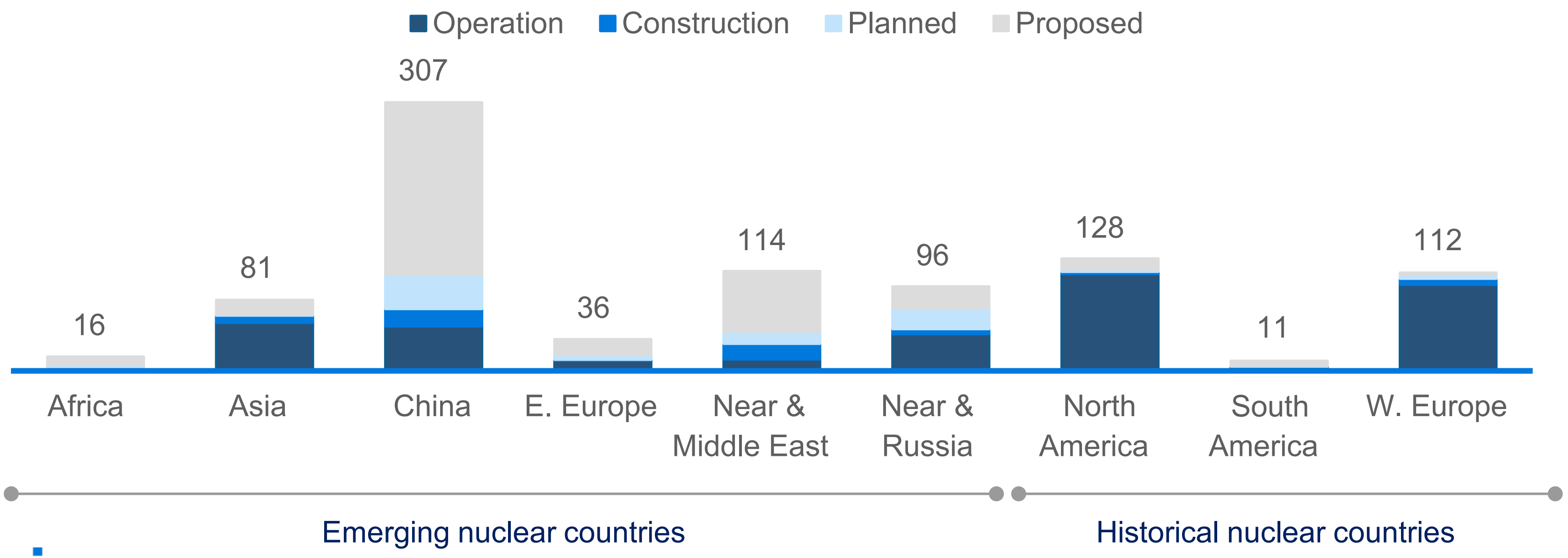
Near& Middle East[3]
ARM, IN, IR, PK, UAE

# reactors	Share of power gen [1]	Capacity GW
32	10%	13

Note that generation share dates from 2020, while number of reactors and GW installed are current values as of January 2022 due to data availability
1. Generation mix is calculated as pure average of the share of nuclear in generation mix in all countries 2. Egypt not yet included as no generation recorded in 2020 3) countries in this group that do not yet have operating capacity are BD; JO, KZ, KSA, TR, UZB 4) note that Japan has 33 operative reactors, of which only 8 are currently operating (restarted)
Source: WNA Jan 2022 for all figures

Growth mainly driven by emerging markets. The majority of the historical markets replacing a retiring fleet

