NNWI Forum 2022

A Sustainable Future – Addressing the Energy Trilemma

#NNWIForum2022

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Nuclear Energy’s role in Pathways to Net-Zero

King Lee
Director Harmony Programme

NNWI Forum 2022
18 October 2022

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We are the Voice of the Global Nuclear Industry

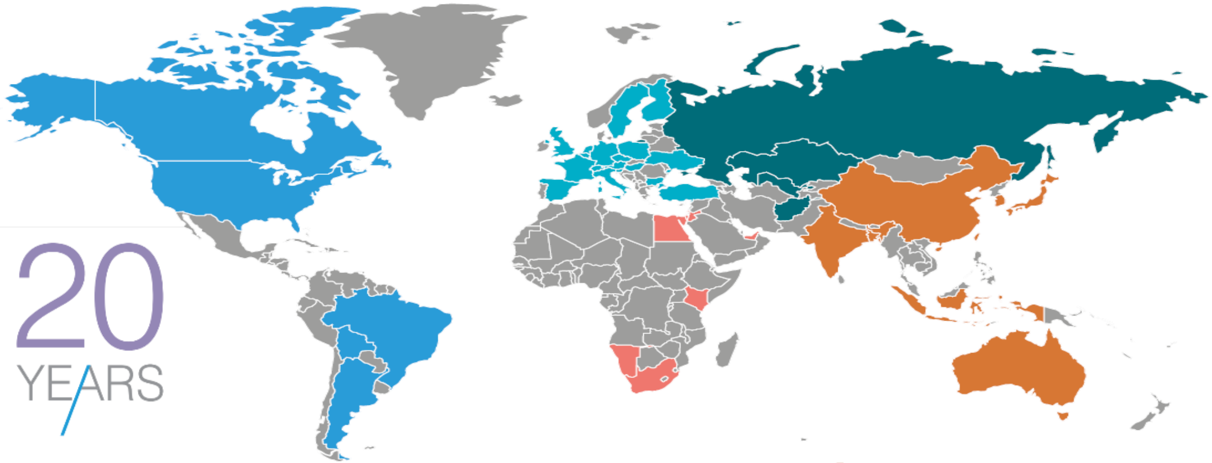
188 members

45 countries

WORLD NUCLEAR ASSOCIATION | 20 YEARS

Europe | 62 members
Austria, Belgium, Bulgaria, Czech Republic, Finland, France, Germany, Hungary, Italy, Luxembourg, Netherlands, Poland, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom

Russia and Central Asia | 14 members
Afghanistan, Kazakhstan, Russia, Uzbekistan



Americas | 45 members
Argentina, Bolivia, Brazil, Canada, USA

Africa and Middle East | 10 members
Egypt, Israel, Jordan, Kenya, Namibia, South Africa, United Arab Emirates

Asia-Pacific | 52 members
Australia, Bangladesh, China mainland and Taiwan, India, Indonesia, Japan, Singapore, South Korea

Major reactor vendors - nuclear utility companies - uranium mining, conversion, enrichment, and fuel fabrication companies - nuclear engineering, construction and waste management companies – R&D organizations - transport, law, insurance and finance service companies

UNECE Committee on Sustainable Energy

75 UNECE

Reducing the Environmental Footprint of the Energy Sector

Group of Experts on Clean Electricity Systems
Group of Experts on Coal Mine Methane
Group of Experts on Gas
Methane Management

Deep Transformation of the Energy System

Group of Experts on Energy Efficiency
Group of Experts on Renewable Energy
Group of Experts on Gas
Group of Experts on Cleaner Electricity Systems

Sustainable Resource Management

Expert Group on Resource Management
Group of Experts on Renewable Energy
Resource Efficiency and Circular Economy

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UNECE Carbon Neutrality Project

Carbon Neutrality Toolkit

Supporting policymakers to make informed decisions towards the implementation of the 2030 Agenda for Sustainable Development and the Paris Agreement.

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https://carbonneutrality.unece.org/

Carbon Neutral Energy System of the Future integrated interplay of all low- and zero-carbon technologies.

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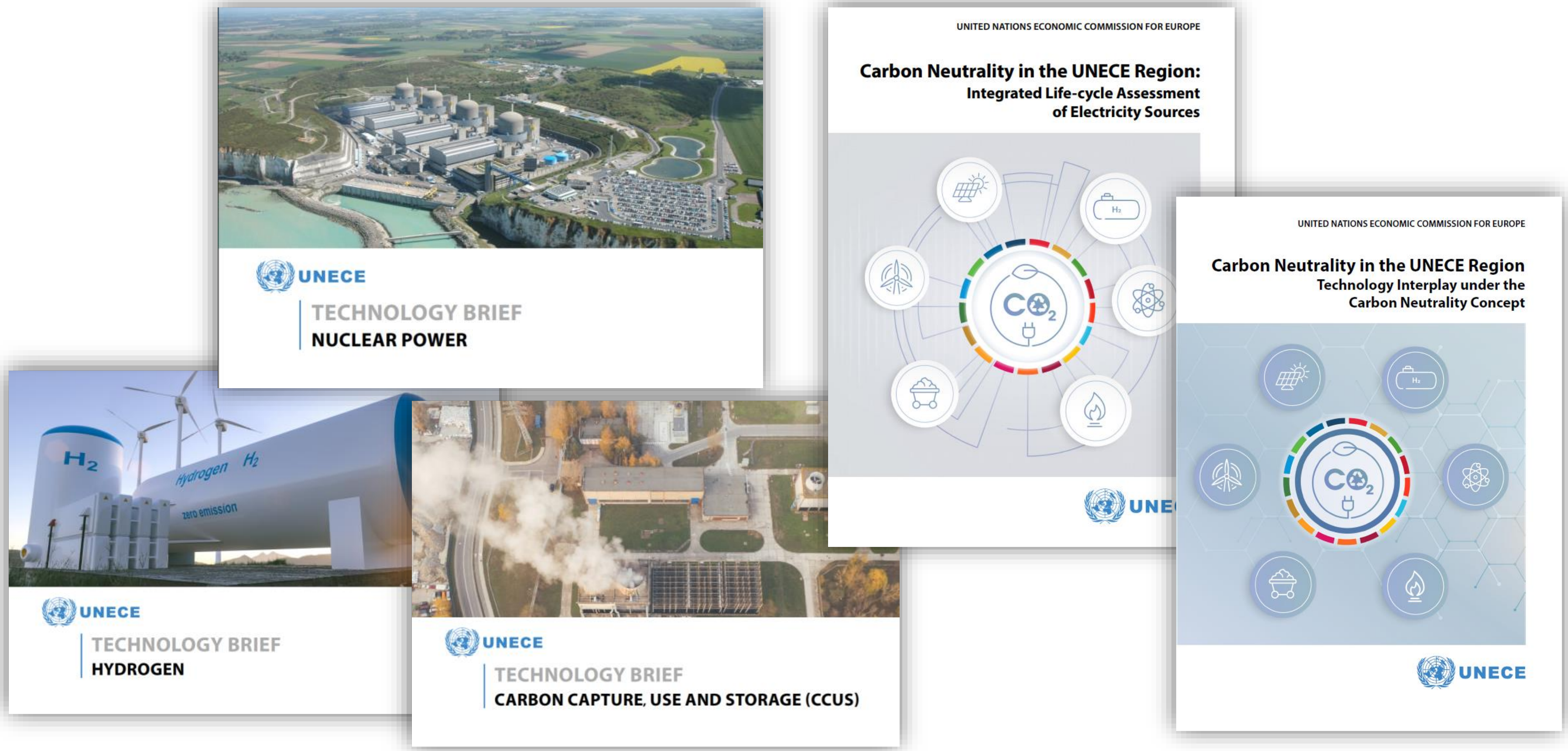
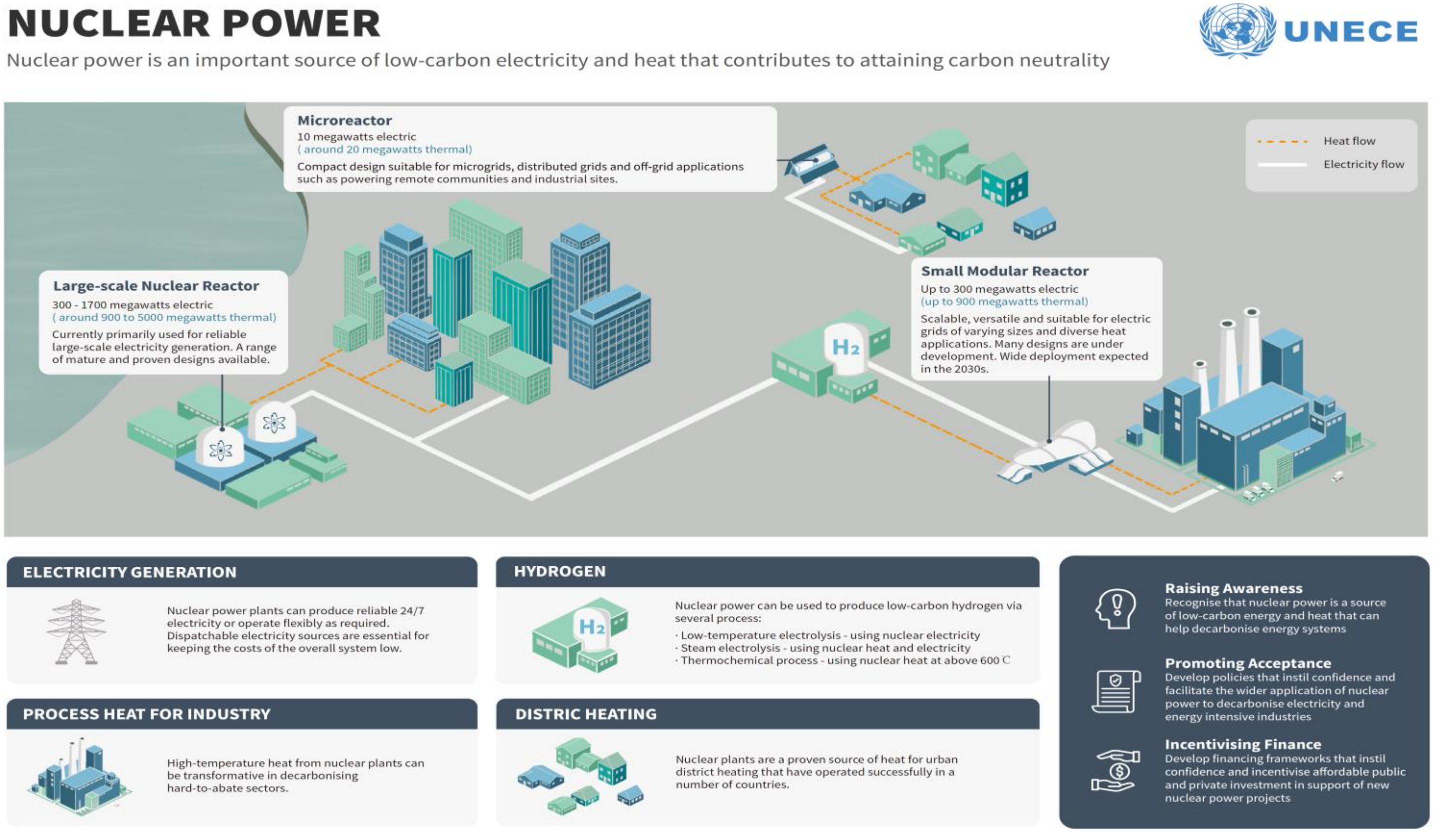
UNECE Carbon Neutrality Toolkit



Nuclear power is an important source of low-carbon electricity and heat that contributes to attaining carbon neutrality.



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Nuclear Power Brief - Key Takeaways

Establish a level playing field for all low-carbon technologies

Decarbonising energy is a significant undertaking that will require deployment of all available low-carbon technologies, including nuclear power.

Provide positive, long-term policy signals for new nuclear development

Consistent policies and clear market frameworks will enable investment in new nuclear power projects and support stable supply chains.

Accelerate the development and deployment of SMRs and advanced reactor technologies

Technical, financial and regulatory support are essential for the deployment and commercialisation of new nuclear technologies. International harmonisation of licensing frameworks should be promoted.

Secure the long-term operation of existing nuclear plants

Long-term operation of existing nuclear plants will avoid unnecessary CO2 emissions and decrease the costs of the energy transition. This must respect safety and economic parameters.

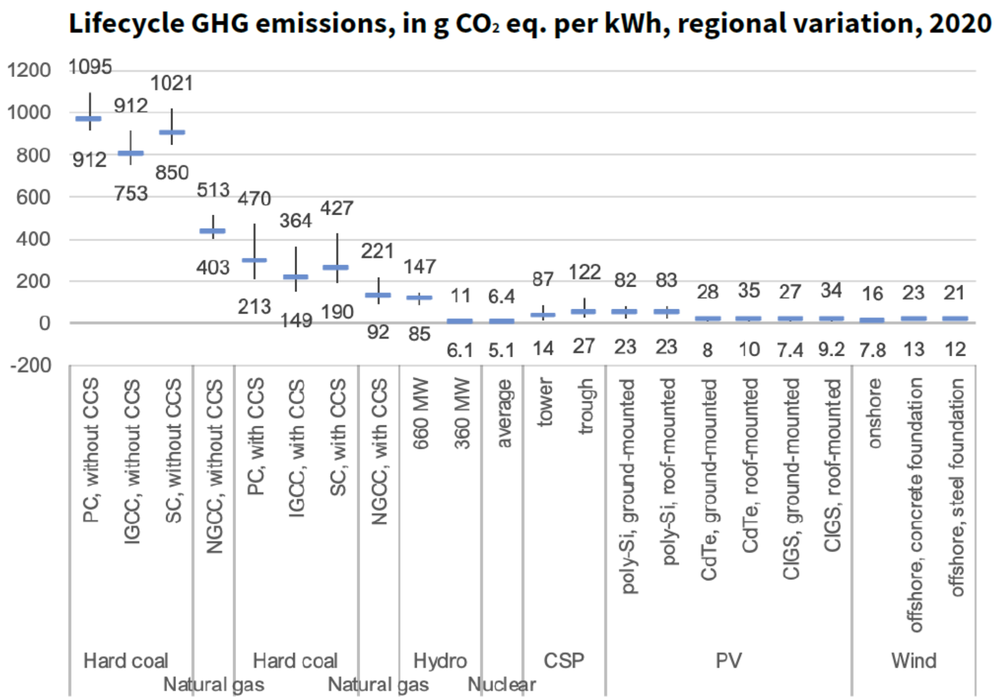
Assess the merits of low-cost financing of nuclear power projects

Green finance classifications should be based on scientific and technology-neutral methodologies. Multilateral banks and international finance institutions should consider nuclear projects as part of their sustainable lending activities.

Life Cycle Assessment – Energy Sources Sustainability

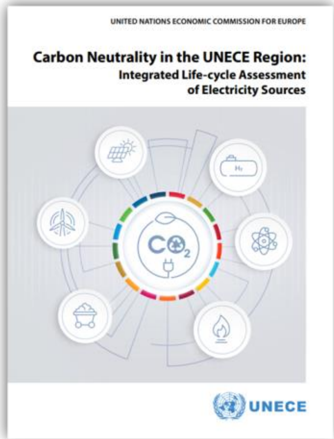
UNECE Life Cycle Assessment compared the main electricity generating technologies over a broad range of impact categories.

Figure 1 Lifecycle greenhouse gas emission ranges for the assessed technologies



Greenhouse gas (GHG) emissions

Nuclear power's lifecycle emissions are estimated with the lowest GHG of all technology assessed.



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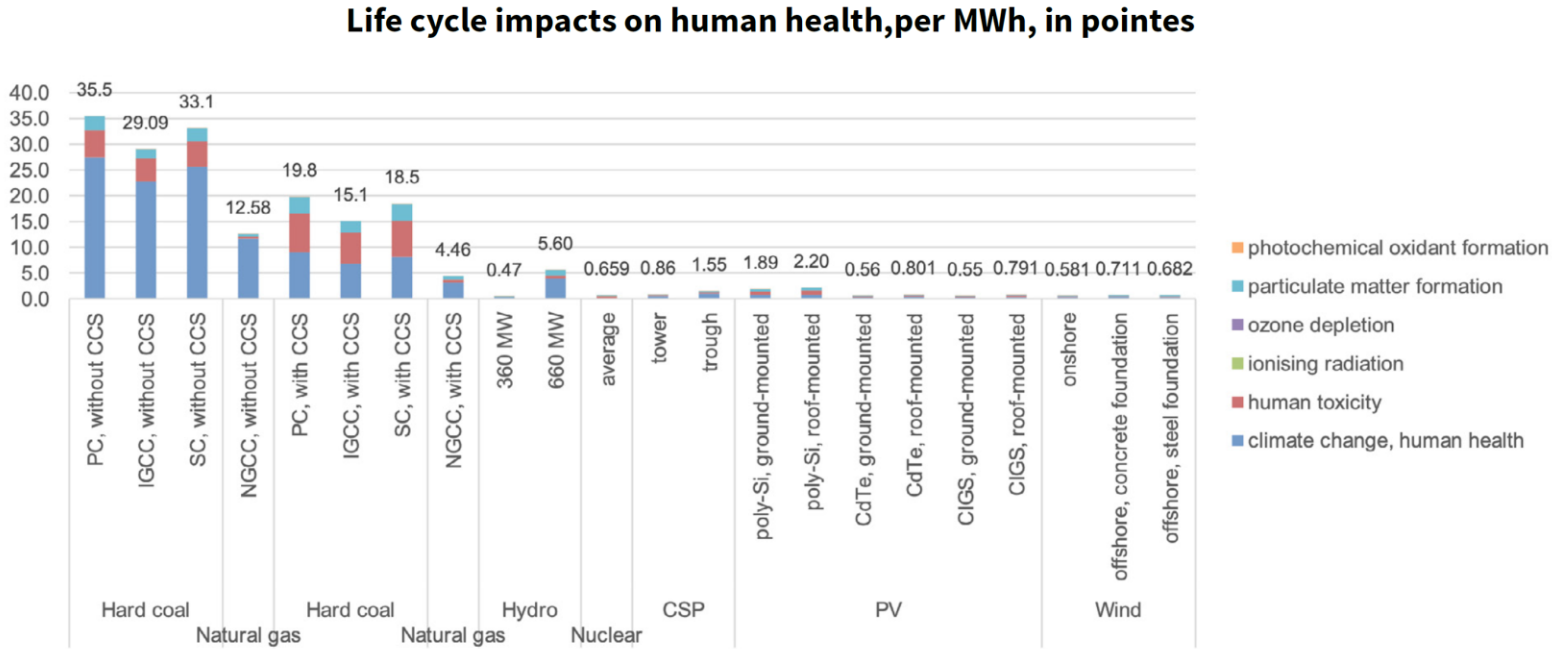
Impact on human health

Human health

Nuclear power has a low impact on human health.

Figure 50 **Life cycle impacts on human health, in points, including climate change.**
Note on unit: 1 point is equivalent to the impacts (in disability-adjusted life years, DALY) of 1 person (globally) over one year.

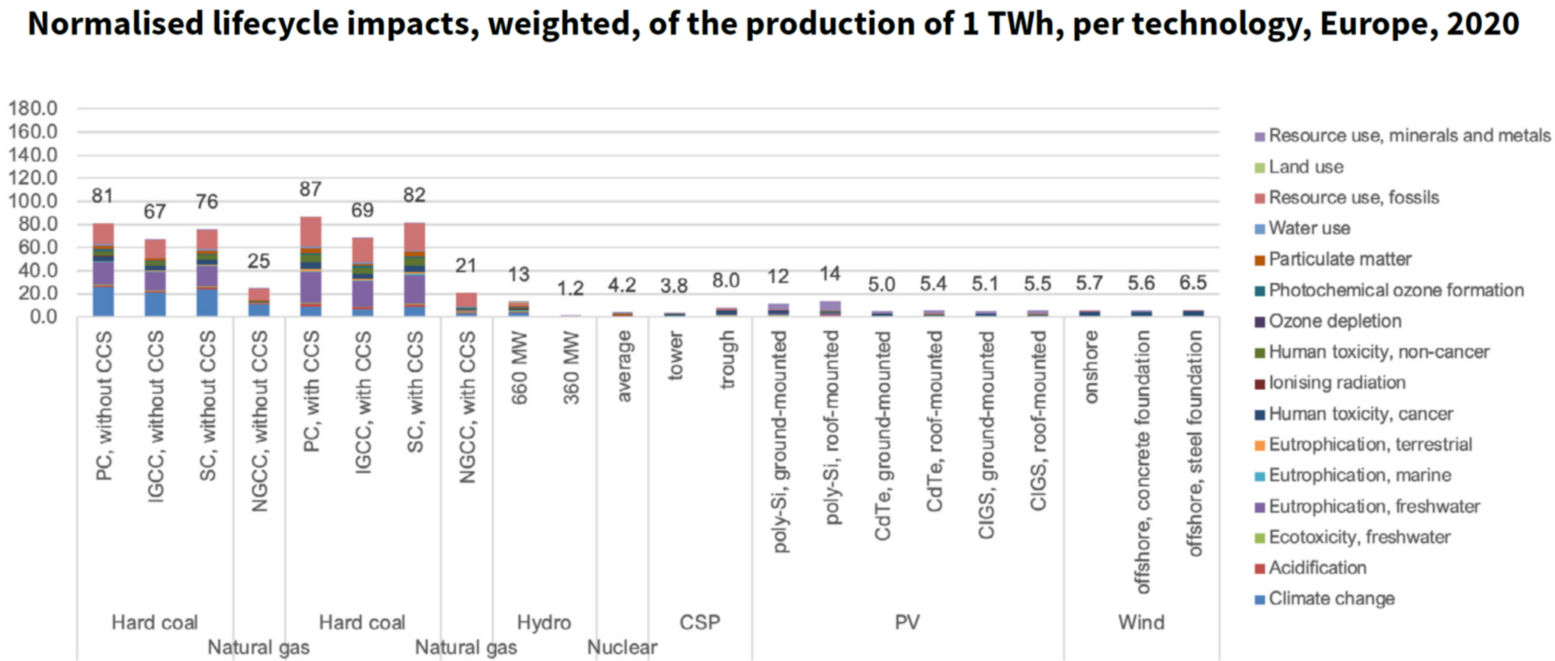


Impact on ecosystems

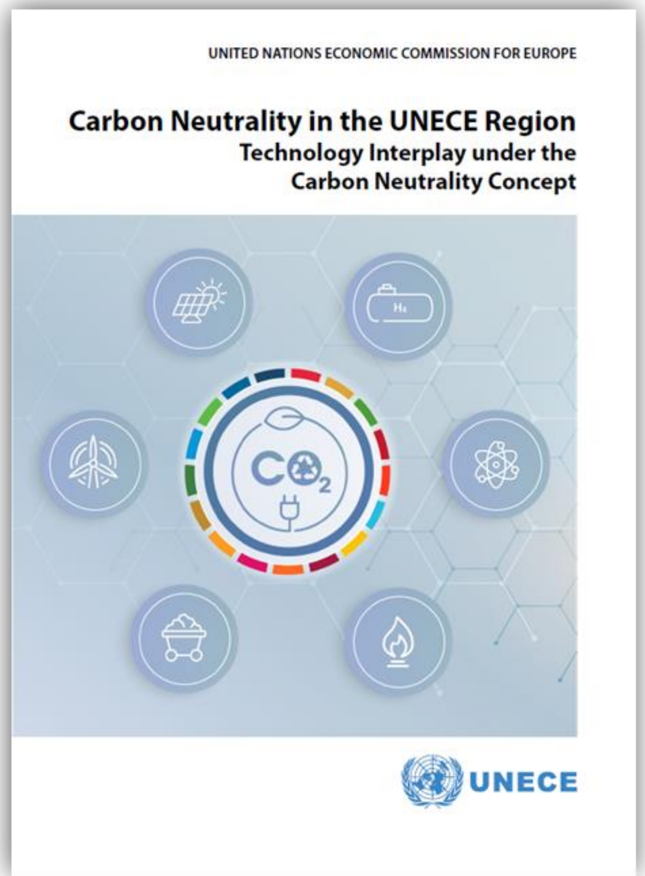
Ecosystems

"Nuclear power show a very low score on the ecosystem damage indicator"

Figure 53 Normalised, weighted, environmental impacts of the generation of 1 TWh of electricity



Carbon Neutrality through Technology Interplay



The UNECE Carbon Neutrality Toolkit is integrated approach looking at interplay of all low- and zero-carbon technologies.