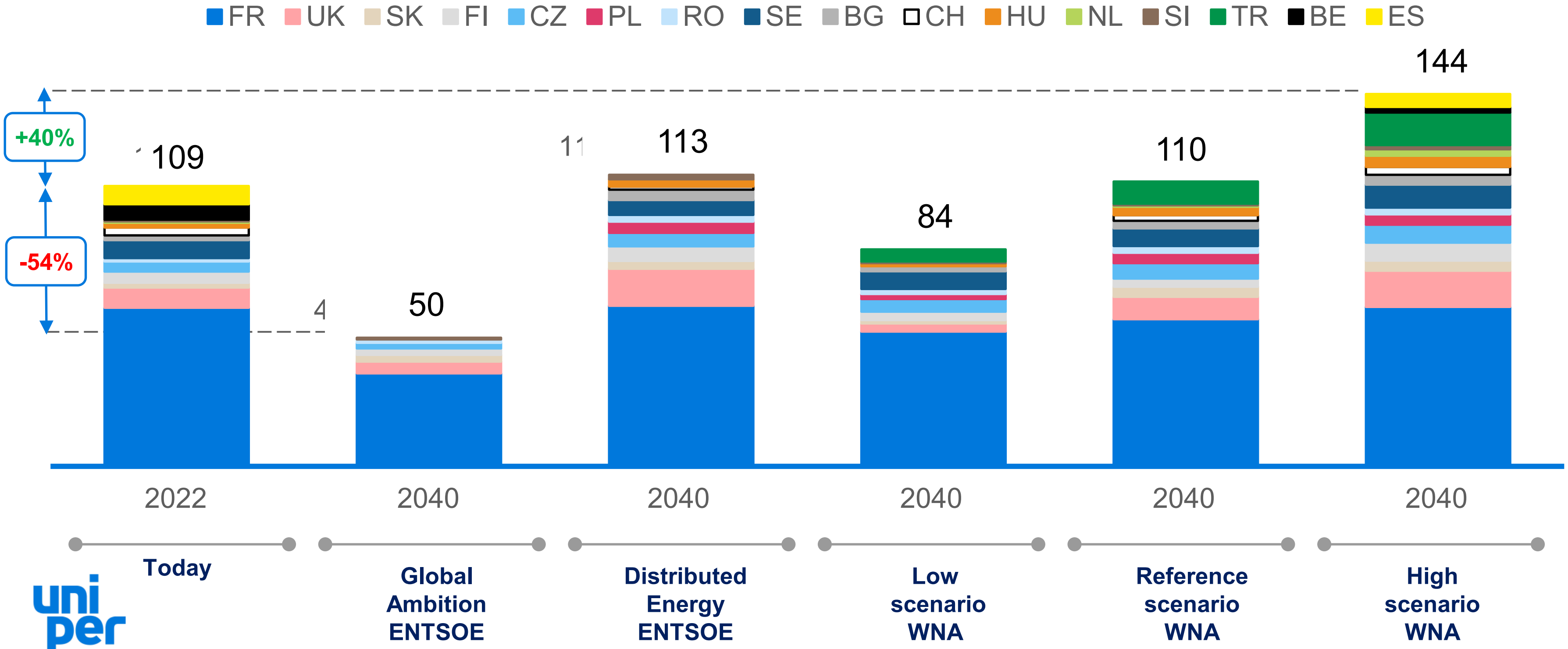
Global Nuclear capacity in GW



Note that non operative reactors are given in gross capacity, operative capacity is provided as net. Understanding capacity as power installed capacity
Source: WNA Jan 2022 for all figures

In Europe, Nuclear faces uncertain prospects, ranging from -54% to +40% of todays capacity by 2040

Nuclear capacity in Europe (Gwe)



Source: ENTSOE Ten-year network development plan TYNDP2020

Several factors are shaping this challenge - Is nuclear power a realistic solution for Europe's transition?

Reduce reliance on **RU gas**, while ensuring security of supply

European **Taxonomy** including Nuclear

Decarbonization and challenging volatile production

Industry electrification and **rising electricity demand**

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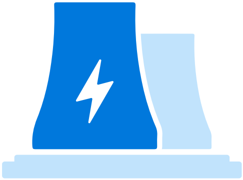
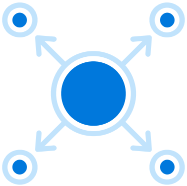
In a rapidly changing energy system with intermittent power production, nuclear power offers a good balance

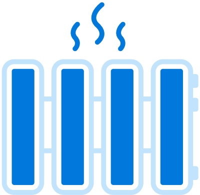
Nuclear power characteristics can complement the energy system, when moving towards an increased penetration of intermittent renewable power generation



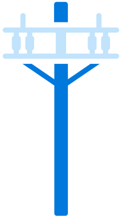
Baseload capacity



Decentralization



Cogeneration



Grid stabilization

1) Some SMR designs can be coupled with energy storage systems

Nuclear power technology can briefly be divided in reactor technology, and design & production

1 Innovation in reactor' technology

Conventional (Gen III+)

Advanced (Gen IV)

Maturity

Conventional (Gen III+):

- Traditional water reactor
- **Experience** licensing & logistics
- **Lower** T° process heat

Advanced (Gen IV):

- Liquid metals, molten salts or gas
- **Inexperienced** licensing & logistics
- **High** T° process heat

2 Innovation in design & production

SMALL

Lower complexity

2-300 Mwe *(vs 1200GW)*

MODULAR

Series-production

(standardization)

On-site assembling

SMALL:

- Reduced complexity
- Faster deployment (1.5-4yr)

MODULAR:

- Flexibility for the end user (matching demand w/ capacity)
- Lower fabrication/ construction costs

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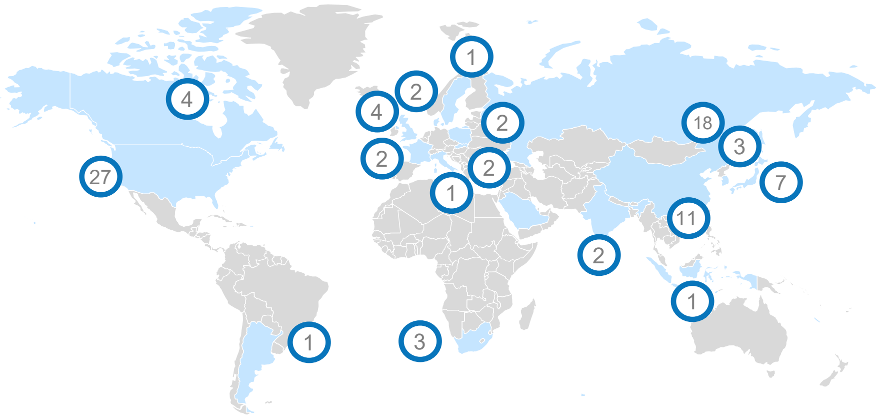
Sources: World Nuclear Association website. IHS Markit Global Clean Energy "SMR An opening window of opportunity" (2021). IAEA SMR Book 2020. Lux Research Platform

Innovation is thriving with +90 SMR projects globally

Project status

Status	#
Early development	56
Advanced development	20
Construction	3
Test facility ,operating	2
Operating	6

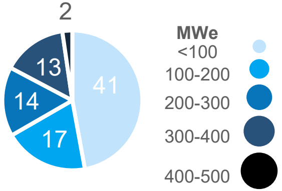
Geographical spread



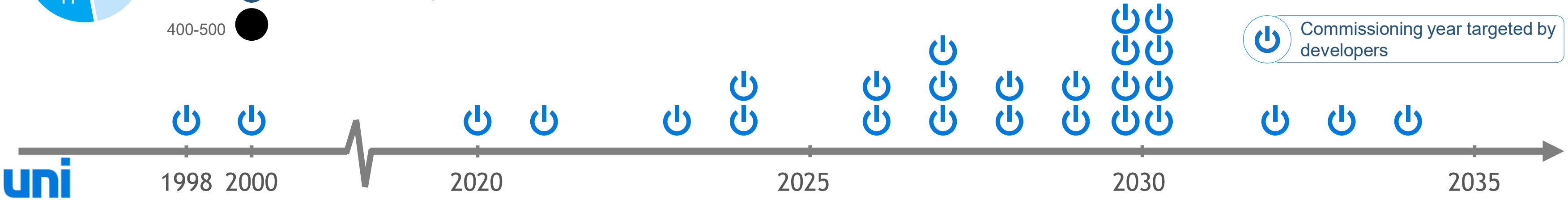
Technologies

#	Technologies
28	Water cooled
16	High temperature gas cooled
16	Fast neutron reactor
13	Molten salt reactor
8	Micro sized
7	Water cooled (marine)
3	Water cooled (heavy)

Size



Ambitious planned project timeline



Source: IHS Markit Global Clean Energy. Technology, data collected November 2021

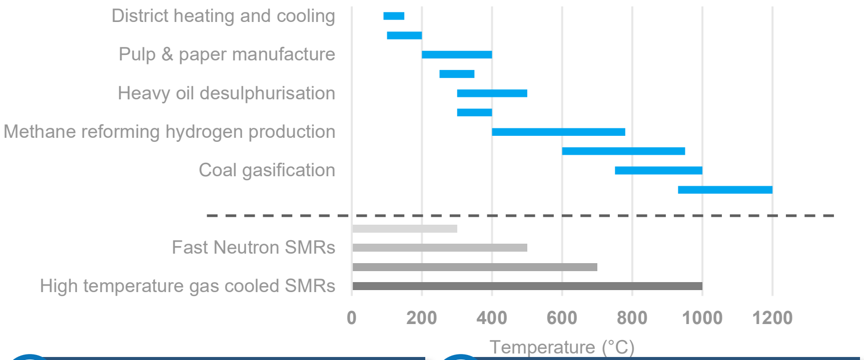
SMR can be applicable for a range of energy applications beyond power generation

Additional application areas

Market overview

- There are a multitude of additional services and products that can be created through SMR
- Dependent on the reactor type, nuclear reactors can be used to produce heat to certain temperatures enabling a multitude of different services
- For multi-unit SMRs, the ability to add modules incrementally could also allow investors to adjust to changes in electricity demand and cash flow/financing availability, thus improving the management of financial risks.