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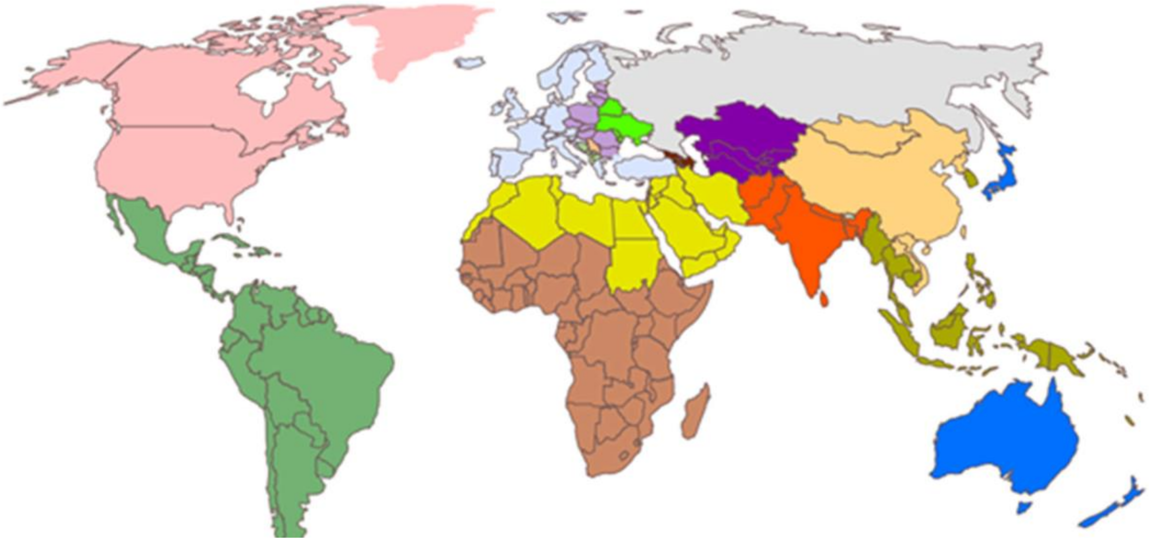
Carbon Neutrality Scenario Design

AFR	Sub-Saharan Africa	LAC	Latin America and the Caribbean	RUS	Russian Federation
BMU	Belarus, Moldova, Ukraine	MEA	Middle East and North Africa	SAS	South Asia
CAS	Central Asia	NAM	North America	SCS	South Caucasus
CPA	Centrally planned Asia & China	PAO	Pacific OECD	SEE	South Eastern Europe/Western Balkan
CEE	Central and Eastern Europe	PAS	Other Pacific Asia	WEU	Western Europe

15 regions (8 of which are UNEC regions) covering the world



Carbon Neutrality Scenario Design

Energy Modelling : a tool for informed decision marking

Stakeholder workshops for informed scenarios assumptions

Different UNECE working groups and stakeholders participated to identify technology markets and prospects for each deep dive

Reference scenario
without dedicated sustainable energy or climate policies.

Carbon Neutrality Scenario
Normative scenario to net zero

Special technology deep dives

- **Hydrogen**
- **Carbon capture, utilization, and storage (CCUS)**, including direct air capture(DAC)
- **Nuclear energy** –realizing its potential, new application and markets

Carbon Neutrality Innovation Scenario
All three technology deep dives combined: synergies and benefits

Exploring the Full Potential of Nuclear Energy

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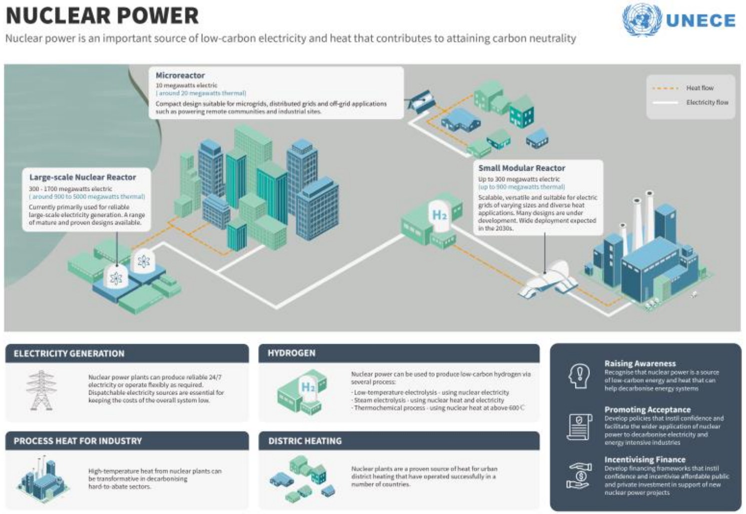
Nuclear Deep Dive

Technology innovation and new marketplaces



Main features of the nuclear deep dive

- Large nuclear power plant - flexible operation
- Large nuclear power plant - providing low-temperature district heat (DH)

- Representation of Small Modular Reactors (SMR) in the model
- Contribution of SMR to power balancing services (flexible operation)
- SMR providing low-temperature district heat (DH) in the cogeneration mode
- SMR producing high-temperature process heat in the industry
- SMR combination with other processes, e.g., in hydrogen production

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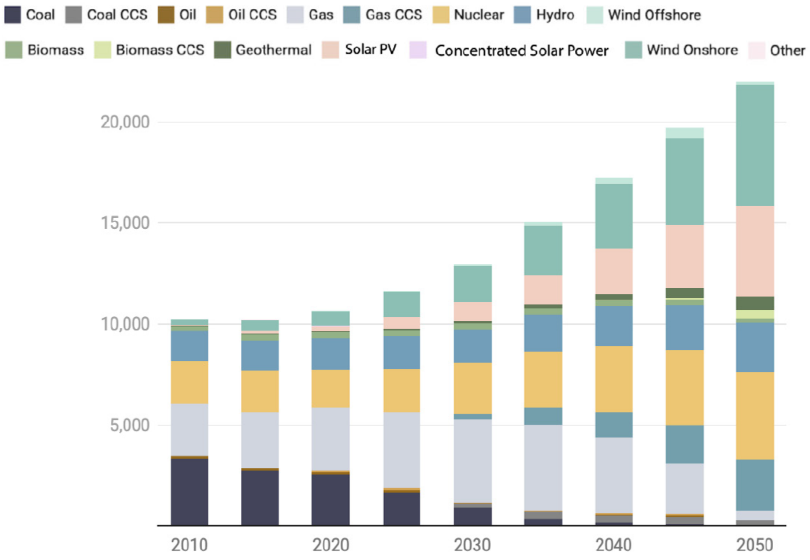
Carbon Neutrality - Electricity Generation Mix

FIGURE 21

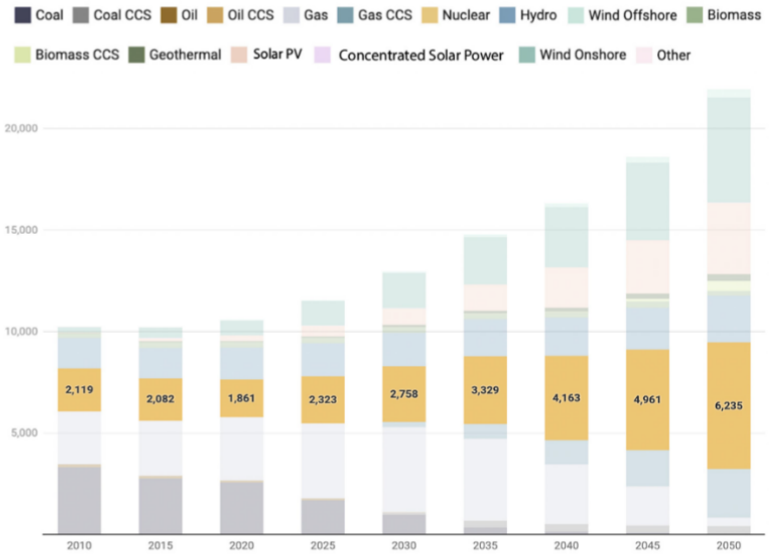
Electricity Generation Mix [TWh] **Carbon Neutrality Scenario**



Carbon Neutrality base scenario. By 2050, nuclear provides 4400TWh of electricity (~20% of supply)

FIGURE 26

Electricity Generation Mix [TWh] Carbon Neutrality Innovation Scenario



Carbon Neutrality Innovation scenario. By 2050, the amount of generation from nuclear energy triples, with 6235 TWh (~30% supply)

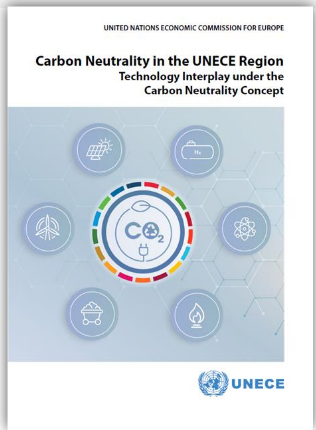
Source: Carbon Neutrality in the UNECE Region: Technology Interplay under the Carbon Neutrality Concept

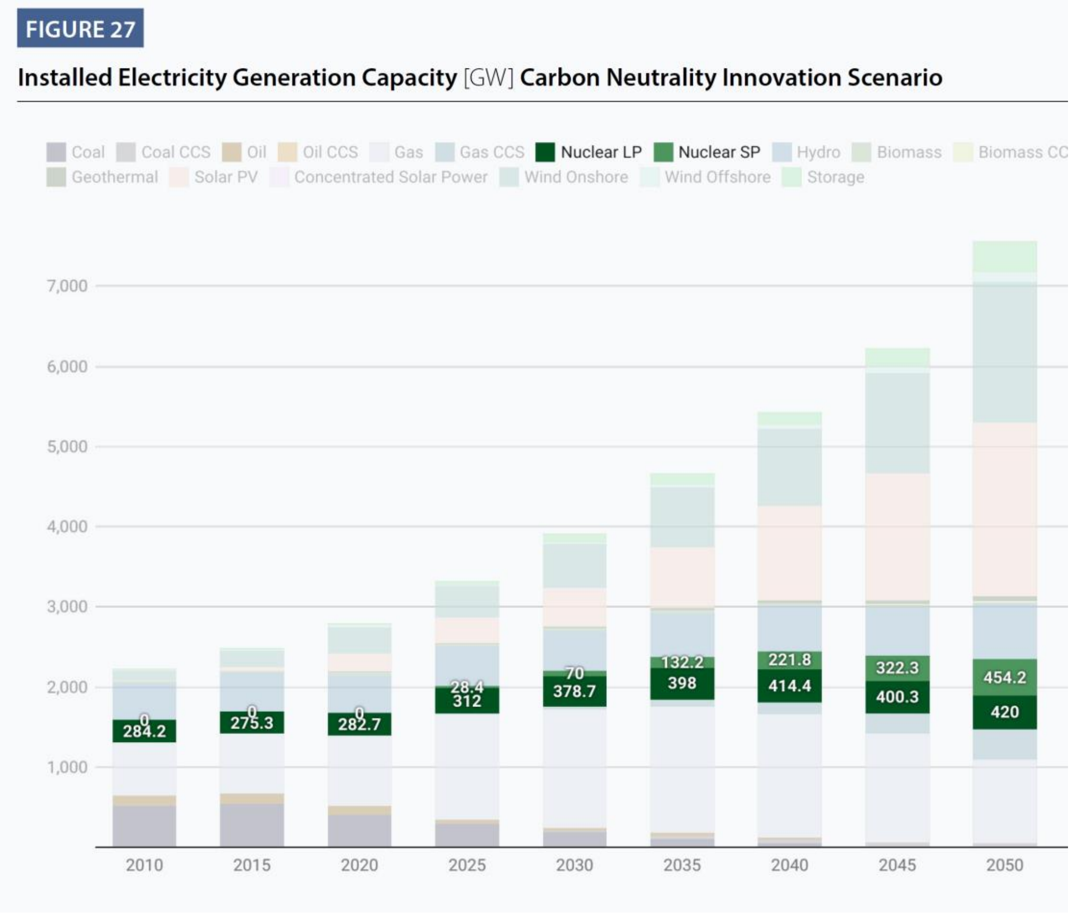
Carbon Neutrality - Electricity Capacity

Carbon Neutrality Innovation Scenario

For the UNECE region, 874 GWe of installed nuclear capacity, of which 450 GWe is projected to be SMRs, by 2050

170 GWth nuclear SMR for process/district heat





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Key Takeaways – Carbon Neutrality Energy System

Diversify Energy

Diversify primary and final energy supply

Phase-Out Fossil Fuels

Accelerate phase-out of unabated fossil fuels

Electrification

Electrify all sectors through renewable energy and nuclear power

Innovate

Scale up innovative low- and zero-carbon technologies such as carbon capture, use and storage (CCUS), hydrogen and advanced nuclear power

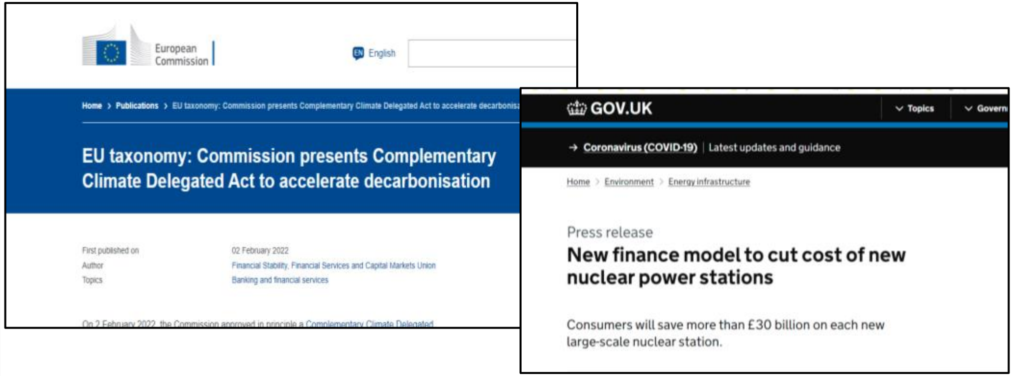
Significant Outreach and Impacts from UNECE Carbon Neutrality Project

UNECE work referenced by a number of governments to support new nuclear development, including

- UK new Nuclear Energy (Financing) Bill
- EU Taxonomy Complementary Climate Delegated Act covering certain nuclear and gas activities

Widely promoted by UNECE

- Over 30 Countries involve and millions of views of the Toolkits
- The toolkit will serve as a basis for the UNECE work on designing and implementing resilient energy systems across the ECE region, starting with Central Asia and Ukraine.



Impacts of the carbon neutrality project

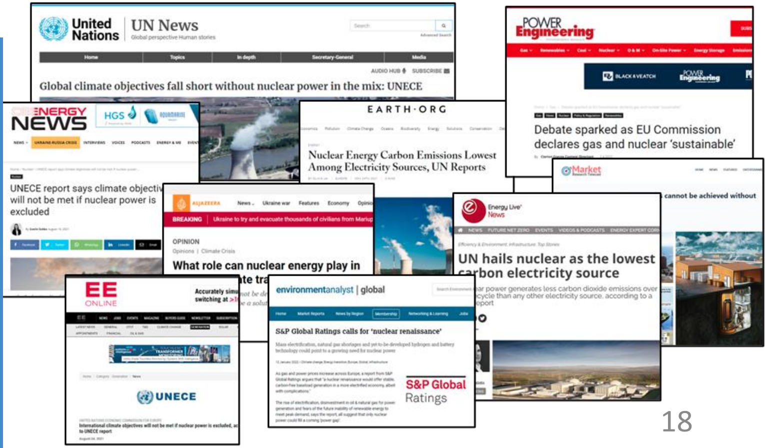
International
30+ Countries actively participating in carbon neutrality project implementation.

Development
15+ capacity building workshops delivered on low- and zero-technologies and carbon neutrality frameworks.

Policies
7+ United Nation's publications on carbon neutrality including technology and policy briefs.

Action
Launch of activities on rebuilding the energy system in Ukraine, and carbon neutrality attainment in Central Asia.

Sharing
Millions of views of the ECE Carbon Neutrality Toolkit at international events, and online.



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Nuclear energy offers a golden opportunity
to build a cleaner, more equitable world,
in which everyone has access to clean abundant
affordable 24/7 energy and a high quality of life.

king.lee@world-nuclear.org

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Energy Security Panel

Chaired by Matthew Job, Partner, Herbert Smith Freehills LLP

- Yves Desbazeille, Director General, **Nucleareurope**
- Keisuke Sadamori, Director of the Office for Energy Markets and Security, **International Energy Agency**
- Tom Greatrex, Chief Executive, **Nuclear Industry Association**
- Fredrik Vitaback, European Director, Market Development, **GE Hitachi Nuclear Energy**
- Ivan Baldwin, UK Business Development Director for Nuclear Power, **Bechtel**

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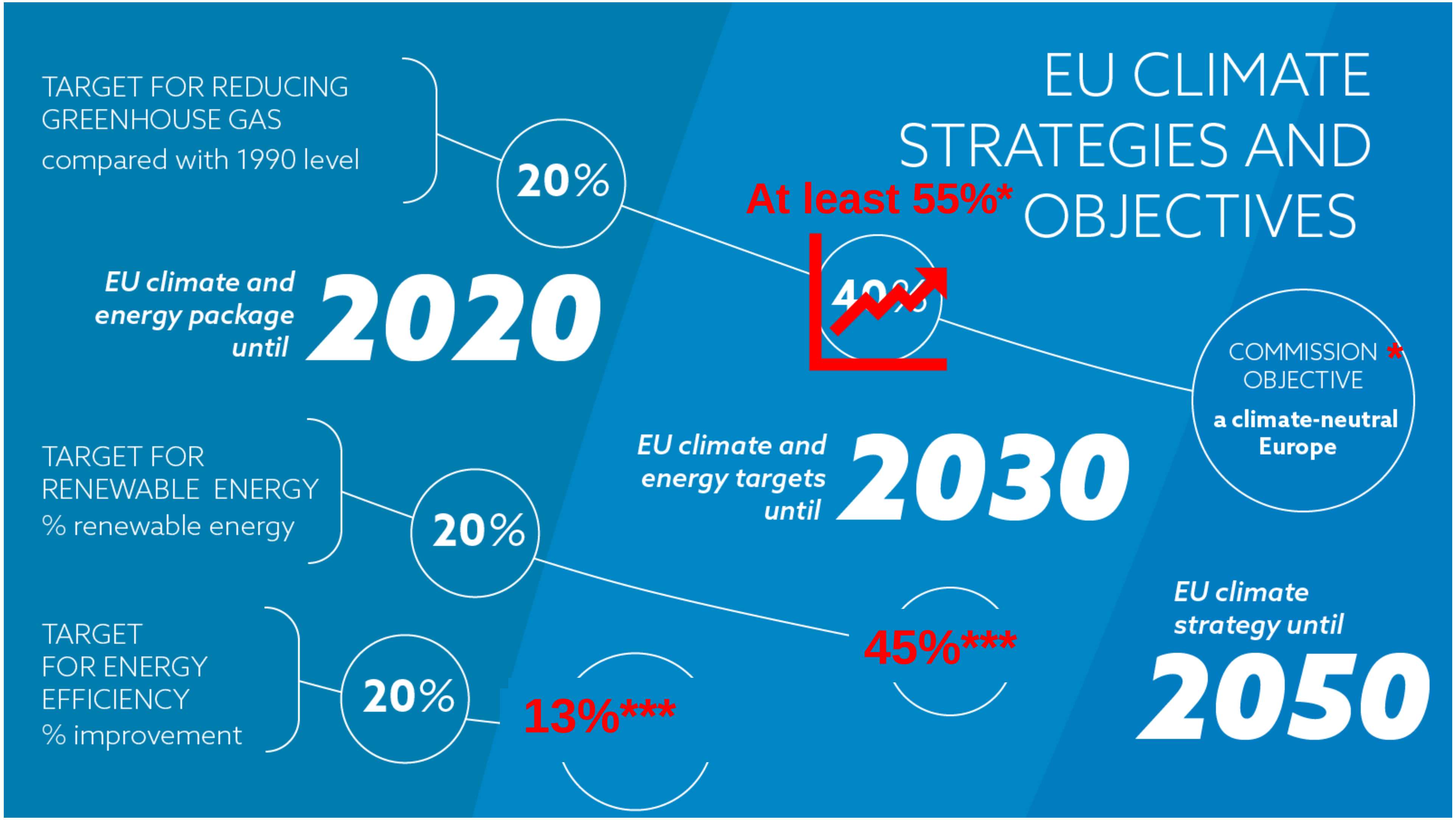
Europe's energy crisis: nuclear benefits