Applications areas (10) and Reactor types (4) temperature



Industry Coupling

Placing energy production nearby large consumers *could be the future when it comes to large facilities being commissioned for both Industry feedstock (chemical industry) and energetic (low/medium/high-grade industry heat).*

District Heating

A small nuclear reactor that makes low-grade heat can be a very simple design. *For example, such reactor could sit at the bottom of a “swimming pool” and just heat the water that is then used for district heating. Because no electricity is produced, it doesn’t need pressure vessels, steam generators or turbines.*

Hydrogen

High temperature gas cooled SMRs could be especially prominent for hydrogen production *by producing steam for more efficient electrolysis*

SMR-based hydrogen and heat could be used for instance in petroleum refinery on-site. Light-water reactor with topping heat or higher temperature reactor would be suitable.

Adjacent use cases

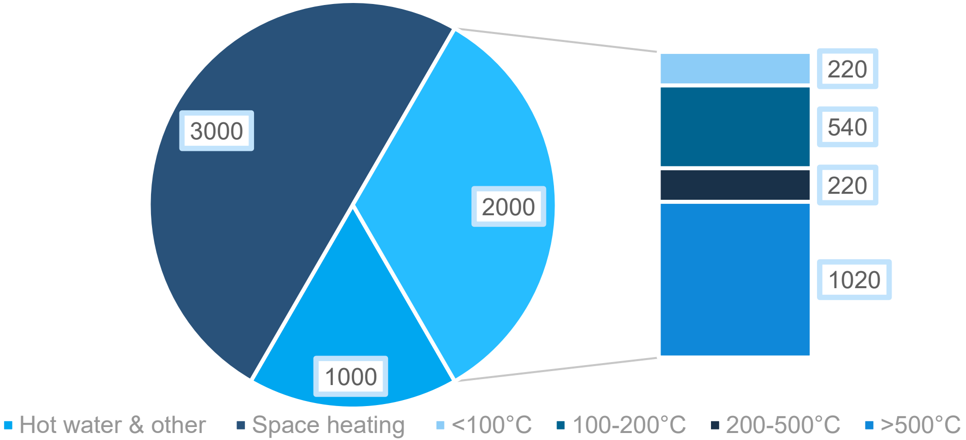
Adjacent use cases include for example ***direct air capture and petroleum refinery****. DAC is an emerging carbon capture method, but combining it with SMR is still expensive and unproven solution.*

Source: Source: Energiforsk, Nature Communications

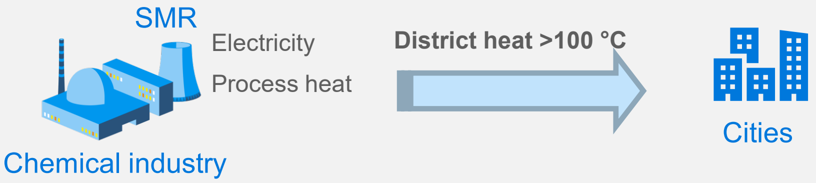
District heating use large parts of energy consumption SMRs could be a key source for rapid decarbonization

- Nuclear reactors have traditionally been used for electricity production, but **modular applications might make it more possible for heat production**
- Large, conventional nuclear power plants are built to produce 3-4 GW of heat whereas **heating networks, for example in Finland, fit around 200-400 MW of heat supply from a single plant**
- SMRs would therefore be a **perfect size-fit especially for smaller grids**. Small size could also allow new economic- and safety approaches as **plants could be built closer to cities and heating networks**
- SMRs have **smaller reactor cores than conventional reactors** and many other safety features which minimizes the exclusion zone which in turn enables reactor placement closer to cities using district heating
- District heating is especially lucrative option for the **Nordic countries** with district heating network, but also **many Eastern European countries** are looking to replace fossil-based heating systems. SMR opportunities for CHPs have also been noted in the UK

European Heat Demand by End-Use (Terawatt Hours per Year)



SMRs can provide heat both for the industry and residential buildings. Simultaneously it can be located close to end-use

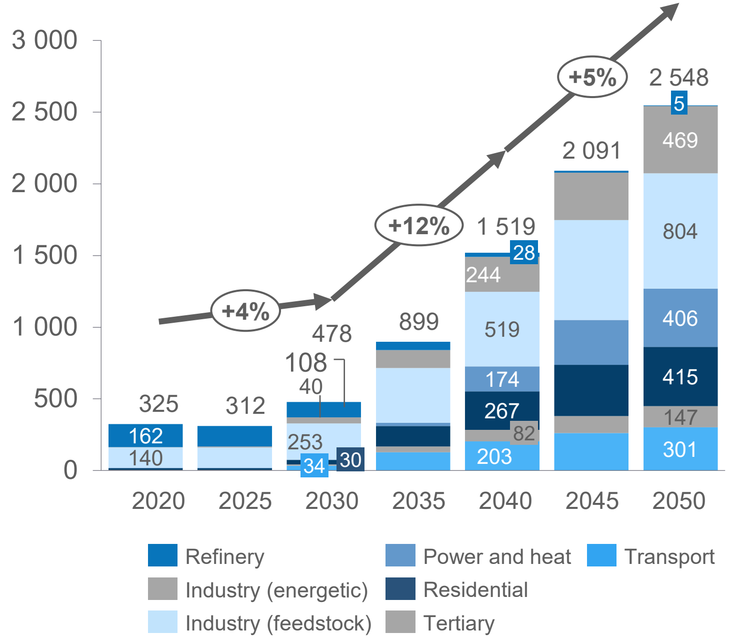


Source: Lux Research: The Future Role of Nuclear Energy (2020), Energiforsk: Small Nuclear Reactors and Where to Use Them, VTT: District heat with Small Modular Reactors (2017), Fortum analysis

Fossil free hydrogen produced through nuclear/SMR would support the strong increase in hydrogen demand

- Hydrogen is currently one of the **most prominent application cases for small nuclear reactors.** SMRs could offer flexible and dispatchable option for hydrogen production and support production from wind and solar
- **If the LCOE of SMRs can drop $65/MWh, it could already be competitive against renewables in hydrogen production**.
- Hydrogen can be produced **using high-temperature steam electrolysis.** High temperature gas cooled SMRs could be especially promising for hydrogen production by producing steam for more efficient electrolysis
- Hydrogen can also be **combined with CO and CO_2 to create synthetic fuels** (e.g. methanol). These chemicals are energy dense, easy to store and transport
- H2 probably a niche in **transport** (fuel cell for heavy duty trucks), but **H2-based production of synthetic fuels** for maritime and aviation will drive demand
- The **hydrogen demand in heating** both residential and industrial uses will increase driven by oil and gas phase-outs
- In the future decades, SMRs could be one of the best-value sources for hydrogen production, but **in the short term nuclear based hydrogen production should be accompanied with electricity production to be economical**
- Hydrogen can be produced during **low electricity demand or when renewables energy load is high**

Hydrogen Demand by Sector EU27+UK+NO+CH (TWh)



Existing nuclear power is the cheapest and fastest way to build up hydrogen production at scale

Source: Wood Mackenzie (2021), Recharge (2021), Uniper analysis, Reuters: Next Generation Nuclear (2022)

The cost of developing SMR's heavily dependent on the license processes – which varies between countries

Cost of SMR development

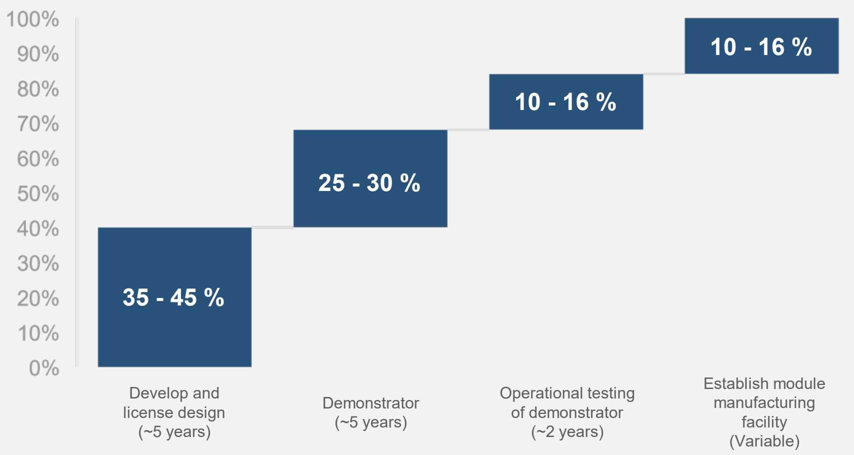
Develop and license design
The large part of the cost for developing a new SMR reactor lies in designing the reactor and getting it licensed by relevant regulators. Especially the cost of licensing the design can vary between countries/design and can be hard to estimate.