Yves Desbazeille

Director General- nucleareurope

nucleareurope

Decarbonisation of the EU economy

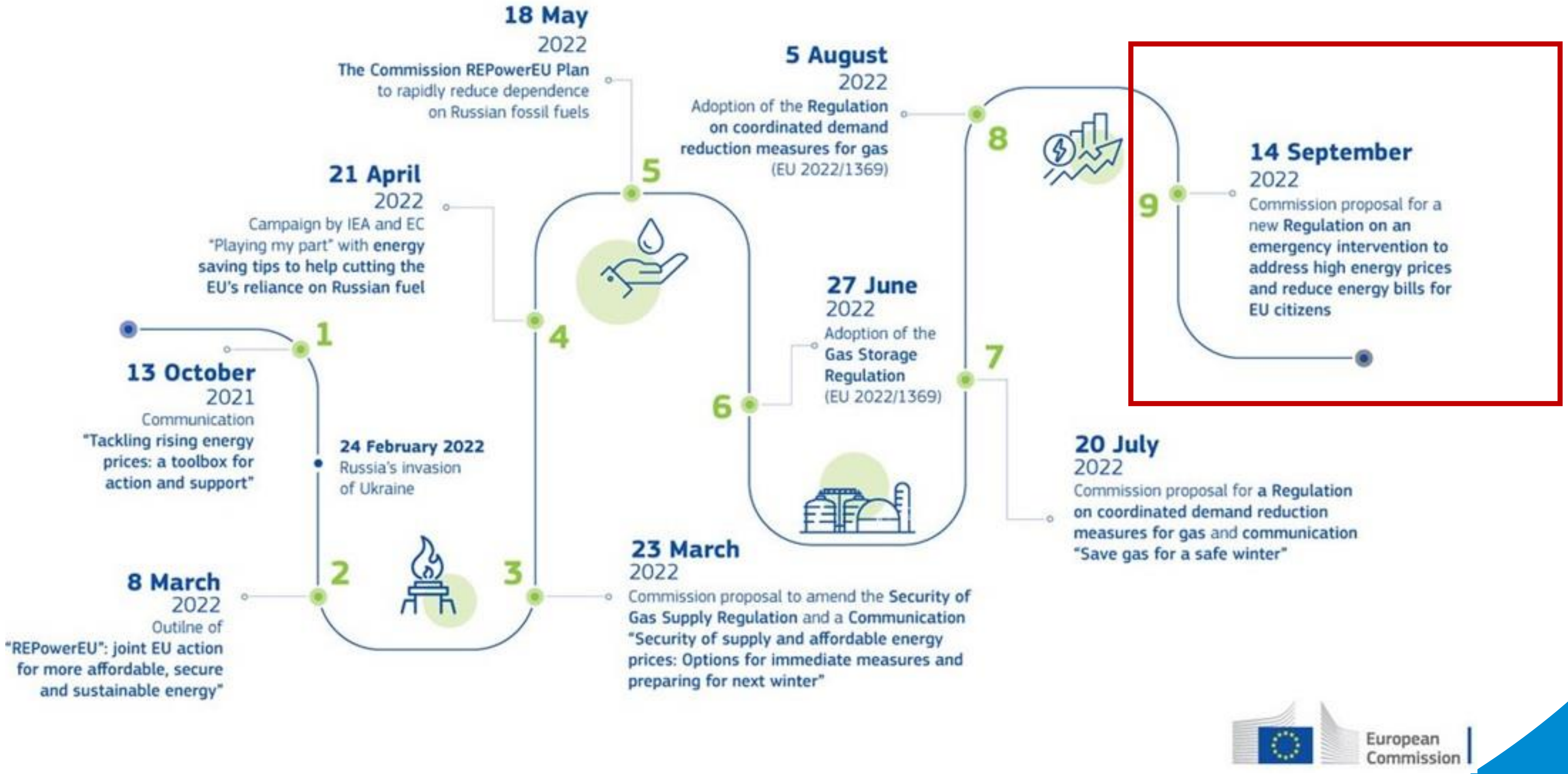


* Set by the European Climate Law

** Proposed in the Fit for 55% package legislative proposals

*** REPowerEU Plan (for Energy Efficiency compared with 2020 – previous target was 9%)

Energy prices and security of supply issues



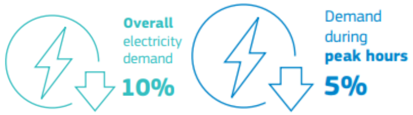
Energy prices and security of supply issues

2022 **2023**

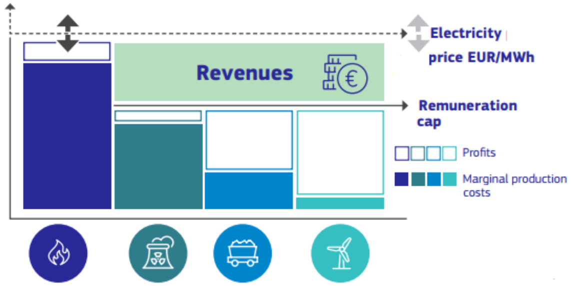
September

[Proposal for a regulation on an emergency intervention to address high energy prices](#) (14/09)

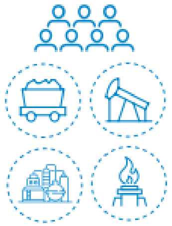
- Reduce electricity consumption



- Revenue cap for low-cost power generation



- Solidarity contribution from fossil fuel companies



October

Expected news on measures that will address:

- capping the price of natural gas
- security of energy supply – can the existing tools be improved;
- liquidity on energy markets – an analysis with possible new measures on financial markets;

November - December

???

Spring 2023

review the Energy Market Design and to finalise the Impact Assessment

Current energy crisis & changing public opinion

Finnish Greens recognise that the fight is against Climate Change – nuclear is therefore part of the solution

The Netherlands is looking at ways to finance new nuclear plants

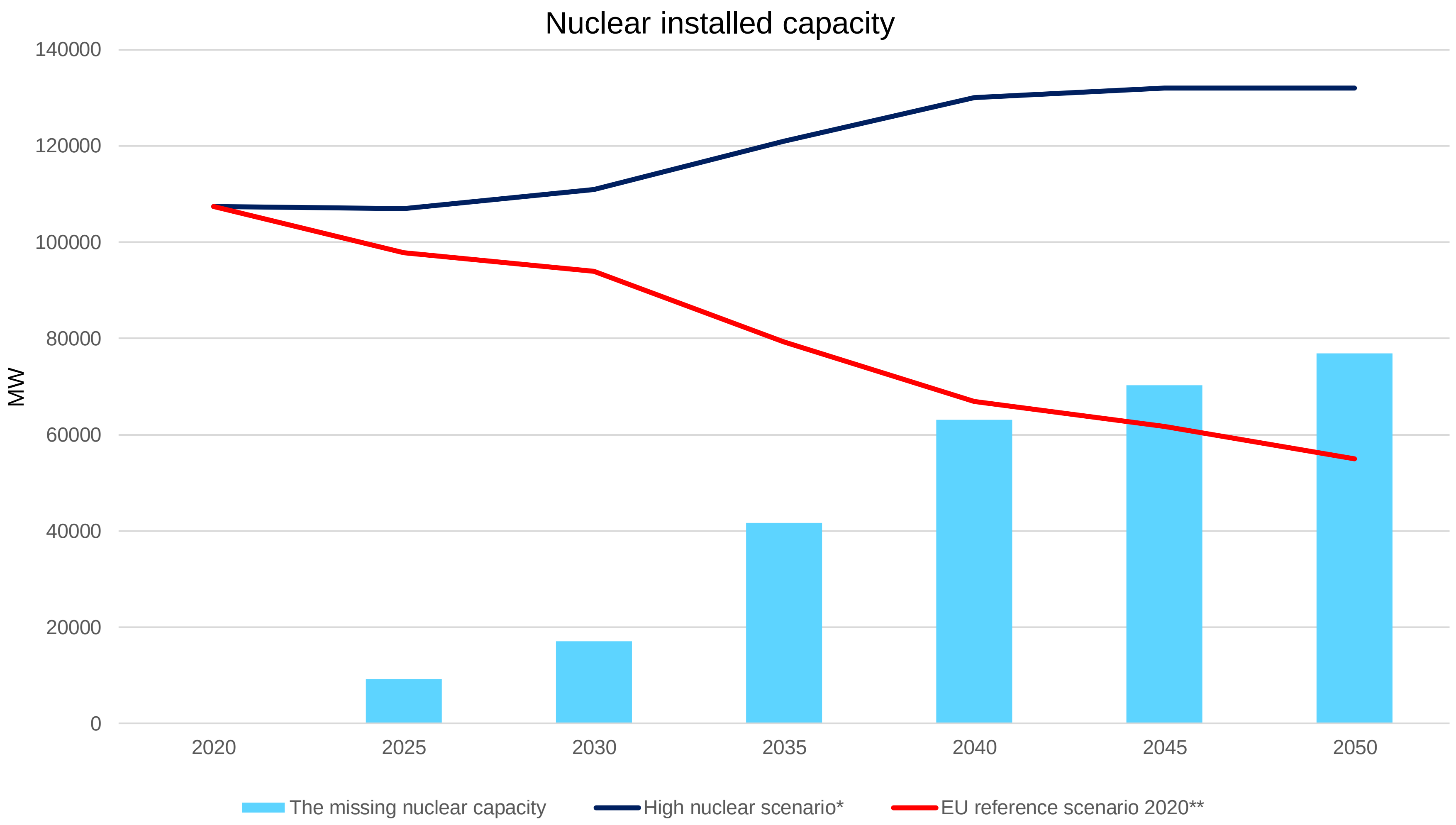
Bulgaria is looking to build a new reactor and potentially moving away from Russian technology

Greece could be potentially interested in investing in the Bulgarian project

Poland is looking to replace some of its coal fired plants with nuclear as it will help meet CO2 targets and create jobs and growth

Estonia is looking at investing in SMRs

How can nuclear help?



* The updated "Pathways to 2050: Role of nuclear in a low-carbon Europe" report, Compass Lexecon, November 2021

** EU Reference scenario 2020, released in July 2021

nucleareurope

What challenges does industry need to tackle?

- Cost overruns and delays in new build projects
- Optimising the supply chain
- Tackling the skills shortage by making nuclear more attractive
- Increased harmonization at EU level (licensing, QA/MS, Codes & standards,…)
- Have a clear vision of the role of nuclear within the future low-carbon energy system
- Send clear messages to policy makers to ensure
  - Better recognition of benefits of dispatchable low carbon sources
  - Development of a conducive investment framework
  - Understanding of role which nuclear can play in producing low carbon hydrogen

Thank you!

Yves Desbazeille

Director General - nucleareurope

nucleareurope

Nuclear Power and Secure Energy Transitions

Keisuke Sadamori, Director of Energy Markets and Security

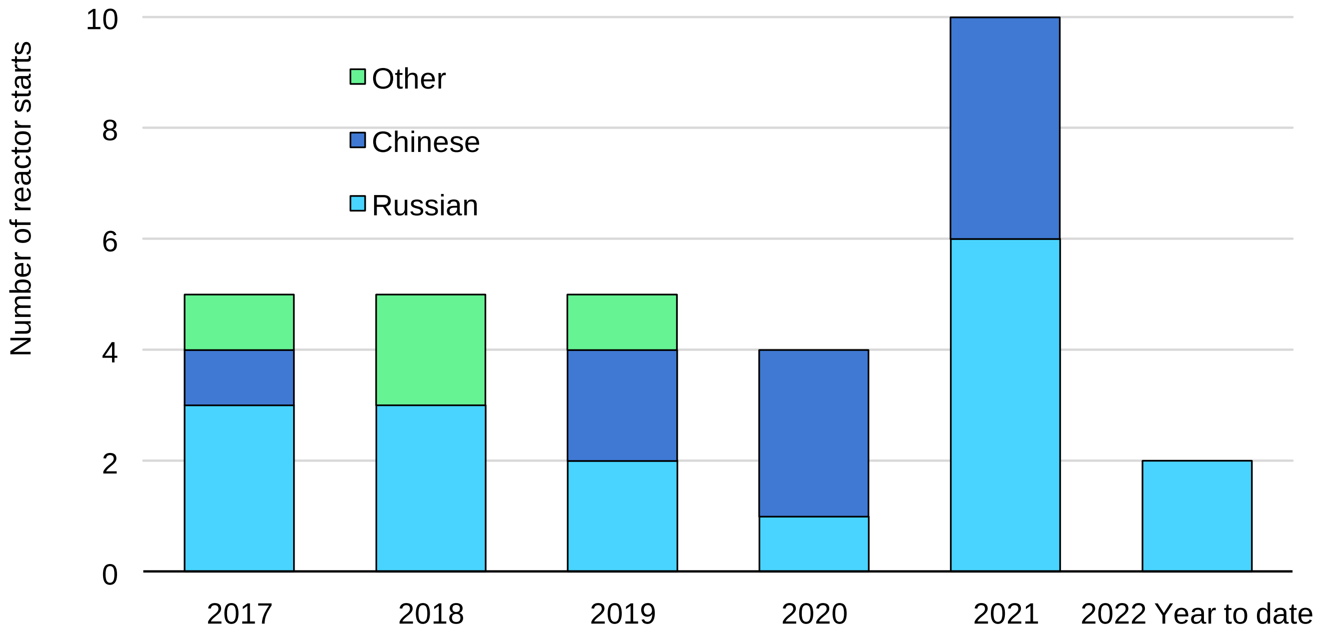
The New Nuclear Watch Institute (NNWI) Forum, 18 October 2022

Context

- Russia's invasion of Ukraine and disruptions in global energy supply have made governments rethink their energy security strategies, targeting diverse and domestic supplies
- Governments in over 70 countries have committed to achieving net zero emissions, covering three-quarters of global emissions and economic activity
- Peaking CO_2 emissions this decade and starting a long-term decline is essential to keep the door open to limiting climate change to 1.5 °C
- The policy landscape is changing, opening up opportunities for nuclear to make a comeback

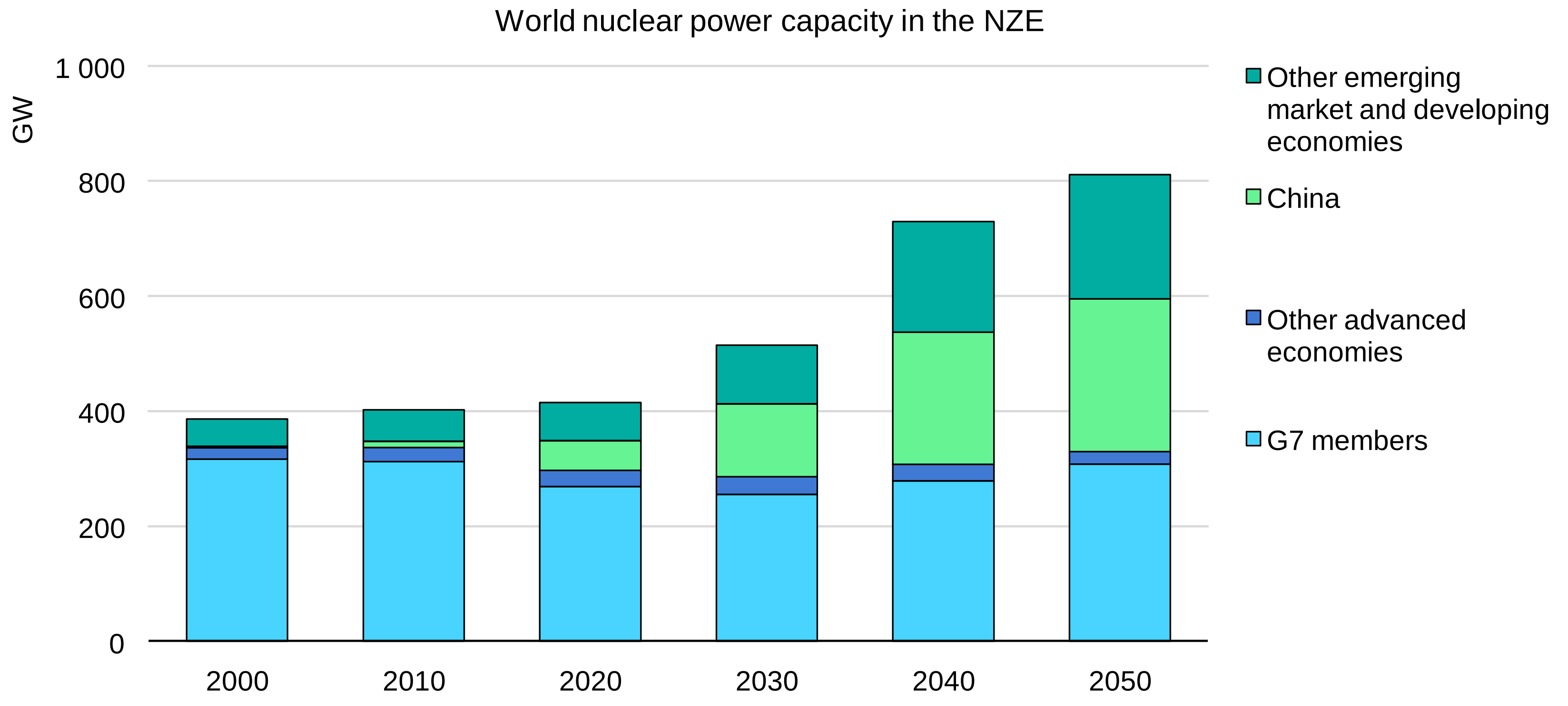
Nuclear market leadership shifting from advanced economies

Nuclear power construction starts by national origin of technology, 2017-2022



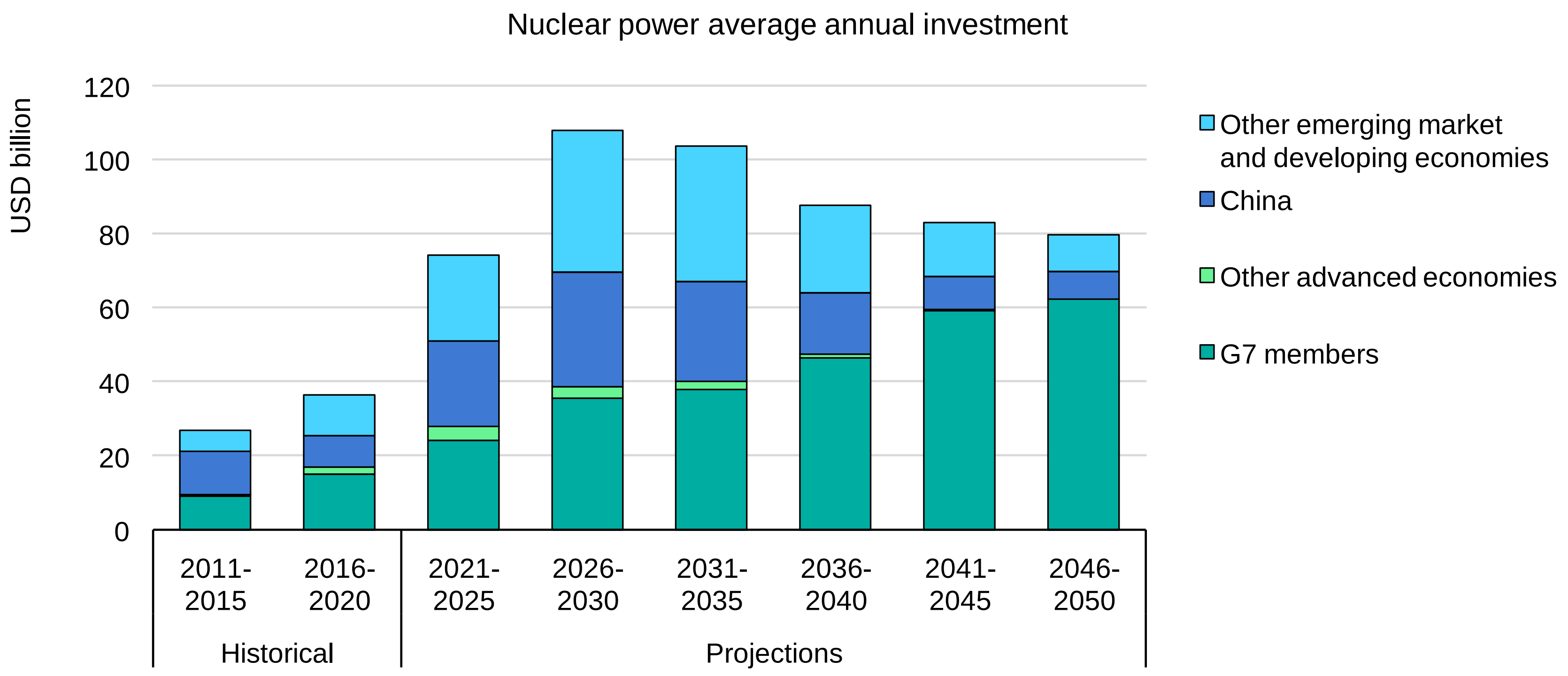
Of the 31 reactors that began construction since the beginning of 2017, all but four are of Russian or Chinese design.

Nuclear capacity doubles to 2050 on the path to Net Zero



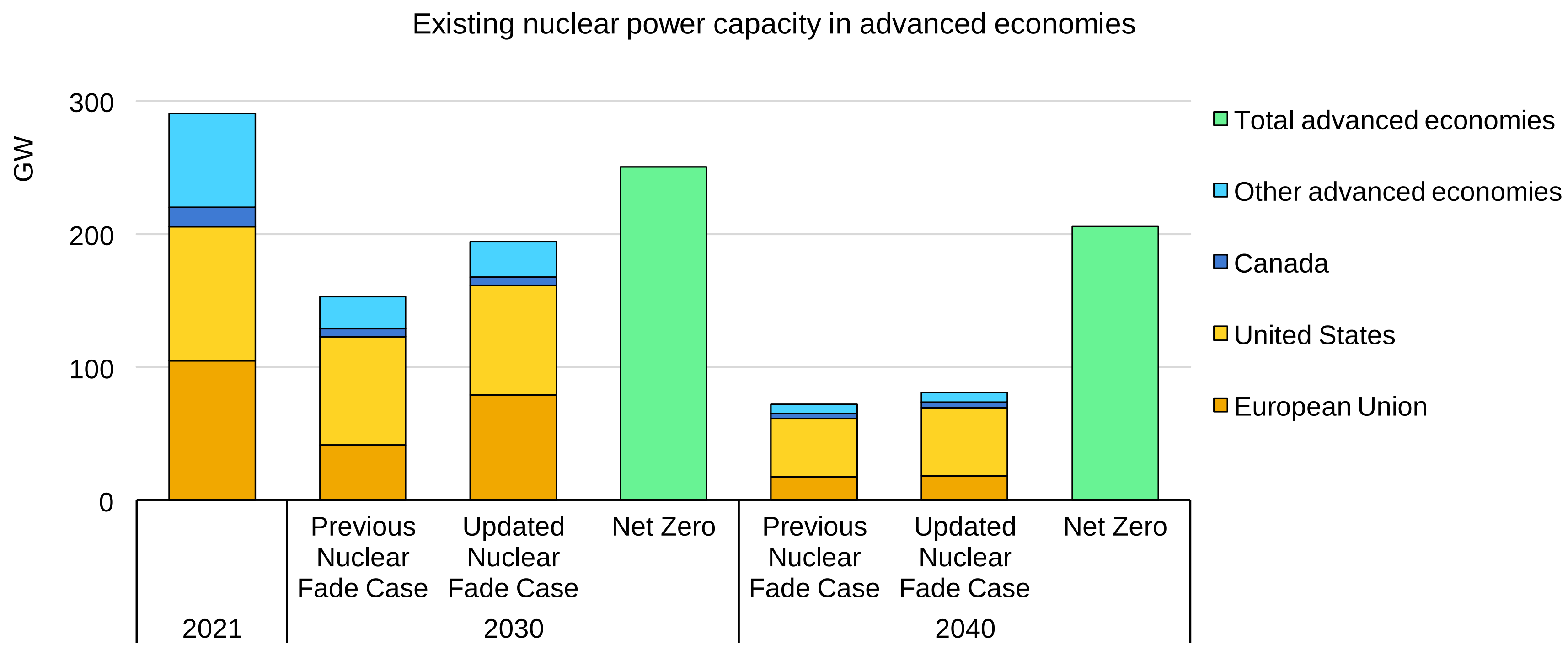
To complement renewables in the NZE, the nuclear industry must deliver new projects on time and on budget, with projects in advanced economies needing to cut costs by almost half from ongoing projects.

Investment in nuclear power must step up



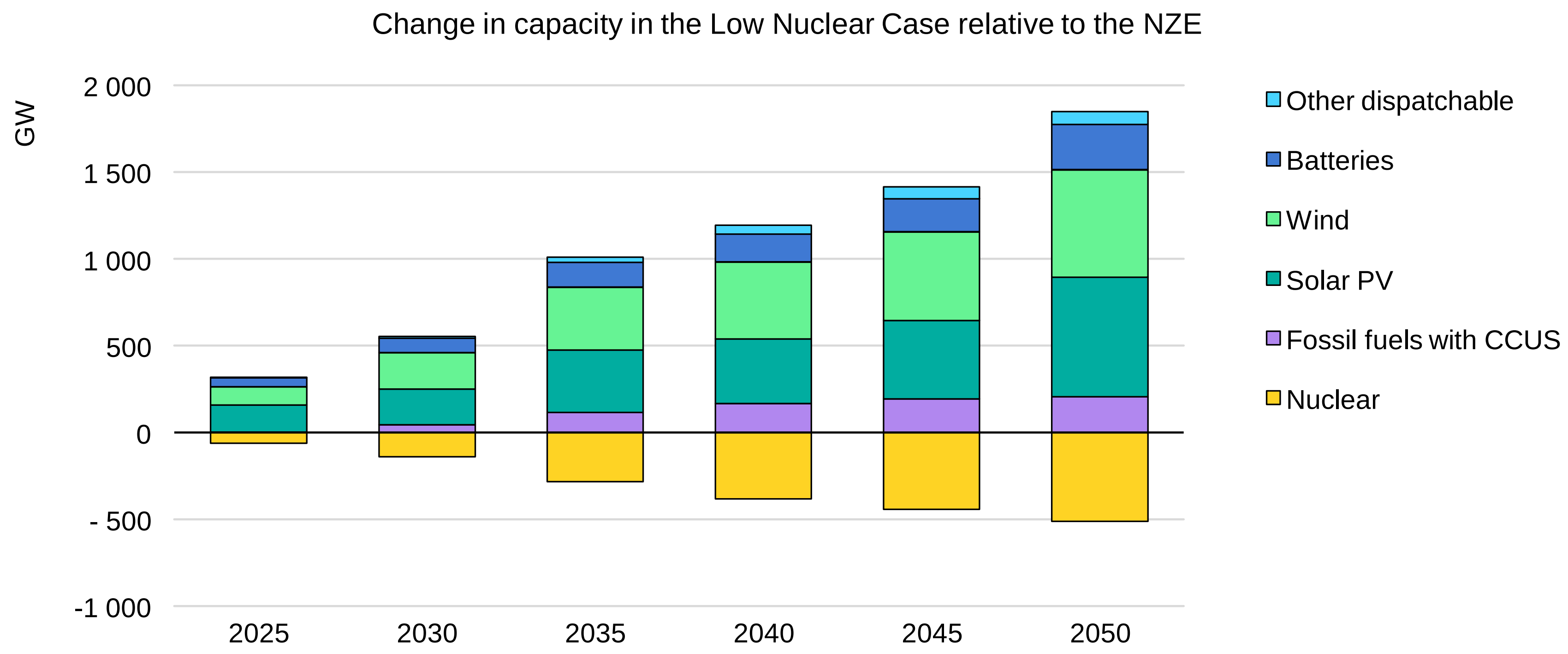
Capital investment in nuclear power needs to triple globally over the next decade on the path to Net Zero by 2050, rising in all active markets

Nuclear could still face a steep decline in advanced economies



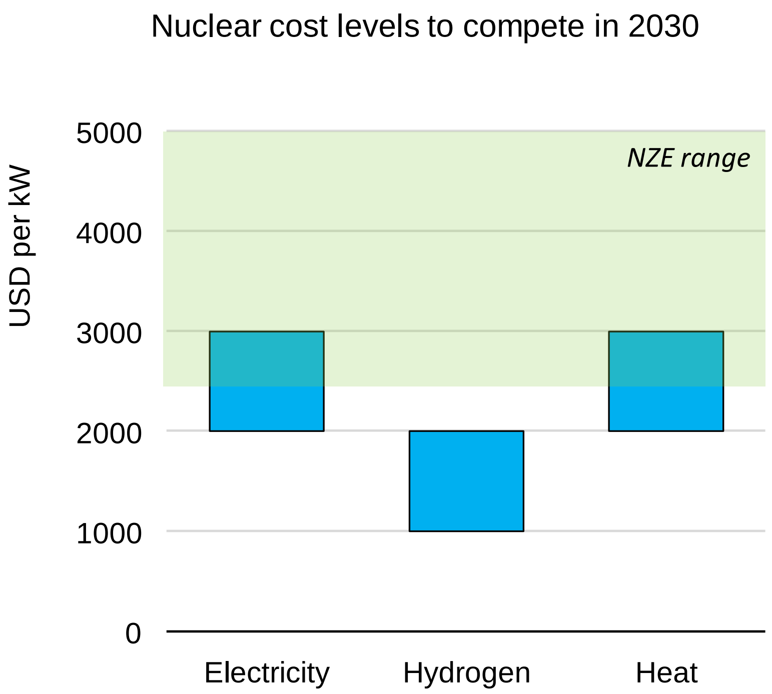
Lifetime extensions have been granted for 50 GW of nuclear capacity since 2019, but the existing fleet of nuclear reactors can contribute much more to affordable and secure clean energy transitions.

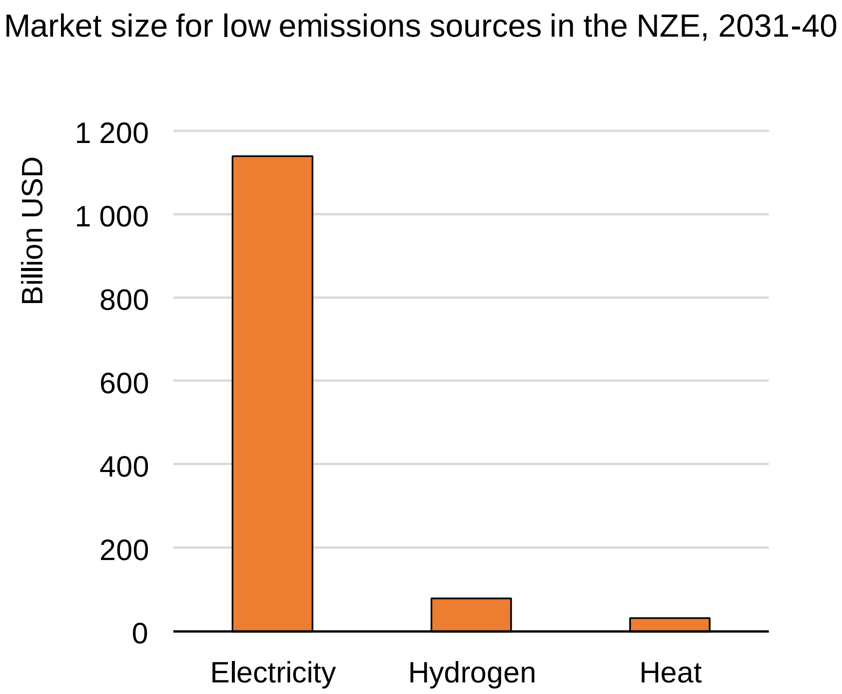
The path to net zero with less nuclear is narrower



While reaching net zero by 2050 would still be possible, failing to step up nuclear construction or extend lifetimes , would cost consumers USD 20 billion more per year and strain supply chains and the need for critical minerals

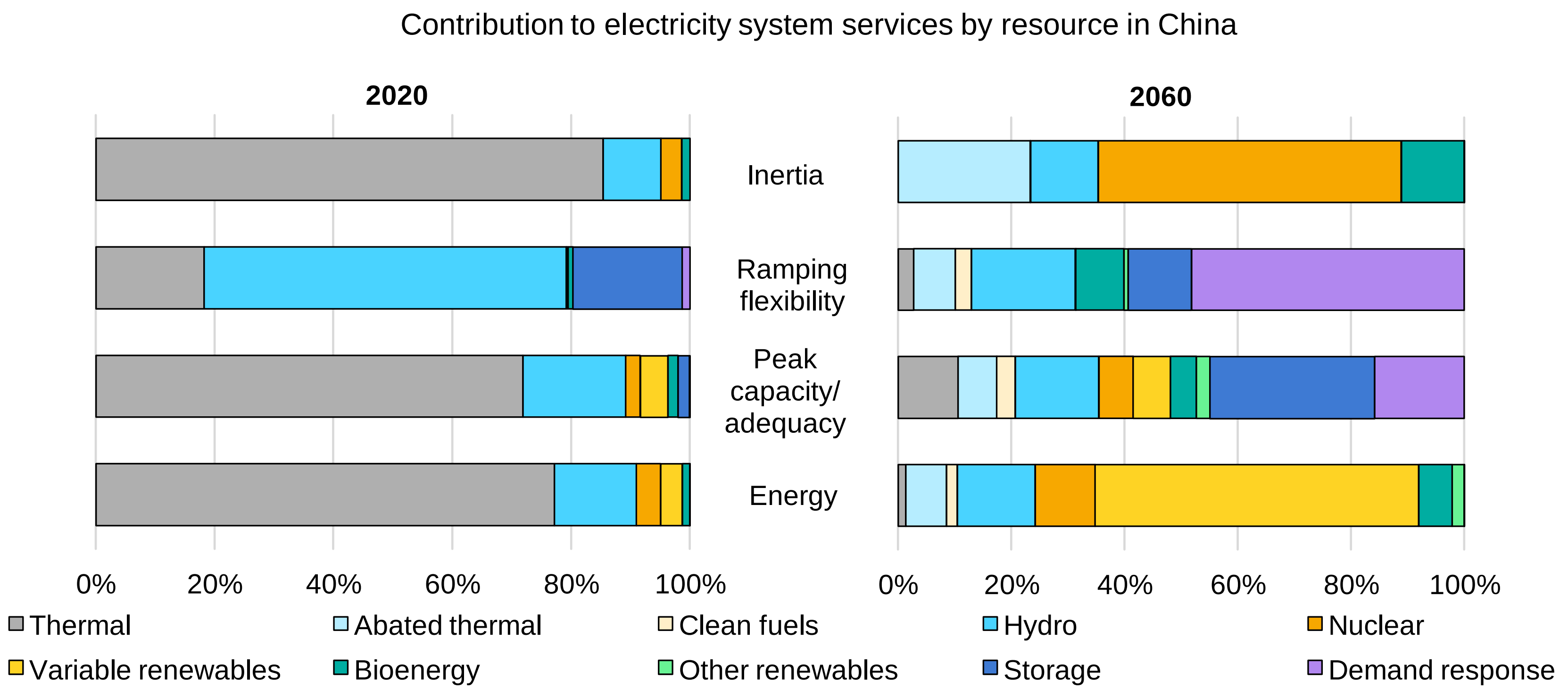
A larger role can open up with lower nuclear costs





Nuclear energy can deliver low emissions electricity, heat and hydrogen.
Further cost declines than in the NZE would enable it to capture higher market shares.

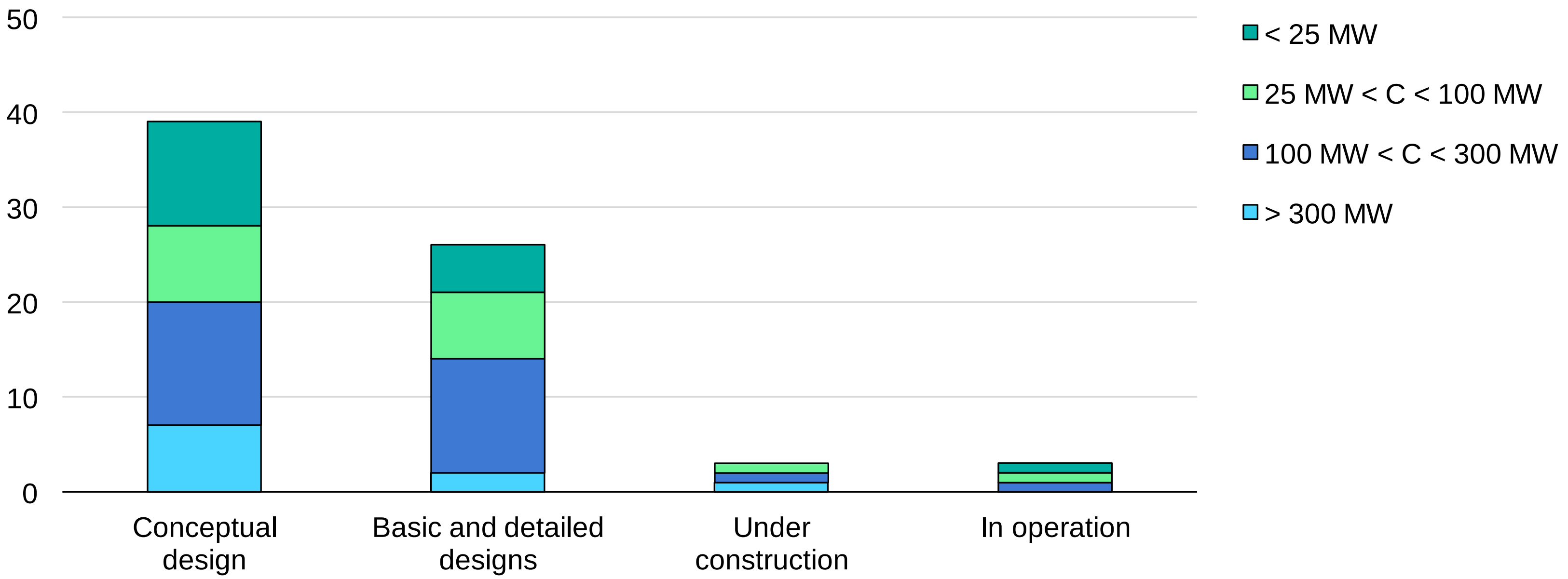
Market designs and risk mitigation can boost nuclear



Alongside other dispatchable sources, nuclear power can contribute to the reliability, stability and security of power systems to a greater degree than its share of generation alone suggests

The net zero challenge has stimulated a burst of activity on SMRs

Number of small modular reactor projects in the world by status of development



With the recent momentum, small modular reactors could complement large reactors and play a significant part in energy transitions, provided investments and development decisions are made now

Conclusions

- In countries where it is accepted, nuclear energy could play an important role in ensuring rapid and secure energy transitions.
- Energy transitions with less nuclear would be more difficult and costly.
- Investments in nuclear must step up fast. Existing nuclear plants must be extended.
- The nuclear industry has to deliver new projects on time and on budget.
- Electricity market designs must recognise the value of dispatchable low emissions capacity.
- Governments should promote efficient and effective safety regulation, implement solutions for nuclear waste disposal and create financing frameworks for new reactors.
- Net zero would require innovation in many areas. Small modular reactors are a promising technology.
- The IEA stands ready to support the security, affordability and sustainability of energy through an all fuels and all technologies approach.

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Energy Security – UK Perspective

Tom Greatrex, Nuclear Industry Association

Nuclear Industry Association

UK Energy At Present

- UK energy approximately 85% fossil fuels
- Electricity is 17% of total energy demand, and is about half decarbonised
- Seven times as much clean energy is needed in total for net zero
- 38% of electricity should be ‘firm’, i.e. not weather-dependent
- **Net Zero Needs Nuclear**

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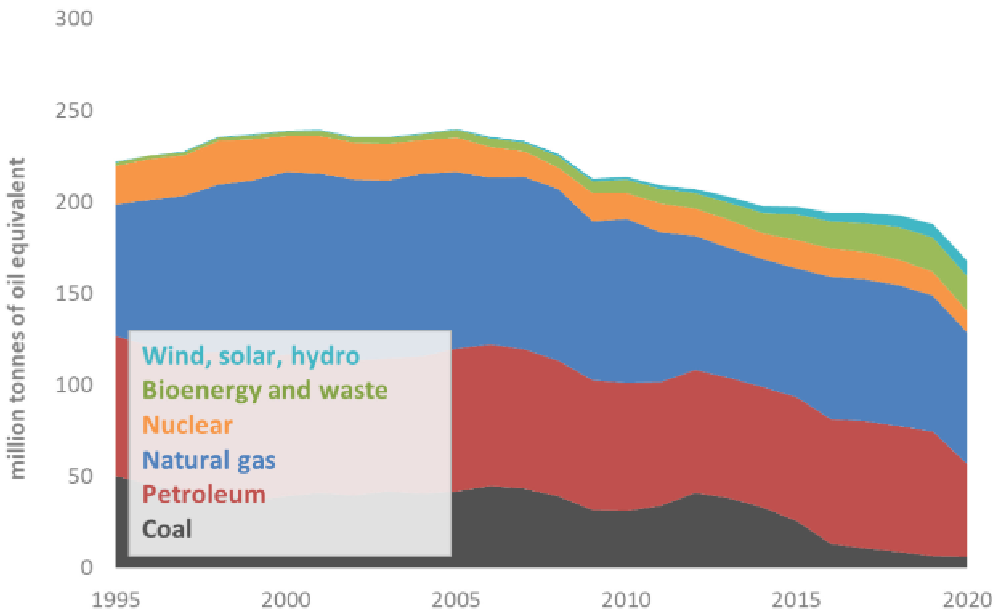
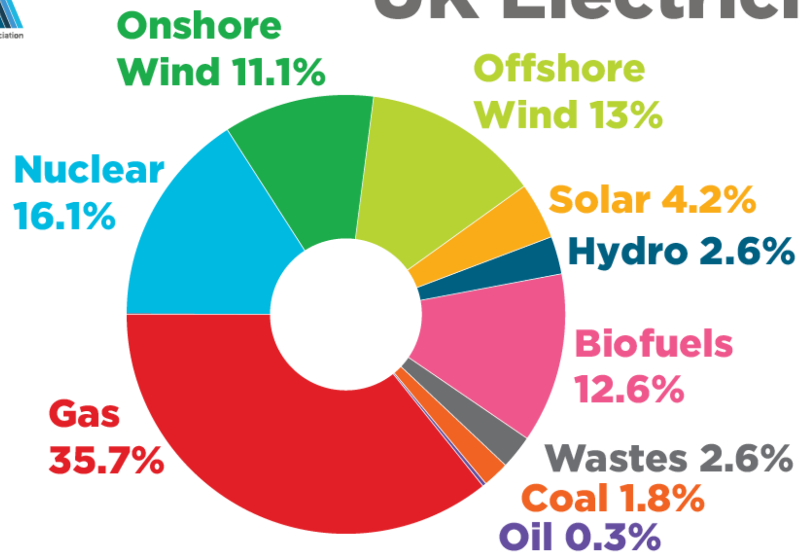
Demand for energy in the UK, 1995 – 2020



UK Electricity Mix



Source: 2021 Digest of UK Energy Statistics, BEIS

Recent Energy Security Issues

- High global gas demand globally, plus other factors, e.g. Ukraine, resulting in electricity price increasing
  - Day Ahead prices well above Hinkley Point C strike price of £92.50/MWh
- **More low carbon generation will result in lower sensitivity to gas prices**
- Balancing costs increase as variable renewables make managing the system more difficult
  - Circa £2.5 billion spent on balancing the grid in 2021, £90 per household
- **Firm power lowers balancing costs**
- **Nuclear is the only viable electricity source that is both firm and low carbon**

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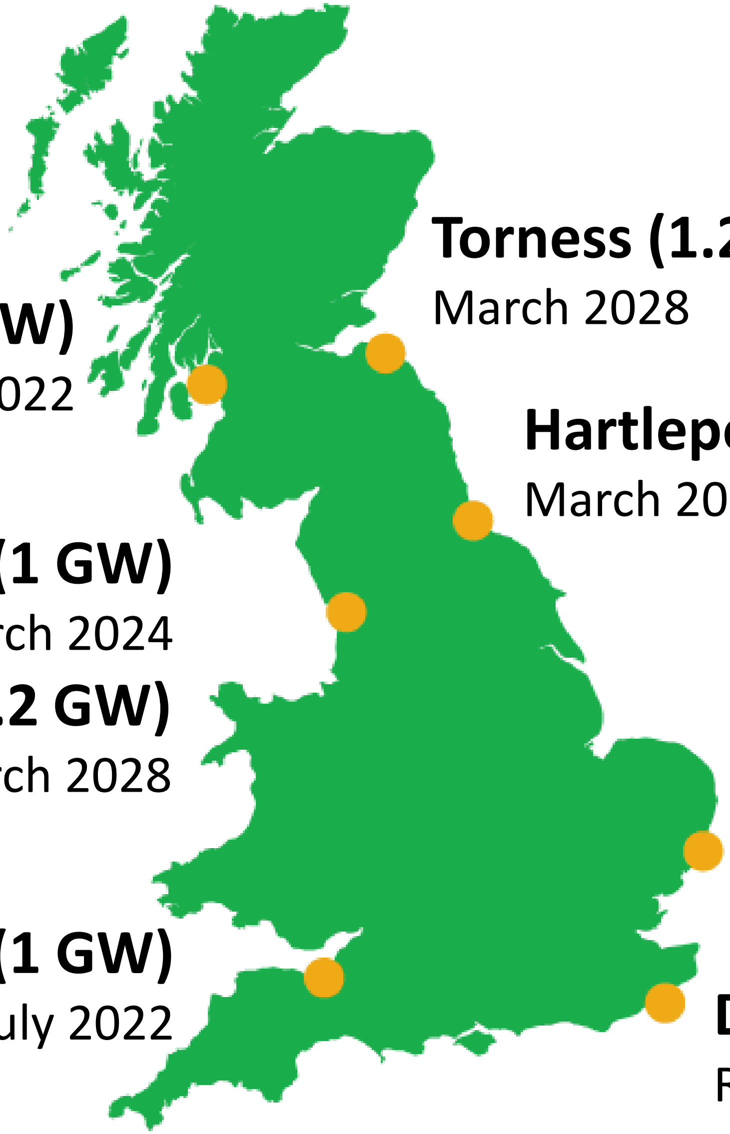
Retirement of current fleet