Demonstrator
The second largest part of the cost is to build a demonstrator reactor to prove the net production and technology of the reactor, before building a commercial version of the reactor

Operational testing
Then there is the cost of operating the demonstrator in order to get the data needed for evaluation

Module manufacturing facility
Finally, there is the cost for building and establishing the manufacturing facility for the modular production of reactors

Estimated cost structure of developing a first of a kind (FOAK) SMR reactor



Source: Analysis – Small Modular Reactor – market insights 2020

…Yet, for the technology to breakthrough, government financial backing is a big enabler

United Kingdom

- June 2020: UK government awarded £40 million in funding to support advanced nuclear development
- March 2022:UK Government has initiated the approval process for Rolls-Royce's small modular nuclear reactors (SMRs)
- UKRI confirms funding[1] of £36M for Rolls Royce SMR design

Finland

- The potential use of SMRs for district heating and electricity generation being studied at the VTT technical research center of Finland

Netherlands

- December 2021: NL government places $564 million as earmarked to support new nuclear build in the period to 2025

Poland

- September 2020: Polish climate minister plan to construct six new NPP by 2040 with $40 billion in expected investment

Estonia

- June 2021: Swedish state-owned energy company Vattenfall invest $1.2 million in Estonian nuclear energy start-up

Sweden

- Uniper SE, LeadCold and KTH to construct 80 MW_{th} SMR SEALER demonstrator by 2030
- February 2022: It has received $ 10.6 MUSD funding from the Swedish Energy Agency