Torness (1.2 GW)
March 2028

Hunterston B (1 GW)
RETIRED January 2022

Hartlepool (1.1 GW)
March 2024

Heysham 1 (1 GW)
March 2024

Heysham 2 (1.2 GW)
March 2028

Sizewell B (1.2 GW)
2035+

Hinkley Point B (1 GW)
July 2022

Dungeness B (1.1 GW)
RETIRED June 2021

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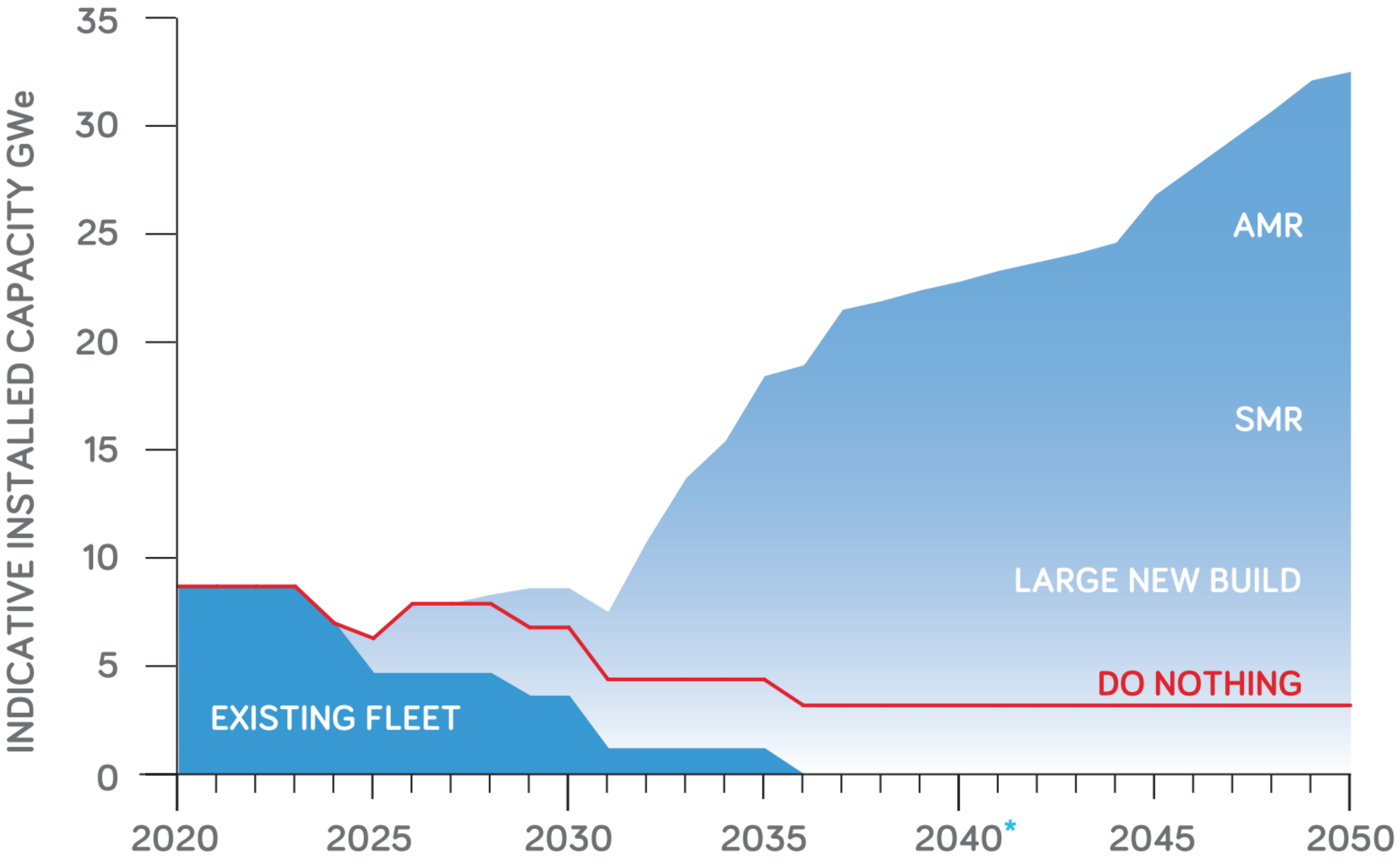
Figure 4 *Potential nuclear capacity to 2050*



* Delivery of a Spherical Tokamak for Energy Production (STEP) prototype reactor by 2040

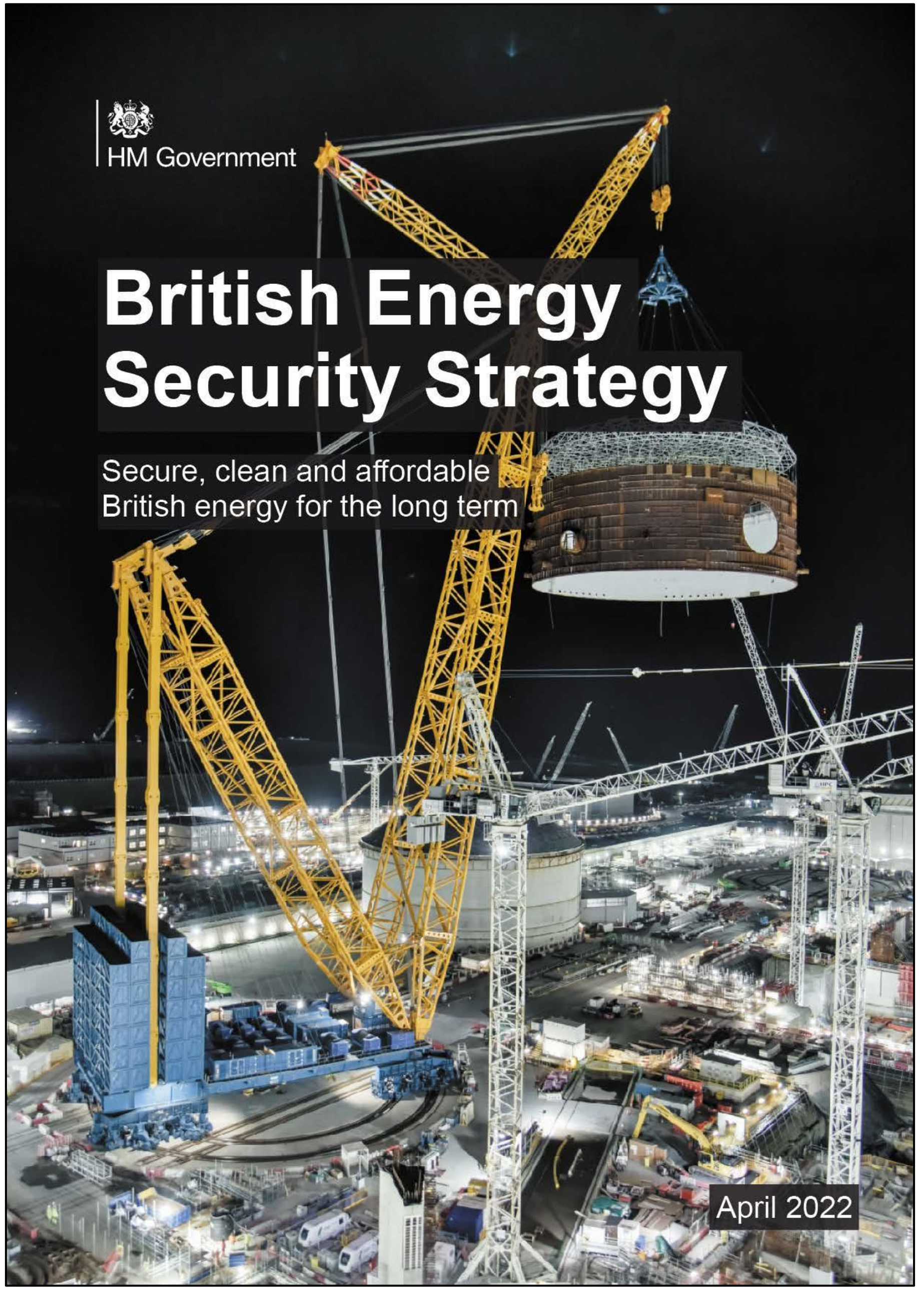
British Energy Security Strategy

24Gw of new nuclear by 2050

Accelerated development timeframes

Large and SMR reactors deployed

Towards 25% nuclear in future power mix



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Public Policy – achieving the ambition ?

Financing mechanism

Policy statement of intent

UK Taxonomy

GB Nuclear – to drive activity

Skills and supply chain

International opportunities

Nuclear Industry Association

Nuclear Industry Association

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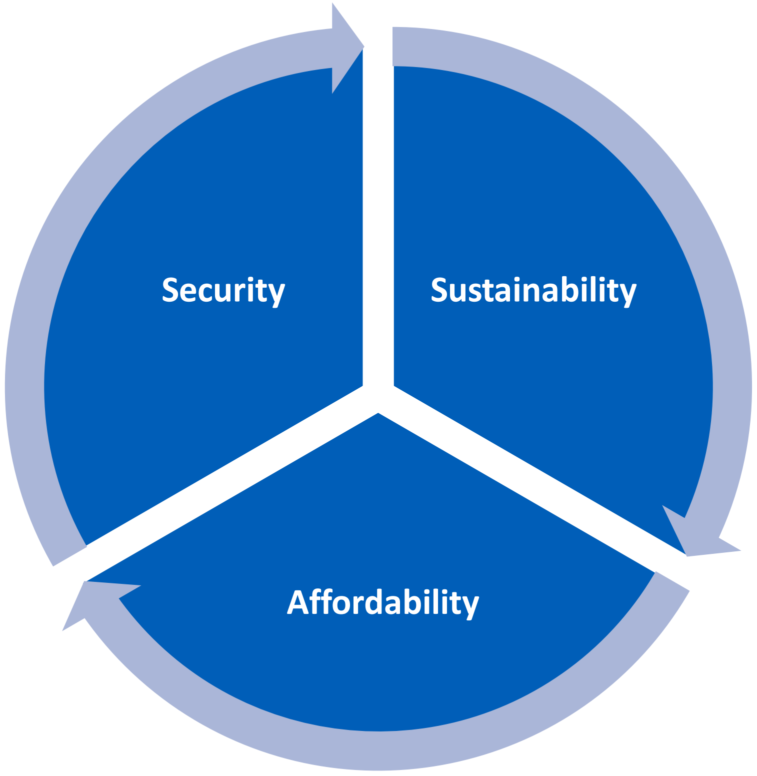
Addressing the Energy Trilemma with BWRX-300 SMR

NNWI Forum 2022
18th October 2022
Fredrik Vitabäck

Nuclear can play a differentiated and critical role in solving the energy trilemma

Nuclear provides safe, reliable, dependable baseload

- Safety record that is superior to other sources/industries
- Provides standalone 24/7 dispatchable baseload
- >90% capacity factors
- Promotes energy independence and diversified supply



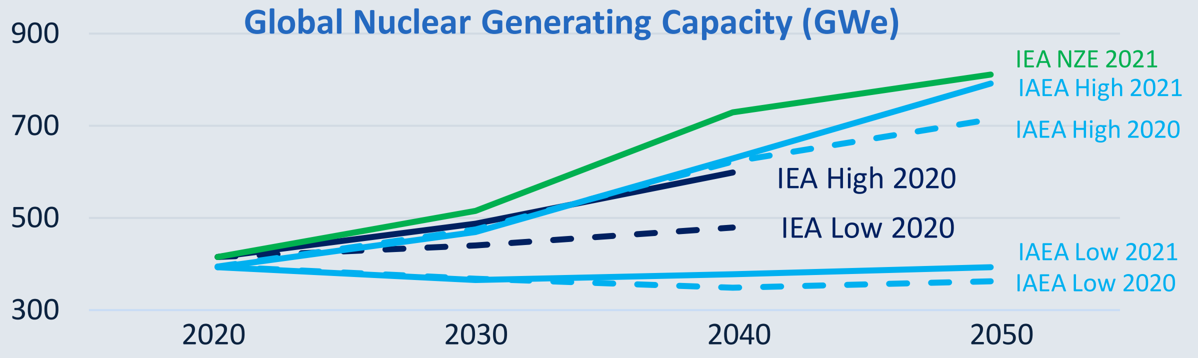
Nuclear will help meet decarbonization and sustainability goals

- Provides 24/7 carbon-free electricity
- Significantly smaller footprint compared to wind and solar
- Potential to drive deep decarbonization of industry through process heat applications
- Spent fuel can be effectively managed and potentially reused

SMR developers are focused on driving down costs and will bring broader economic advantages

- Serial construction of simplified and standardized SMR modules will reduce Capex
- Shorter construction duration achieved by developers will reduce the cost of financing
- Ability to add modules and generate electricity incrementally will drive economies of scale, further reducing investment risk
- Rejuvenation of communities driven by high paying jobs, localized supply chains and economic multipliers

Net-zero outlook shows nuclear as a key part of the energy transition



2X

Global installed **nuclear capacity expected to double between now and 2050** to around 800 GWe under IEA and IAEA decarbonization scenarios

- Expect new construction in emerging markets to be driven by large-scale, conventional reactors
- Expect new construction in advanced economies to be driven by advanced nuclear SMRs

NEI survey and modeling grid nuclear demand for 2050s decarbonization

- Surveyed their members resulted in 57-92 GWe (high-cost vs nominal cost)
- Scaled that survey to all of US … 133-219 GWe
- Commissioned Vibrant Clean Energy to model 95% reduction in carbon … 60 – 336 GWe (constrained vs nominal case)
- INL/DOE modeling forecasted 163 GWe for nominal case (3/4 SMRs)

Conservatively estimating **90 GWe by 2050**, equating to ~**300 SMRs** of 300 Mwe

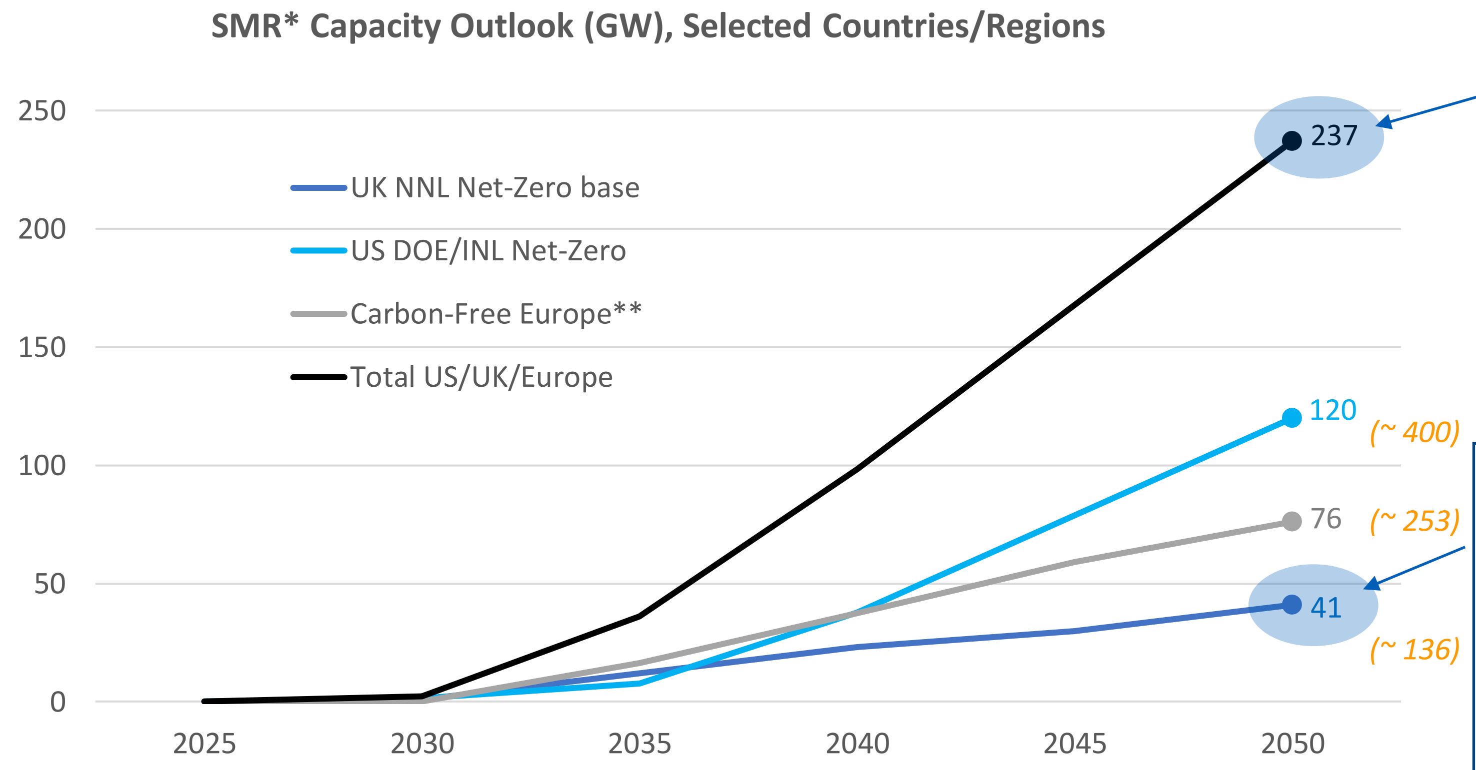
Key Challenges

- Successes with First-of-a-Kind
- NRC Licensing Efficiency
- Siting
- Supply Chain Ramp-up … global demand
- Workforce Expansion
- Facilitation of Export … global demand
- Global demand may dwarf U.S. – heavy competition

Nuclear plays an increasing role in achieving net zero targets by mid-century in most models

Sources: IEA WEO (2020); IEA Net Zero Emissions (NZE) by 2050 (2021); IAEA Power Estimates Through 2050

Decarbonization, electrification and energy security will drive opportunities for new nuclear deployment as a reliable, carbon-free source of baseload generation



* Includes Gen III+ and Gen IV designs
** Includes Belgium, Bulgaria, Czech Republic, Estonia, Finland, France, Germany, Hungary, Lithuania, Netherlands, Poland, Romania, Spain, Slovenia, Sweden. Assumes SMRs account for 75% of new nuclear capacity installed post-2030

Sources: INL, NNL, Carbon-Free Europe

Projected SMR market in US/UK/Europe estimated value
~$1.2 trillion

(~ 790 SMRs of 300 MWe size)

New British energy security strategy goal of 24GW from nuclear by 2050 represents around 25% of projected electricity demand

Additional capacity could be dedicated to

- Industrial process heat applications
- Hydrogen production
- On-site (behind-the-meter) generation

Investment in sustainable, affordable, reliable nuclear power will become an essential pathway to achieving net-zero

BWRX-300 small modular reactor

- 10th generation Boiling Water Reactor
- World class safety
- Leverages U.S. NRC licensed ESBWR
- Design-to-cost approach
- Significant capital cost reduction per MW
- Capable of load following
- Ideal for electricity generation and industrial applications, including hydrogen production
- Constructability integrated into design
- Initiated licensing in the U.S. and Canada
- Operational as early as 2028

MOST
COMPETITIVE SMR

Current projects

Ontario Power Generation selects **GEH's BWRX-300**

CLARINGTON, ONTARIO | DEC. 2, 2021

GE Hitachi Nuclear Energy Selected by Ontario Power Generation as Technology Partner for Darlington New Nuclear Project.

- Deployment could be complete as early as 2028
- Substantial economic opportunity for Ontario and Canada
- The project will leverage the Canadian supply chain
- First BWRX-300 could deliver …
  - $2.3 billion in gross domestic product
  - $1.9 billion in labour income
  - $750 million in tax revenue

Current projects

TVA, GEH cooperate on **BWRX-300 deployment at Clinch River**

AUGUST 3, 2022

Tennessee Valley Authority (TVA) announced it has entered into an agreement with GEH to support its planning and preliminary licensing for the potential deployment of a BWRX-300 small modular reactor (SMR) at the Clinch River site near Oak Ridge, Tennessee.

This follows a collaboration agreement with Ontario Power Generation (OPG) in April to support the development of SMRs in both Canada and the US.

Significant momentum

POLAND | DECEMBER 2021

Polish companies Synthos Green Energy (SGE) and PKN Orlen have signed an investment agreement to establish a joint venture for the deployment of a small modular reactor (SMR) fleet in Poland.

SGE plans to deploy at least 10 BWRX-300 SMRs in Poland by early 2030s

GE Hitachi Nuclear Energy, BWXT Canada and Synthos Green Energy Announce Intention to Support Deployment of Small Modular Reactors in Poland

SaskPower
Powering our future®

SASKATOON | JUNE 2022

SaskPower selects the GE Hitachi BWRX-300 small modular reactor technology for potential deployment in Saskatchewan

Multi-year assessment focused on several factors including safety, technology readiness and fuel type

Selection of same technology as OPG helps enable a pan-Canadian, fleet-based approach to SMRs

Sweden | March 2022

Kärnfull Next and GE Hitachi signed memorandum of understanding to collaborate on deployment of BWRX-300 in Sweden.

Kärnfull Next is the first project development company to focus on SMRs in Scandinavia

GE Hitachi Nuclear Energy
BWRX-300 Small Modular Reactor

HITACHI

Key Takeaways

In the 2020s
Proven technology
<50% material/MW
More catalogue items
<30 months construction
Gets along with wind and solar
Lowest cost Hydrogen production

NNWI Forum 2022
18th October 2022
Fredrik Vitabäck

GE

HITACHI

ENERGY
INFRASTRUCTURE
MINING & METALS
NUCLEAR, SECURITY
& ENVIRONMENTAL

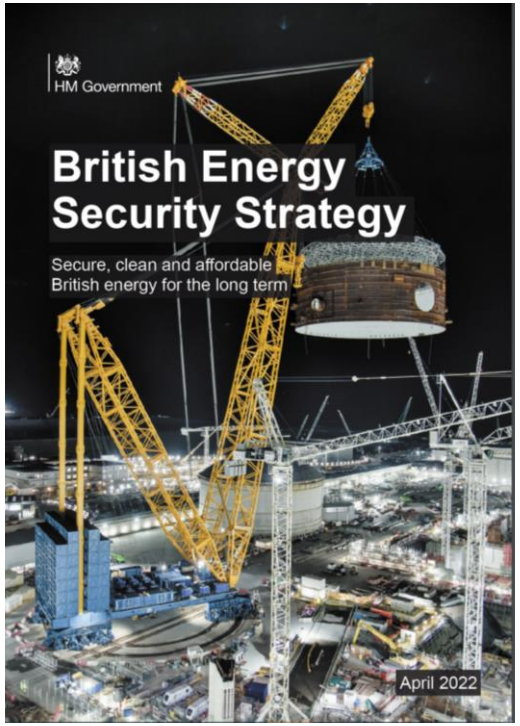
Presentation to: NNWI

Accelerating Future Nuclear Projects

October 2022

Level 4 – Public

GB Energy Security Strategy & Nuclear

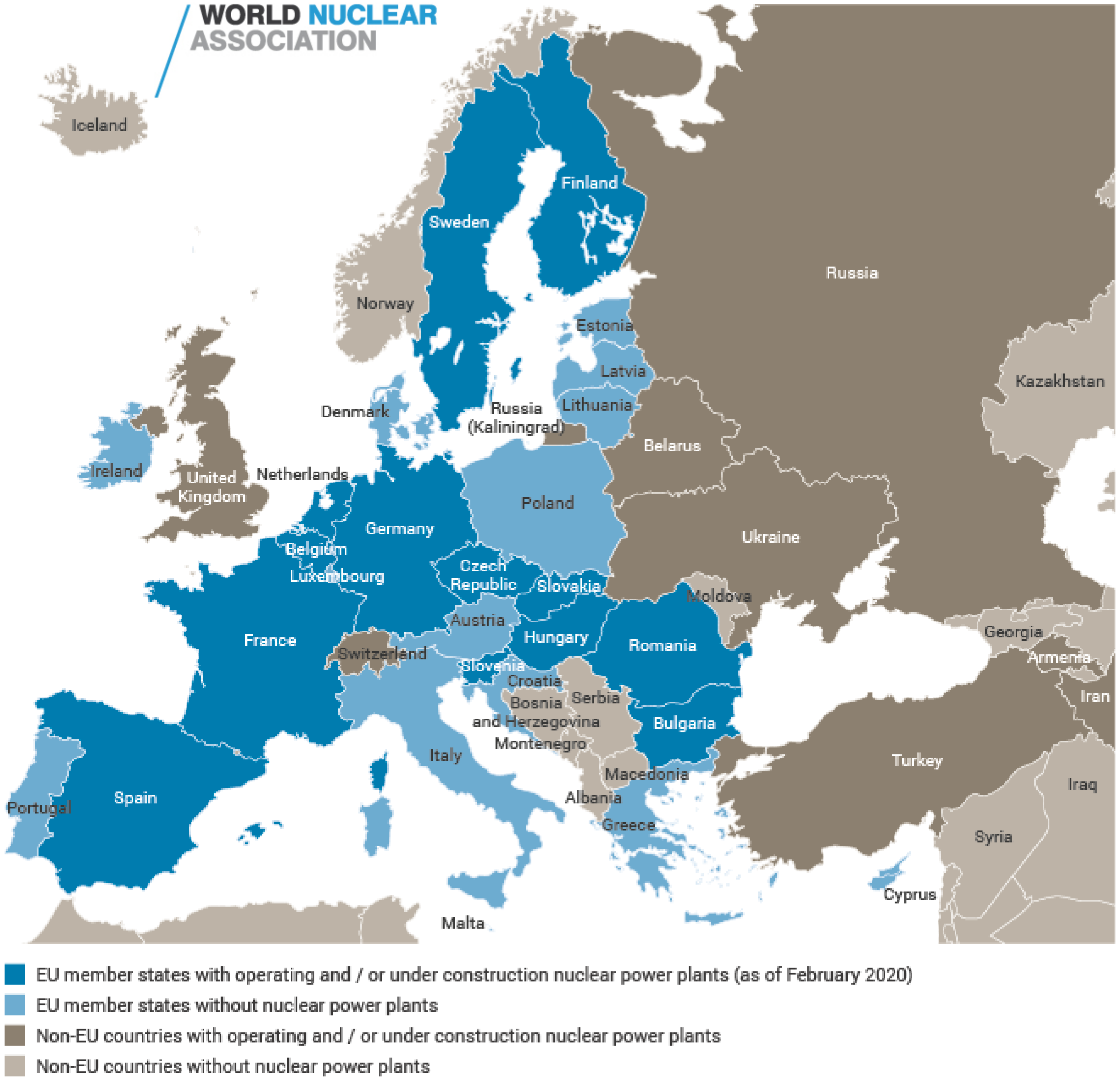


16+ GW =

- 6 x Large Reactors GEN III+
- 30 x Small, GEN III+ & GEN IV
- 10,000 days

1 X FID	2 X FID	6.4 GW
2022 - 2024	2024 - 2028	2028 - 2050

No Country is a Nuclear Island…



Country	Potential New	Date
Poland	Up to 8GW	2030's, 40's
Czech Republic	Up to 2.4GW	2030's
France	Up to 9.6GW	2030's, 40's
Ukraine	Up to 10GW	2030's, 40's
Slovenia	Up to 1.1GW	2030's

This is just for the grid, and just in Europe.

Greater cooperation is required with our allies, will support our own programme and export potential.

Bechtel | Nuclear experience over seven decades

NNWI

We have delivered civil and defence nuclear projects in both the front-end and back-end of the nuclear fuel cycle.

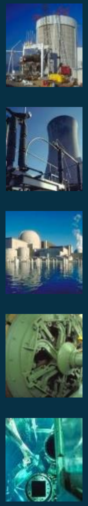
1949 Contract to build Experimental Breeder Reactor (EBR-1)

1948 Design of AEC's nuclear accelerator at Los Alamos

1955 Dresden, world's first privately-financed nuclear plant

1957 Vallecitos, General Electric's first Boiling Water Reactor (BWR)

1962 NPD, Canada's first nuclear plant



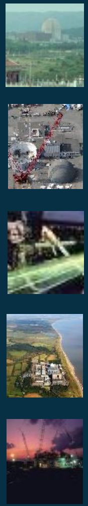
1971 Palisades

1974 Limerick, restart program

1976 Palo Verde 1, 2 & 3, largest U.S. nuclear plant

1978 Waste Isolation Plant, New Mexico

1979 TMI 2, stabilization and decontamination



1984 Maashan, China (Taiwan)

1993 Hanford Environmental Restoration

1995 Atomic Vapor Laser Isotope Separation (AVLIS), development and deployment

1995 Sizewell B, UK's only PWR

1996 DOE Savannah River Site, remediation and project management and construction

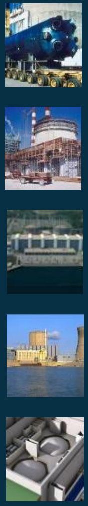
2001 Yucca Mountain

2002 Dominion, Early Site Permitting (ESP), North Anna site

2003 TVA, cost and feasibility study, Bellefonte site

2005 Hanford River Corridor Closure

2006 Los Alamos National Laboratory



2007 **SGR and reactor head removal & disposition**

2008 Extended power uprates
- Turkey Point
- St. Lucie
- Pt. Beach

2008 Calvert Cliffs EPR Design/and Construction Planning

2009 Davis Besse SGR

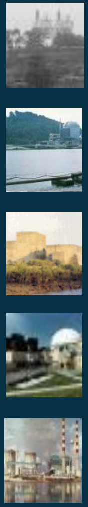
2010 mPower Small Modular Reactor (SMR)

2020 VTR

2020 Vogtle Units 3&4

2020 Natrium

1940 1950 1960 1970 1980 1990 2000 2010 2020



1963 Humboldt Bay, first pressure suppression containment

1966 Peach Bottom, first HTGR reactor

1969 Tarapur 1 & 2, India

1960s Two additional nuclear plants

1971 Turkey Point 3 & 4, first pre-stressed, post-tensioned concrete containment

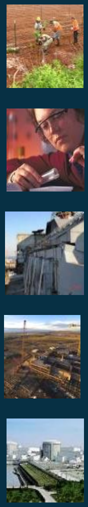
1981 South Texas, Completion transferred to Bechtel

1981 Kuosheng 1 & 2, China (Taiwan)

1982 Turkey Point 3, Bechtel's first SGR

1983 KORI 3 & 4, South Korea

1984 ASCO 1 & 2, Spain



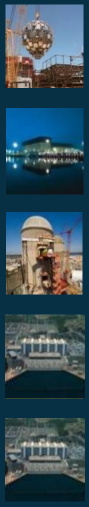
1998 Oak Ridge, Management and Operation

1999 INEEL, Management and Operation

1999 Chornobyl, Shelter Implementation Plan

2000 Waste Treatment Immobilization Plant, Richland, Washington

2000 Qinshan, China



2007 Lawrence Livermore National Laboratory

2007 TVA, Browns Ferry Unit 1 restart

2007 Comanche Peak SGR—sets world record

2007 Watts Bar Unit 2 Completion

2007 New Generation activities
- 3 site-specific engr. studies
- 2 ESPs
- 7 COLs

2010 Bellefonte Engineering

2011 Xcel Energy Fleetwide Engineering Services & Columbia Engineering Services

2011 KEPCO E&C Consulting Services
- Shin Kori
- Shin Ulchin
- Barakah

2012 Pile Fuel Cladding Silo at Sellafield

2015 Watts Barr

Fusion & Big Science Experience

- **International Thermonuclear Experimental Reactor (ITER).** We provided initial engineering management and support to the U.S. Home Team in site & facility design
- **National Ignition Facility (NIF).** In an integrated team, we manage the US$3.5B Inertia Confinement Fusion facility using lasers to attain ignition & self-sustaining fusion reaction at Lawrence Livermore National Laboratory
- **TriAlpha Energy (TAE).** We provided on facility support to TAE in the facility design including balance of plant and supercritical cycle for heat exchanging
- **U.S. Department of Energy ARPA-E Fusion Program.** We prepared conceptual fusion power plant design and cost estimate for four compact fusion reactor technologies
- **Princeton Plasma Physics Laboratory (PPPL).** We provided support to PPPL's Tokamak Fusion Test Reactor (TFTR) in the areas of tritium retrieval, shielding, and remote handling
- **University of Illinois (UI) and Pennsylvania State University (PSU).** Bechtel has been collaborating with UI and PSU in conceptually designing the lithium blanket, tritium extraction facility, and heat exchanging systems for fusion reactor power plant

Proven Team with a Proven Technology

Vogtle Units 3 and 4.
Images courtesy of Southern Nuclear Company.

- 4 x AP1000 Units are breaking industry records in commercial operation, 2 are in final stages of commissioning and 4 more are in construction.
- In the US, Bechtel and Westinghouse, are working together to complete the first nuclear power station in a generation – Plant Vogtle.
- Vogtle Unit 3 is ready for fuel load and Unit 4 is now 96% complete, moving toward final systems testing.
- The AP1000 Plant is highly modularised, uses significantly fewer material quantities per MW/h, and is easier to construct, leading to faster and lower cost construction than other available technologies.

Team Wylfa – Accelerating Delivery

NNWI

A Three-Phase Approach

Team Wylfa envisions a 3-phase approach to the project, all geared toward making Wylfa Newydd a viable project for developers, delivering power to the grid as quickly as possible whilst maximising the value of investment to UK plc.


2 Unit AP1000 Rendering, Wylfa Newydd

Phase 1a & 1b – Pre-Developer – Project Viability

- Demonstrate viability of project for investors
- Perform early design & planning activities to de-risk the project
- Develop supply chain strategy, maximise the value to UK companies
- Secure access to the site

Phase 2 – Developer Led – Project Enablement

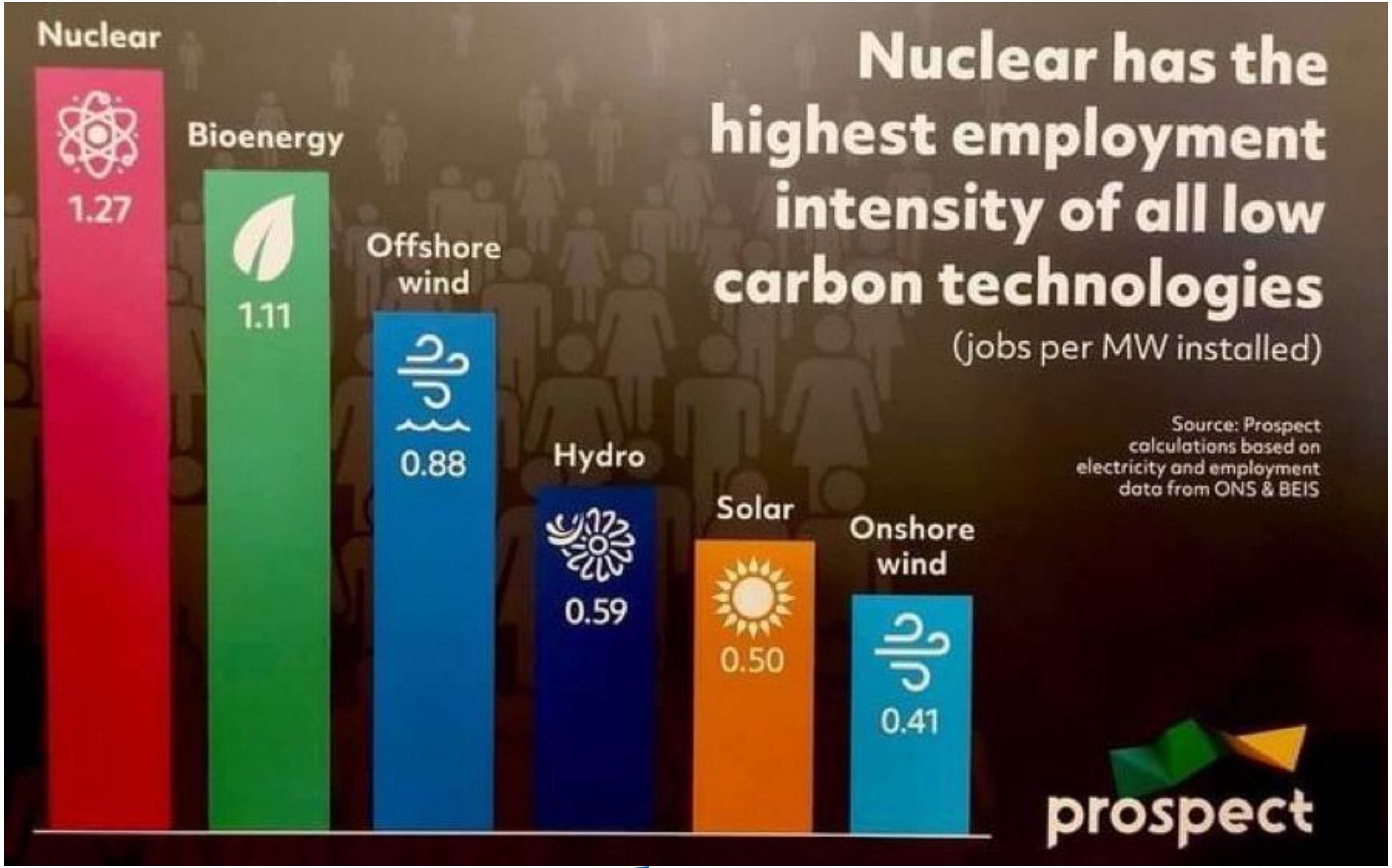
- Complete Development Consent Order and site licencing processes.
- Complete preliminary design for nuclear island, turbine island, and balance of plant.
- Begin procurement on long-lead time equipment
- Begin placing construction contracts and start production of work packages
- Finalise estimate, schedule, and risk assessment

Phase 3 – Developer Led – Construction, Commissioning & Start-Up

- Complete engineering design
- Receive long-lead time items, modules, plant equipment & components, bulk commodities
- Plant construction
- Commissioning & Start-Up

Lessons Learned, Plant Vogtle

Team Wylfa – Levelling Up



TEAM WYLFA

Q&A

Level 4 - Public

NNWI Forum 2022

Economic Efficiency Panel

Chaired by Phil Chaffee, London Bureau Chief and Deputy Editor, Nuclear Intelligence Weekly

- Tim Yeo, Chairman, **New Nuclear Watch Institute**
- Chris Heffer, Director of Nuclear Power, Infrastructure and Decommissioning, **BEIS**
- Antonio Vaya Soler, Senior Energy Analyst, **OECD NEA**
- Harry Keeling, Head of Industrial Markets, **Rolls-Royce SMR**
- Attila Hugyecz, Chief Economic Advisor, **Paks II. Nuclear Power Plant**

#NNWIForum2022

Why Nuclear Power is Economically Efficient

Tim Yeo
Chairman
New Nuclear Watch Institute

- Net Zero Emissions by 2050 is minimum goal
- Accelerate investment in all low carbon electricity generation technologies and energy efficiency
- Clean energy transition – the high growth economy option

- The opportunity for nuclear

- The cost of leaving nuclear out

The economic efficiency of nuclear

- Stable costs
- Reliable performance
- Lowest carbon footprint

Priority actions

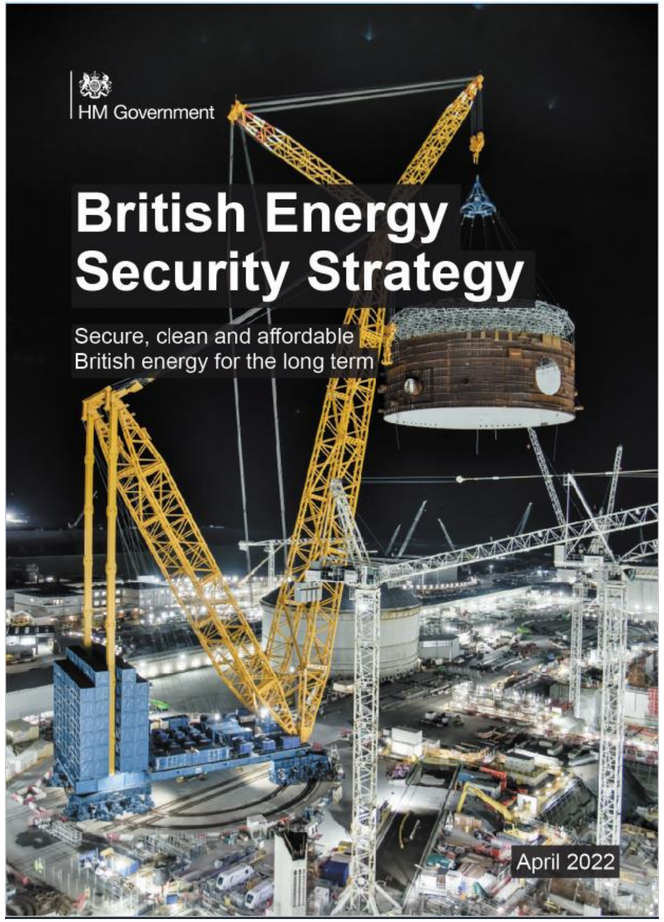
1. Extend life of existing plants – the low hanging fruit

2. Reap economies of scale – avoid larger FOAK reactors

3. Stay in the SMR race

Nuclear:
Competitive Environment & Economic Growth

NNWI: Addressing the Energy Trilemma
18th October 2022

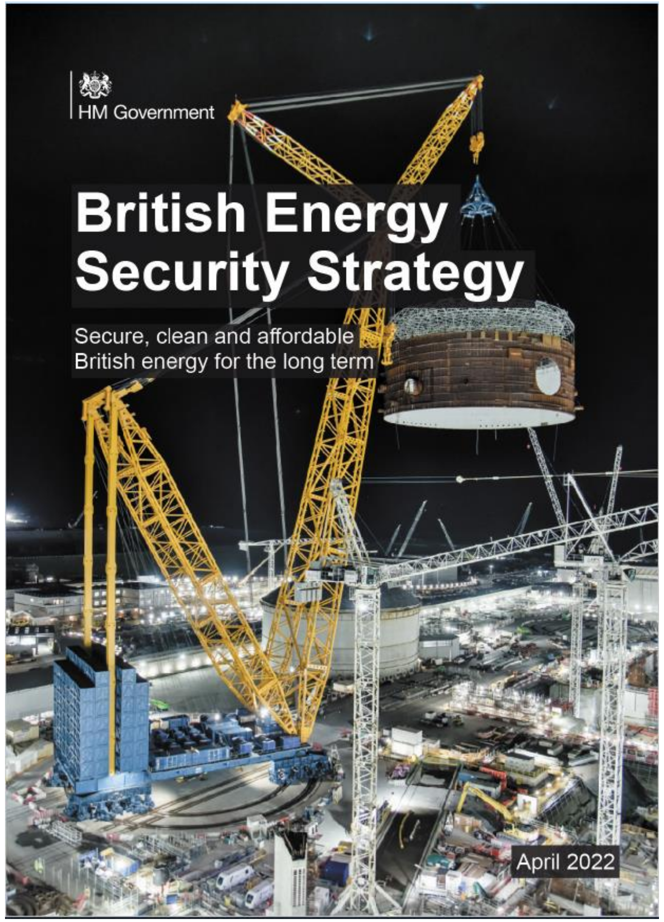


Energy Trilemma - Nuclear

The economic competitiveness of nuclear energy is crucial for increasing its share in world electricity production, as well as for future economic growth. From an economic and sustainability standpoint, it is crucial to have the right balance of variable renewables and dispatchable resources, such as nuclear, to enable a resilient long-term energy infrastructure

- Secure
  - Commitment to nuclear
- Economic
  - Program
  - Finance & Delivery
- Sustainable
  - Low-carbon
  - Skills/ supply chain
  - Public & Waste

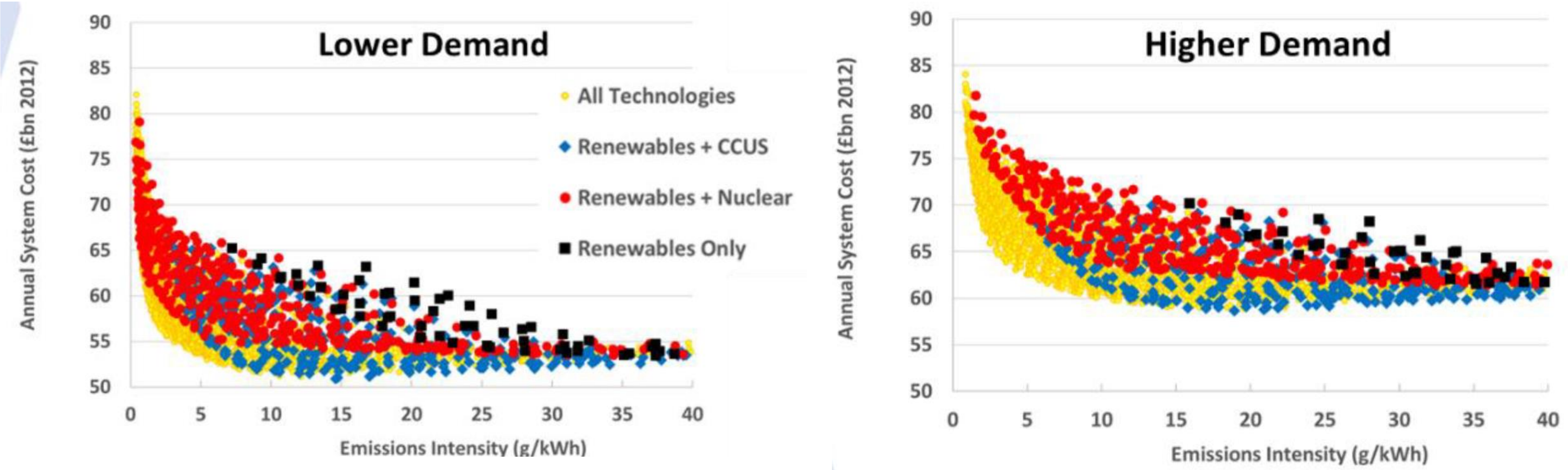
Commitment to Nuclear



- Nuclear is a key part of the British Energy Security Strategy (BESS)
  - Up to 24GW ambition by 2050
  - Two projects to Final Investment Decision next Parliament