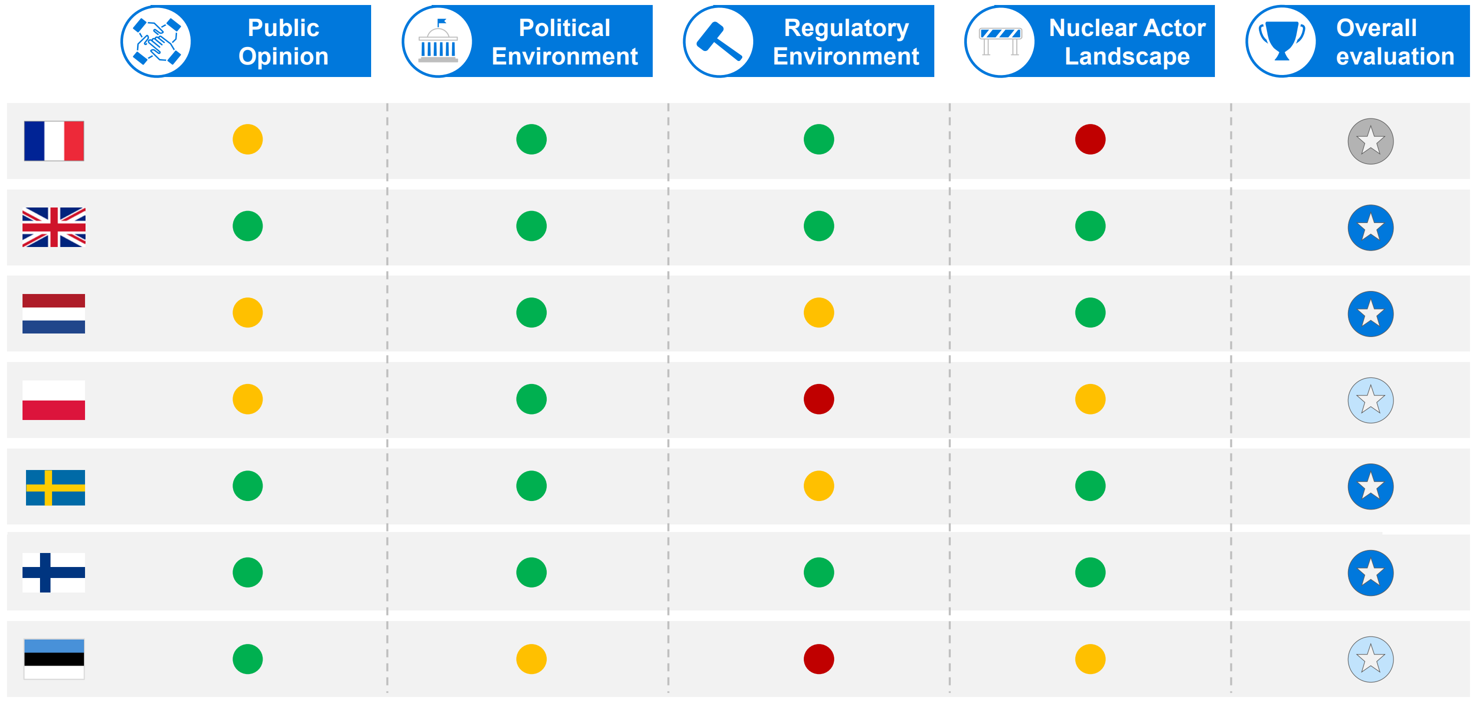
France

- February 2022: New investments announced up to €500 million of the French SMR (Nuward)
- Another €500 million are planned for innovative nuclear reactor concepts

1. Joint public and private investment to enable the consortium to further develop SMR design in UK (gov.uk) UKRI (UK research and innovation) will contribute with £ 18M

Sources: May 2018, World Nuclear Association, "Small Nuclear Power Reactors"; 16 Feb 2017, Forbes, "SMR Smart: Small Modular Reactors Are Nuclear's Future; 18 Aug 2017, Popular Science, "These are China's plans for floating nuclear reactors")

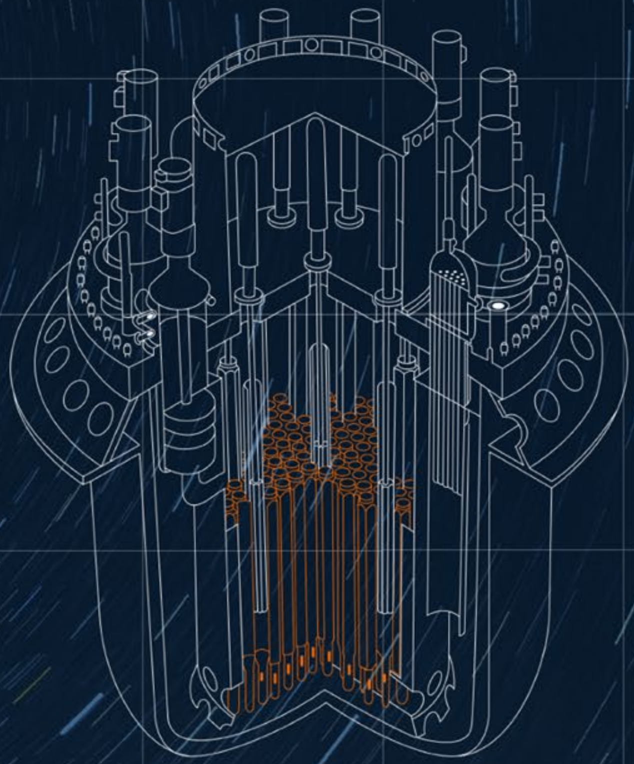
A country evaluation of new nuclear power potential