Why Commit? Cheaper with Nuclear

2050 PSO – without hydrogen



Department for Business, Energy & Industrial Strategy

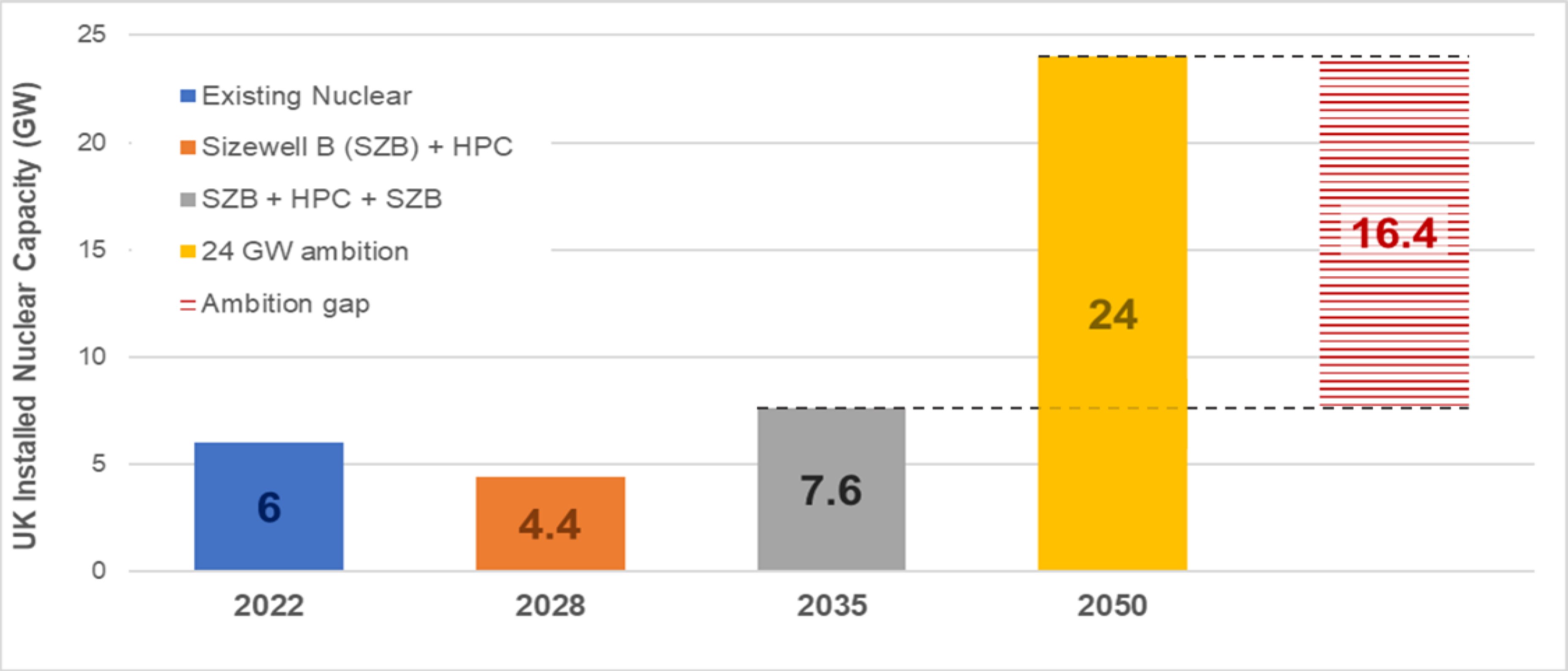
Why Commit? (2) And it's low carbon

The Committee on Climate Change (CCC) also estimate lifecycle emissions of nuclear and counterfactual technologies in a 2013 report: Reducing the UK's carbon footprint[81]. The report presents results from previous studies as well as their own estimates.

Technology	Literature Estimate gCO2e/kwh	CCC Estimate gCO2e/kwh
Nuclear	5-55	3–10
Onshore wind	7-20	4-7
Offshore wind	5-24	3-5
Gas CCS	90-245	60-120
Solar PV	40-80	20-45

Source: https://www.theccc.org.uk/publication/carbon-footprint-and-competitiveness/69

Have a program – beyond SZC



OFFICIAL SENSITIVE

Department for Business, Energy & Industrial Strategy

Have a delivery model

- Setting up the Great British Nuclear Vehicle this year, tasked with helping projects through every stage of the development process and developing a resilient pipeline of new builds.
    - We will work with industry to scope the functions of this entity starting straightaway – building on UK industrial strengths and expertise
- Backing Great British Nuclear with funding to support projects to get investment ready and through the construction phase.

Have a finance model

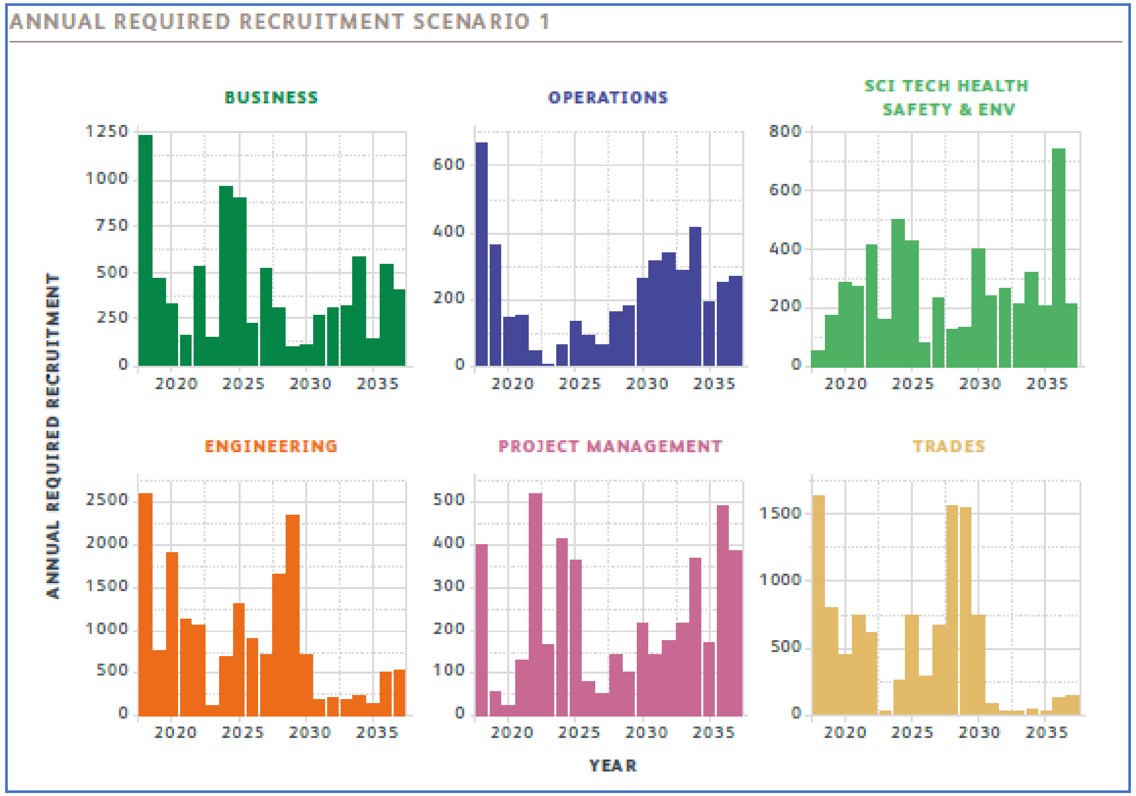
- The UK Government has enacted the “**Nuclear Energy (Financing) Act 2022**” which allows for Regulated Asset Base (RAB) models to be used for new nuclear.

__A RAB financing model splits the initial project risk__

The RAB model used shares risk between investors, HMG and consumers. Any risk which is placed on consumers is spread among a large number of individuals. Although each consumer may be risk averse, each consumer is exposed to a very small risk.

This is in contrast to Hinkley point C which required the investors to hold all the upfront risk.

Build the skills



*Demand for skills is based on an NSSG skills assessment scenario in which Hinkley Point C (under construction), Sizewell C (proposed) & Bradwell B (proposed 9 GWe) are delivered.

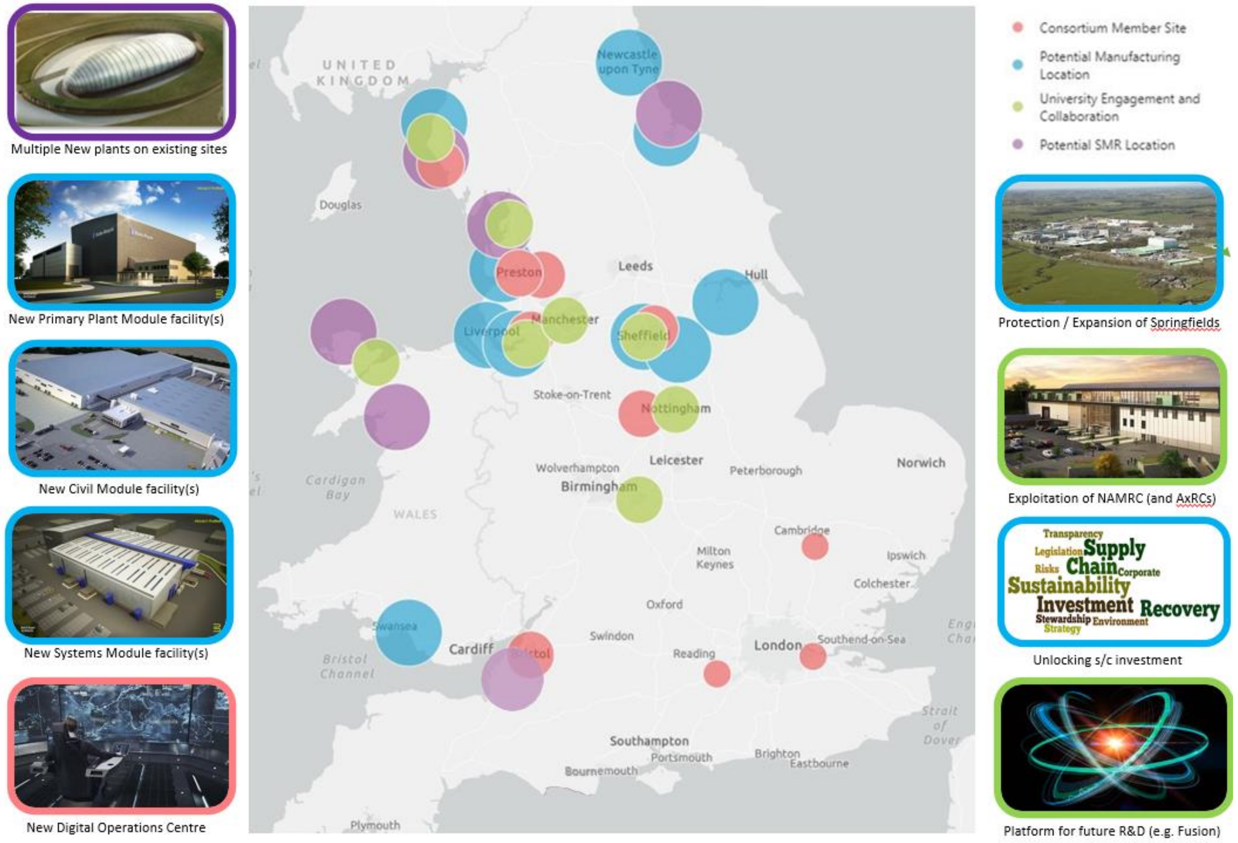
- Current nuclear workforce is dispersed across sites around the UK, but with a heavy concentration in the northwest of England, with a maturing nuclear workforce; overall one fifth of the workforce is 55 or older.
- The construction of Hinkley Point C (underway) and Sizewell C, and Bradwell B (proposed) will cause further growth, initially in the Southwest of England (2020) and later in the Southeast (2027).
- The pipeline to replenish the workforce consists of both the flow of experienced workers from other industries, and new trainees. Female participation in the workforce is 20% and women are also under-represented in STEM roles
- Trainees represent an important opportunity to increase the participation of women; the female trainee participation rate is currently 24%.
- Recruitment into the sector includes both experienced workers from inside and outside of the nuclear industry, and apprentices and graduates beginning careers in the industry.
- Of the three quarters of experienced recruits in the civil sector who had transferred from similar occupations, 60% were from outside of the nuclear industry. Of the 25% who were trainees, two thirds were apprentices and the remainder graduates.

Department for Business, Energy & Industrial Strategy

Build the future supply chain

- Advanced Nuclear also has multiple potential uses in addition to direct power generation, e.g.:
    - Industrial heat generation (for Concrete, Glass, Steel)
    - Domestic heat generation
    - Hydrogen generation
    - Water desalination
    - Medical isotope generation
    - Synthetic aviation fuel generation.

- The supply chain for the advanced nuclear would need to include a significant number of additional facilities as well as considering expansion of current capabilities, specifically Springfields which could potentially produce fuel for a number of reactor designs.



Bring public with you

Climate change

- Eight in ten people (80%) in Summer 2022 were either very concerned (39%) or fairly concerned (44%) about climate change.

Energy bills

- In Spring 22 64% worried about paying bills (29% very worried)
    - vs March 2021 when was 40% worried

Nuclear energy

- Almost four in ten people (37%, Winter 2021) either strongly supported (13%) or supported (24%) the use of nuclear energy in the UK, whilst just 14% opposed it (6% strongly opposing)
- Comparable with Shale 38% (Autumn 21), but below Fusion 48% (Spring 22) and Renewables 85% (Summer 22)

Ipsos Mori Public Attitudes survey for BEIS, Autumn 2022

Can make the case

What did we find?

A majority of participants showed caveated support for the siting and deployment of advanced nuclear to support net zero.

To **deploy** advanced nuclear:

- it must be essential to support renewable technology in achieving net zero targets,
- it should be one of several energy solutions supporting a focus on renewable energy,
- health and safety must be prioritised,
- it should not present long-term risks or leave a negative legacy, and
- there must be robust, independent regulation.

When **siting** advanced nuclear:

- distance from people must ensure health and safety,
- prioritise environmental impacts,
- make the most of existing sites and infrastructure, and
- optimise for benefits and alternative uses.

Participants' views were complex and nuanced

Participants had more questions and concerns than they had hopes

Participants were surprised that nuclear energy is a low-carbon option

Participants considered meaningful public involvement to be essential

Participant support for advanced nuclear grew over the dialogue

Moving forward, more engagement could be done on topics such as:

- waste storage and disposal
- safety
- different uses of the technologies
- different types of technologies
- advanced nuclear and other energy solutions in the pathway to net zero

www.gov.uk/government/publications/public-dialogue-on-advanced-nuclear-technologies-ants

Energy Trilemma - Nuclear

The economic competitiveness of nuclear energy is crucial for increasing its share in world electricity production, as well as for future economic growth. From an economic and sustainability standpoint, it is crucial to have the right balance of variable renewables and dispatchable resources, such as nuclear, to enable a resilient long-term energy infrastructure

- Secure
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  - Finance & Delivery
- Sustainable
  - Low-carbon
  - Skills/ supply chain
  - Public & Waste

NEA
NUCLEAR ENERGY AGENCY

Meeting Climate Targets: The Role of Nuclear Energy

NNWI Forum 2022

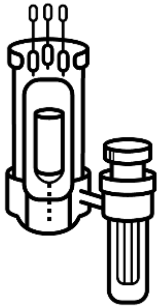
Antonio Vaya Soler
Analyst at OECD Nuclear Energy Agency

18 October2022

The Full Potential of Nuclear Energy to Contribute to Emissions Reductions

Long Term Operation

Large Gen-III Reactors



Small Modular Reactors

H_2

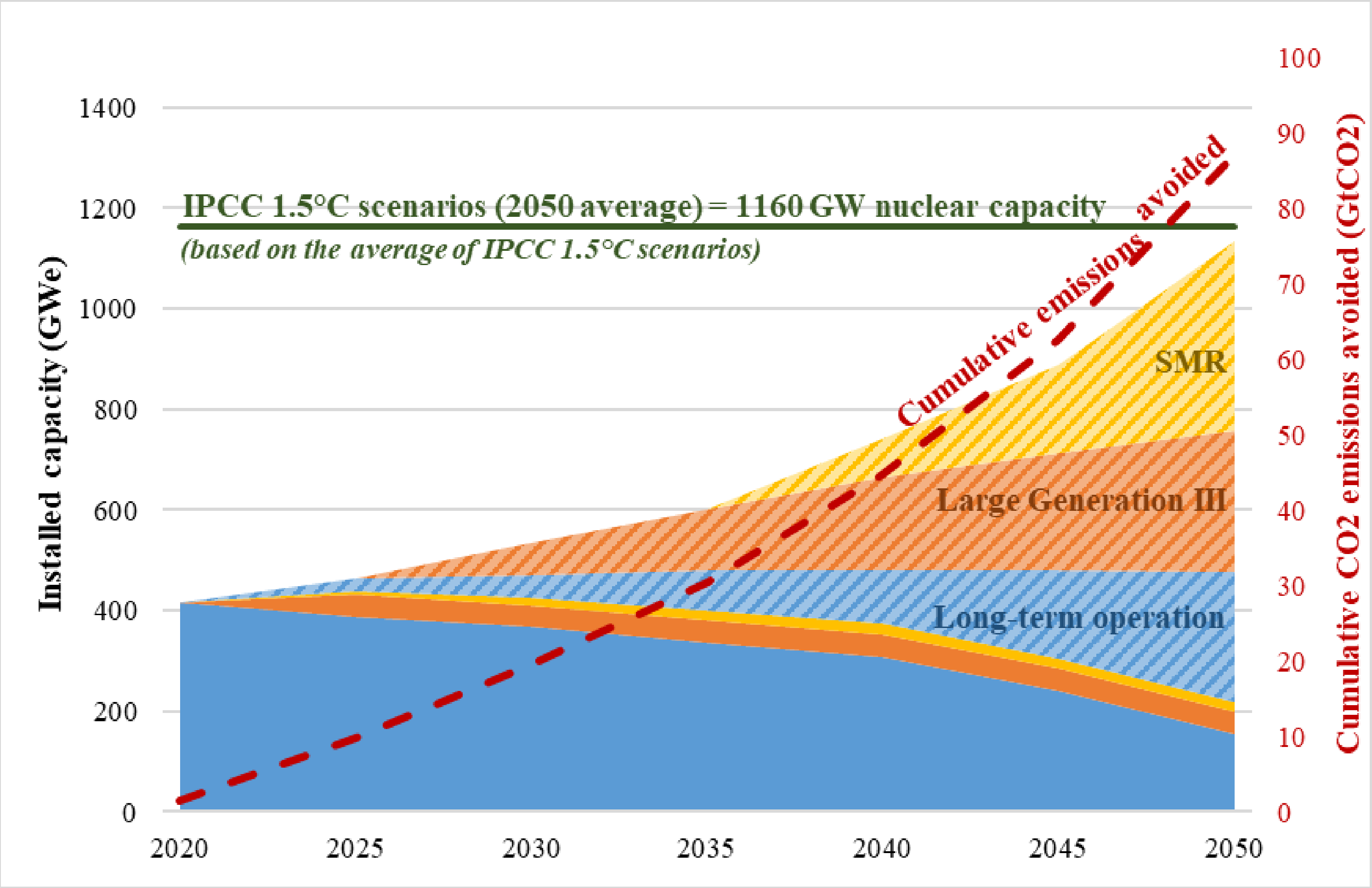
Non-Electrical applications

Complementary nuclear technologies and 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

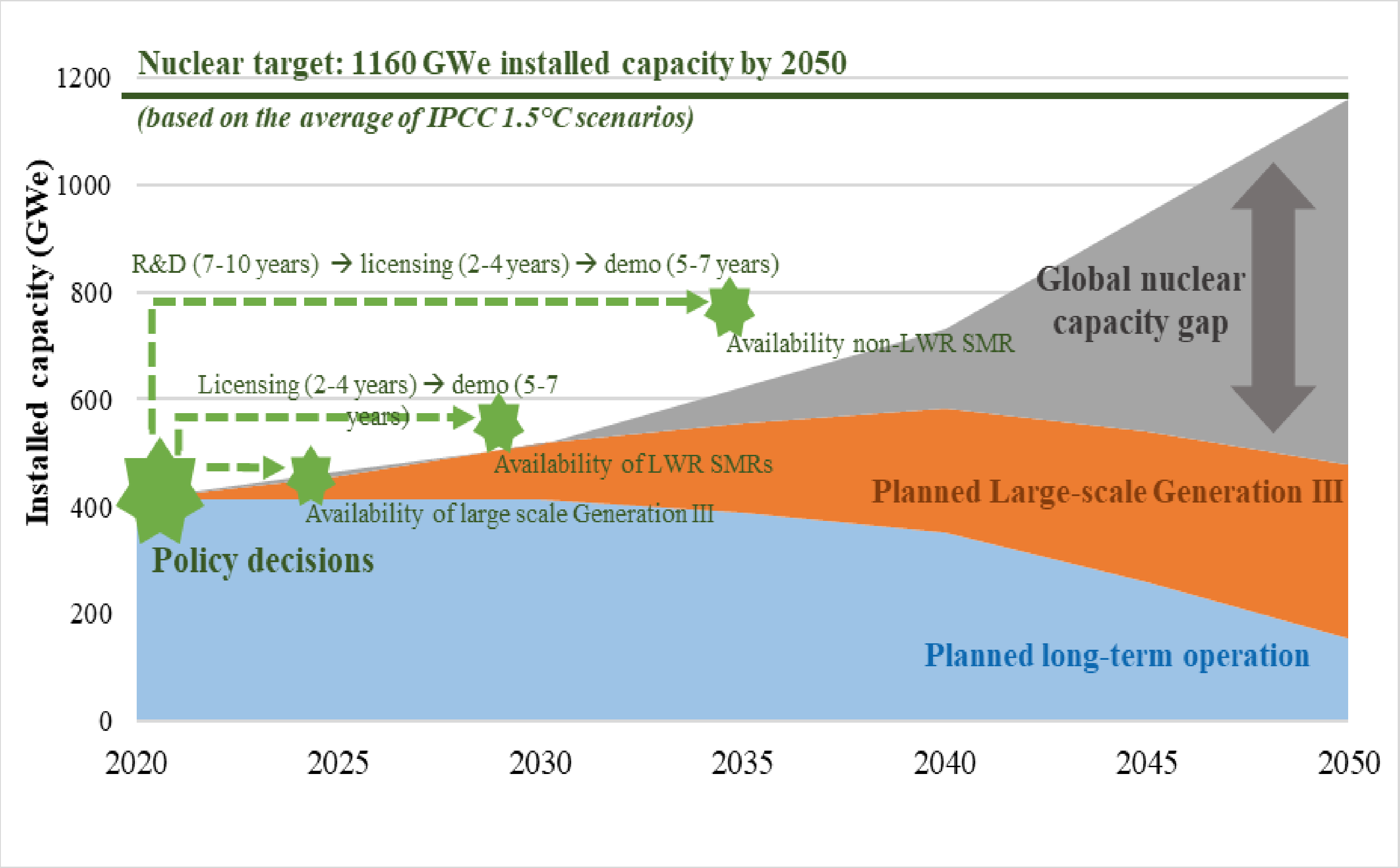


Source: NEA, 2022, "Meeting Climate Targets: The Role of Nuclear Energy"