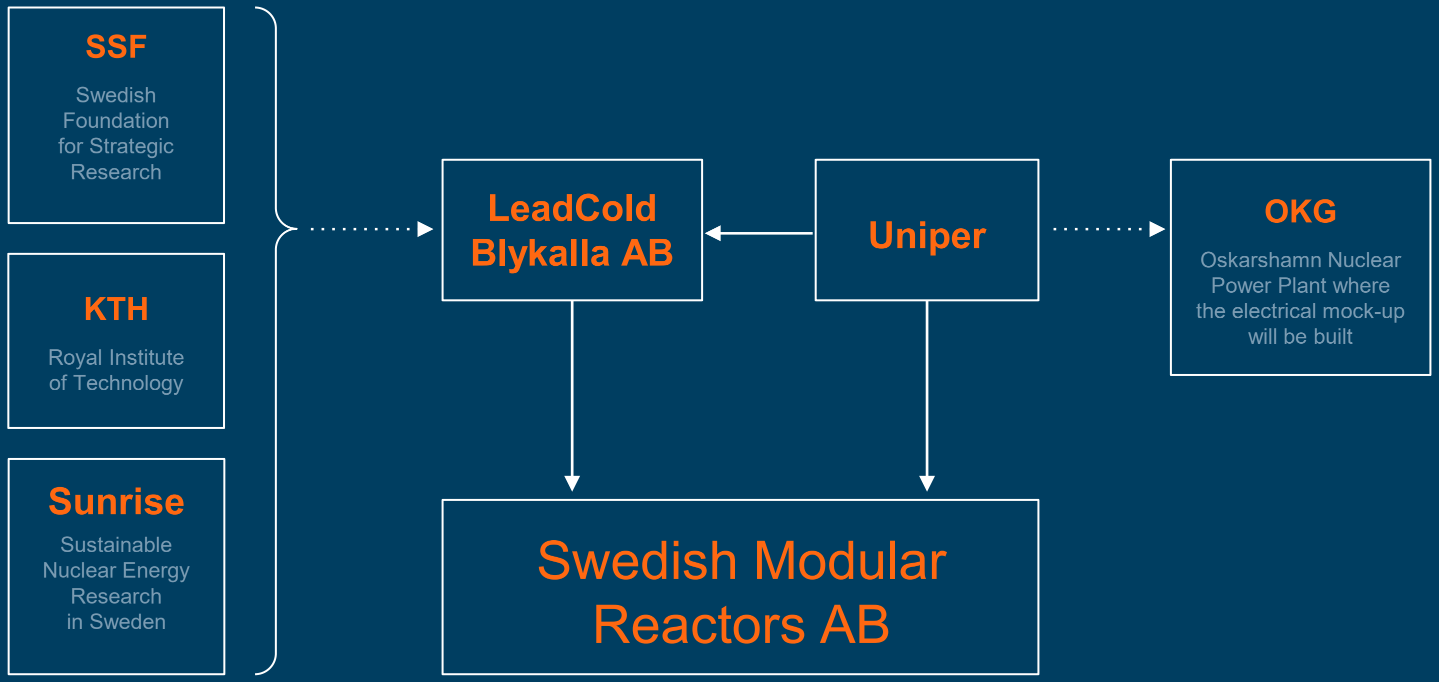
These countries are interesting from a new build perspective. Especially the UK and Finland, followed by Sweden and the Netherlands. From a system perspective, nuclear is a suitable source for all countries as an enabler source for industry electrification and decarbonization

SMR AB LEAP INTO A NET-ZERO FUTURE

A Lead-Cooled Modular Reactor



A COLLABORATIVE VENTURE



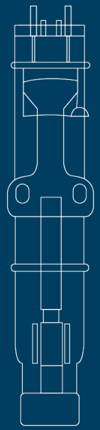
VOLUME COMPARISON

Small Modular Reactors < 300 MW

2020

NuScale

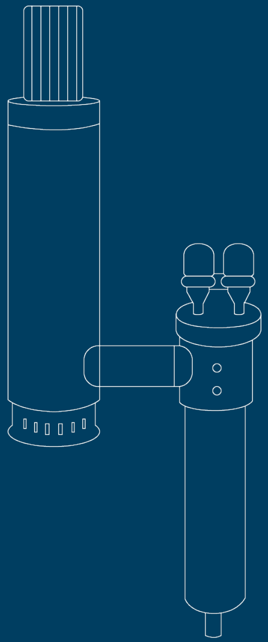
Water



2022

Xe-100

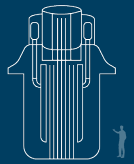
Helium



2026

Sealer-55

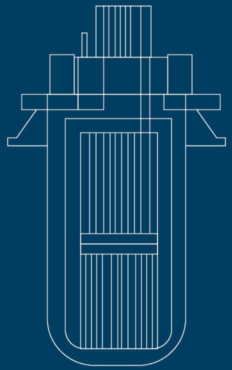
Lead



2027

Arc

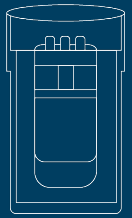
Sodium



20XX

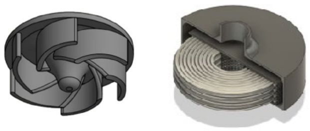
TerraPower

Salt



Our Roadmap

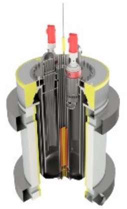
SUNRISE



Design, test and qualify pump impellers and material for the research reactor Ca € 6 mn

2021-2026

Sealer-E
(2,5 MW$_{th}$)



Electrically heated prototype
Ca € 25 mn

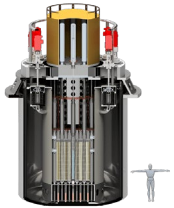
2021-2024

Sealer-D
(80 MW$_{th}$)

Nuclear demonstration Reactor
Ca € 150 mn

2030

Sealer-55
(140 MW$_{th}$)



Commercial Product

2032

THANK YOU!