Global Installed Nuclear Capacity Gap

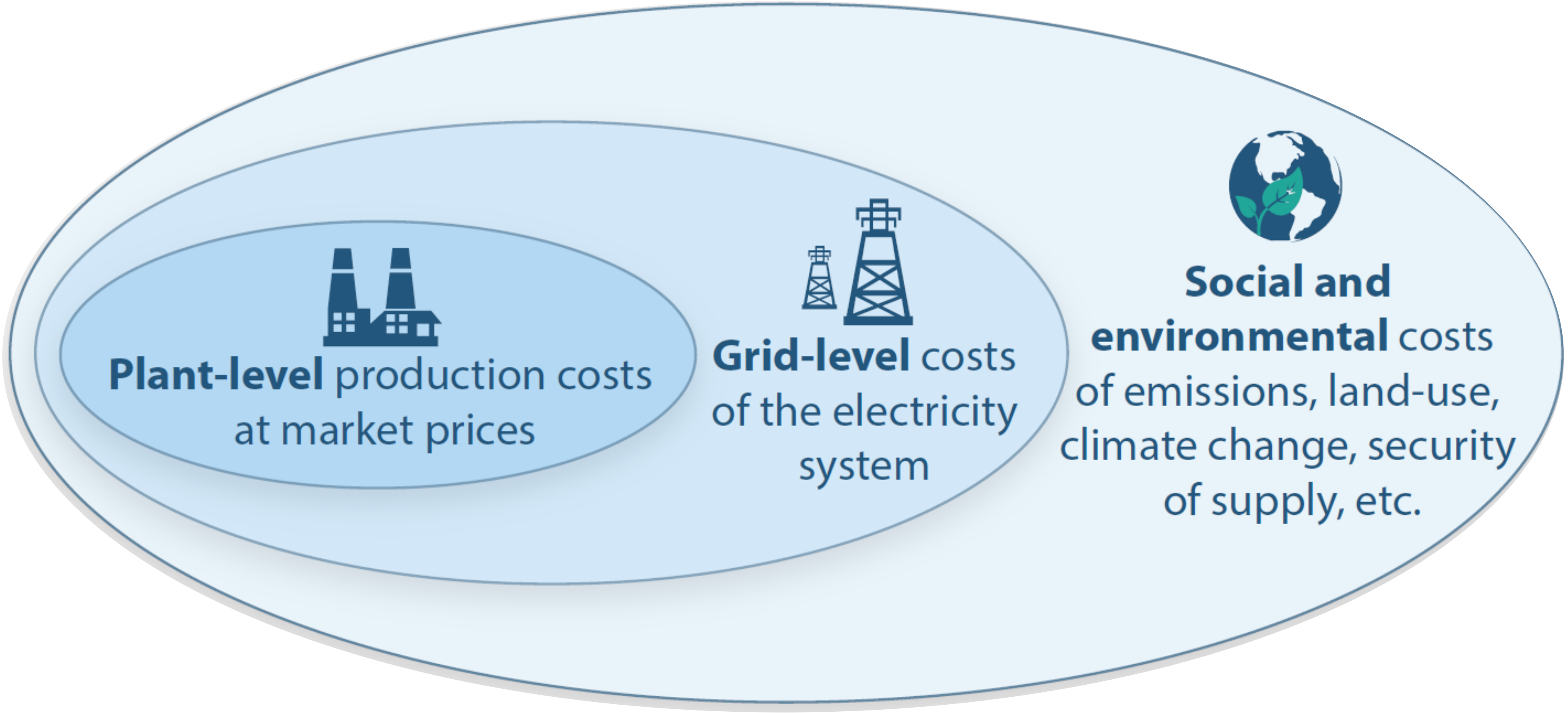
- Under current policy trends, nuclear capacity in 2050 is expected to reach **479 gigawatts** – well below the target of 1160 gigawatts of electricity
- Owing to the timelines for nuclear projects, there is an **urgency to action now to close the gap in 2030-2050**

Global installed nuclear capacity gap (2020-2050)



Source: NEA, 2022, "Meeting Climate Targets: The Role of Nuclear Energy"

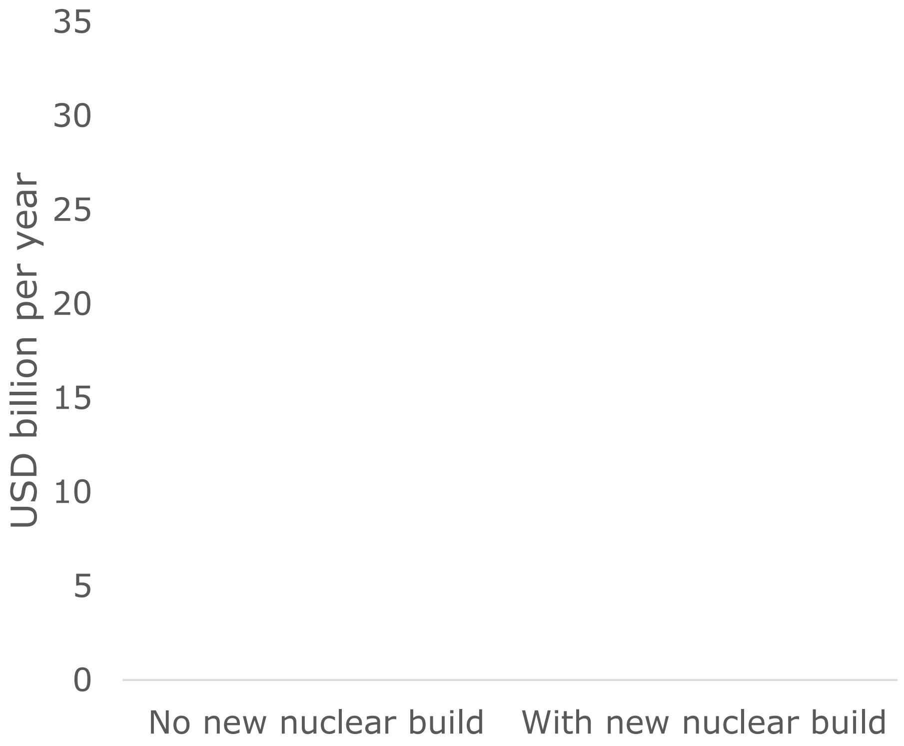
Understanding the Costs of Electricity Provision



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

Firm Nuclear Capacity Can Significantly Reduce the Overall Costs of Integrated Energy Systems at Net Zero

Costs for two power systems of 50 GW, meeting a 0.5 Mt hydrogen demand and under a net-zero carbon constraint



Note: Both cases have initially 18 GW of existing nuclear power. Historical investments in existing capacity are not considered. The total economic system costs account for the physical costs (CapEx and OpEx) minus net export revenues. Balancing costs, connection costs and transmission and distribution costs are not considered. Discount rate = 5%. Adapted from "The Role of Nuclear Power in the Hydrogen Economy: Cost and Competitiveness"

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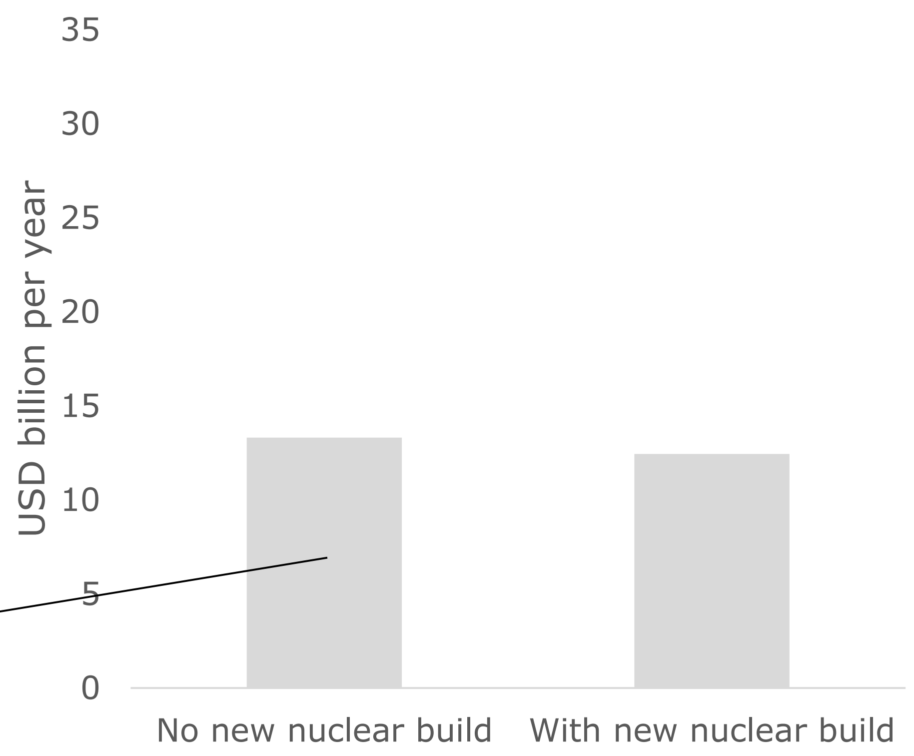

A system of **residual carbon emissions (~50gCO2eq/kWh) without new nuclear build** can be built at a **limited cost premium**. Gas still provides most of the system flexibility

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Firm Nuclear Capacity Can Significantly Reduce the Overall Costs of Integrated Energy Systems at Net Zero

Costs for two power systems of 50 GW, meeting a 0.5 Mt hydrogen demand and under a net-zero carbon constraint

Forcing the system to provide **carbon-free electricity 24/7 (net zero) without new nuclear build** requires massive deployment of variable renewable capacity and storage **doubling overall system costs**

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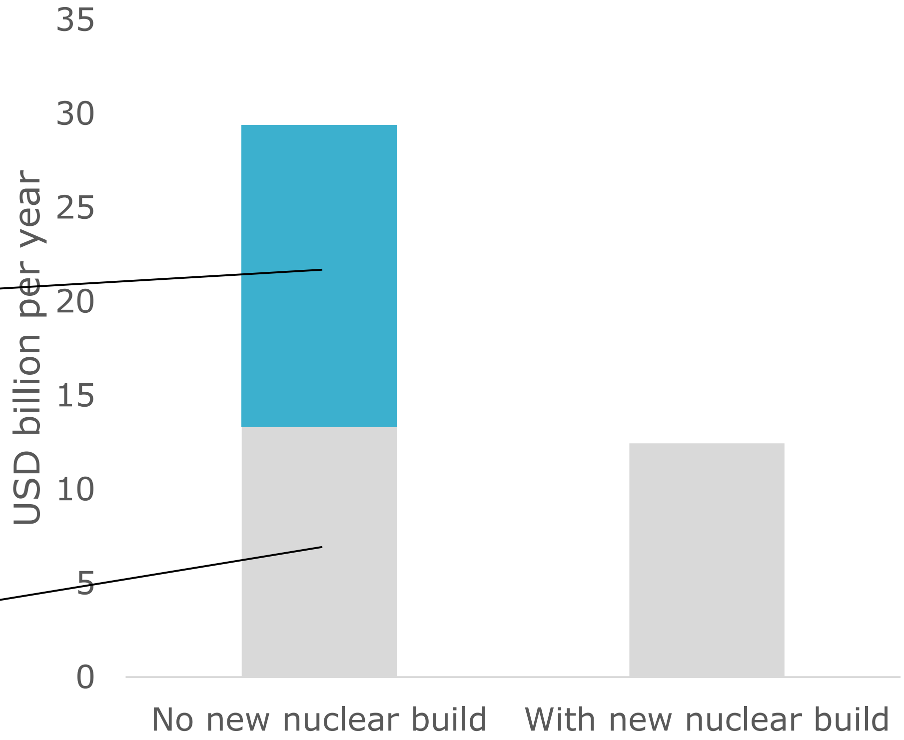

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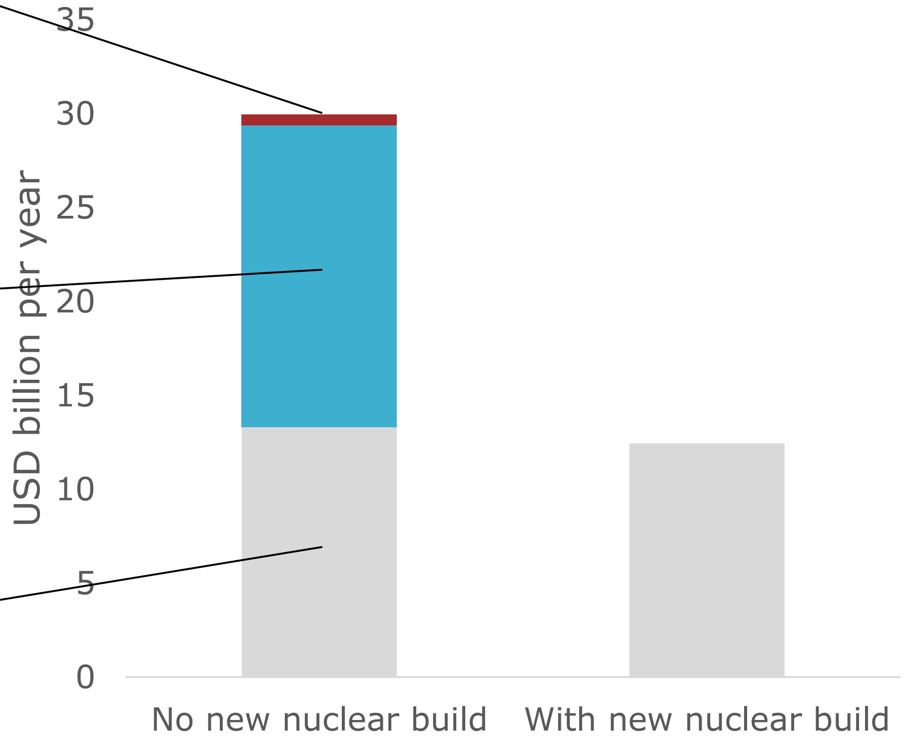

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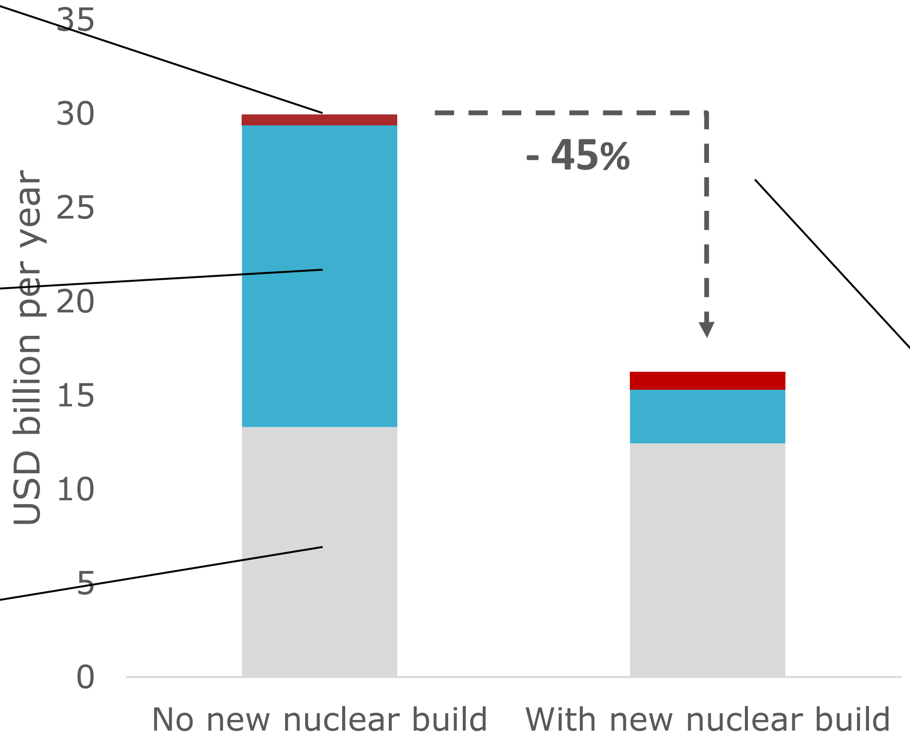

If **nuclear new build is allowed** to enter in the optimal mix portfolio, **overall system costs are reduced by nearly 50%** since nuclear power displaces residual emissions more efficiently, **drastically limiting variable renewable and storage overcapacity**

Hydrogen production costs are slightly higher due to the lack of periods of excess of electricity from variable renewables, however **the overall cost of the integrated system are significantly lower**

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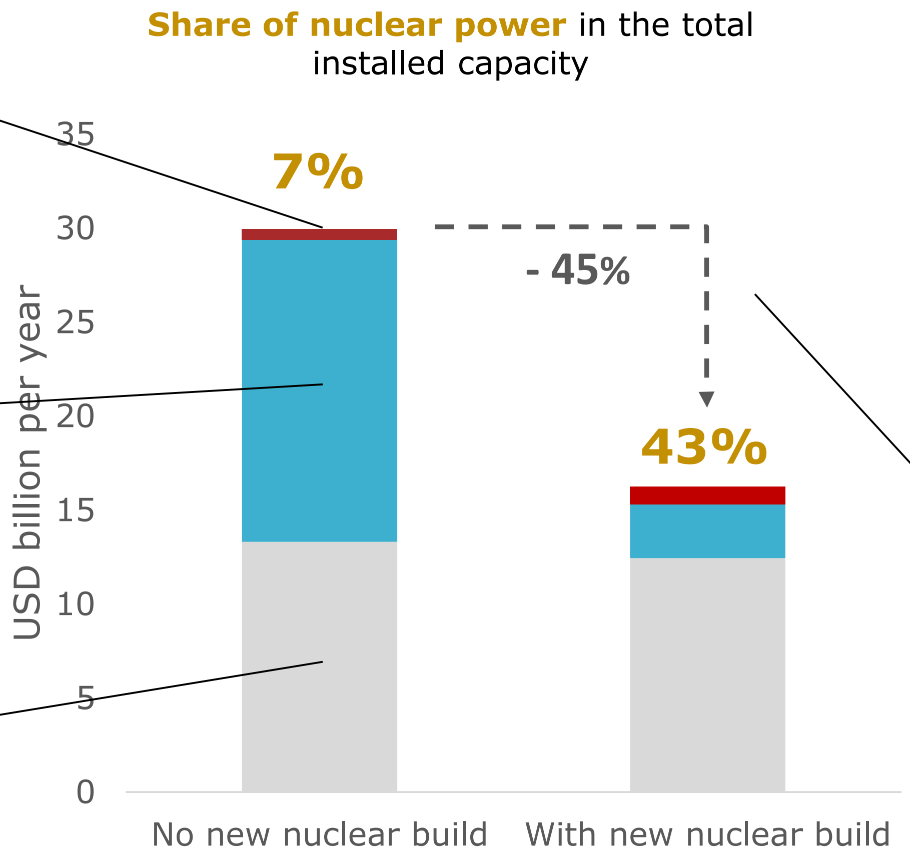

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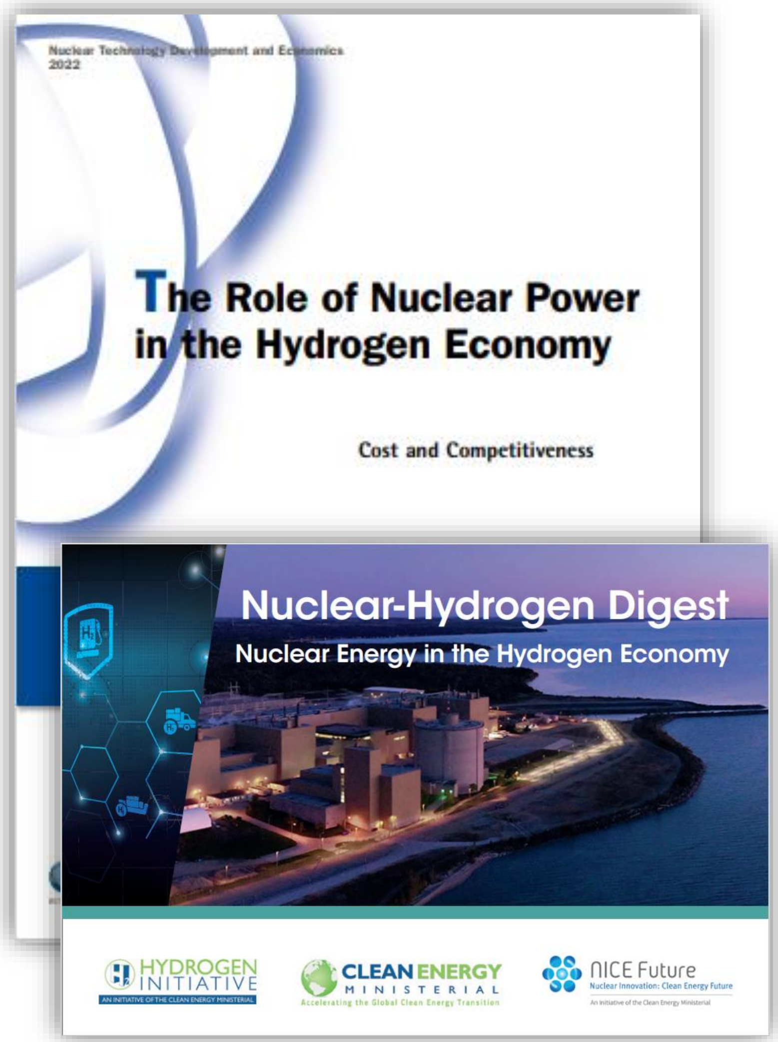
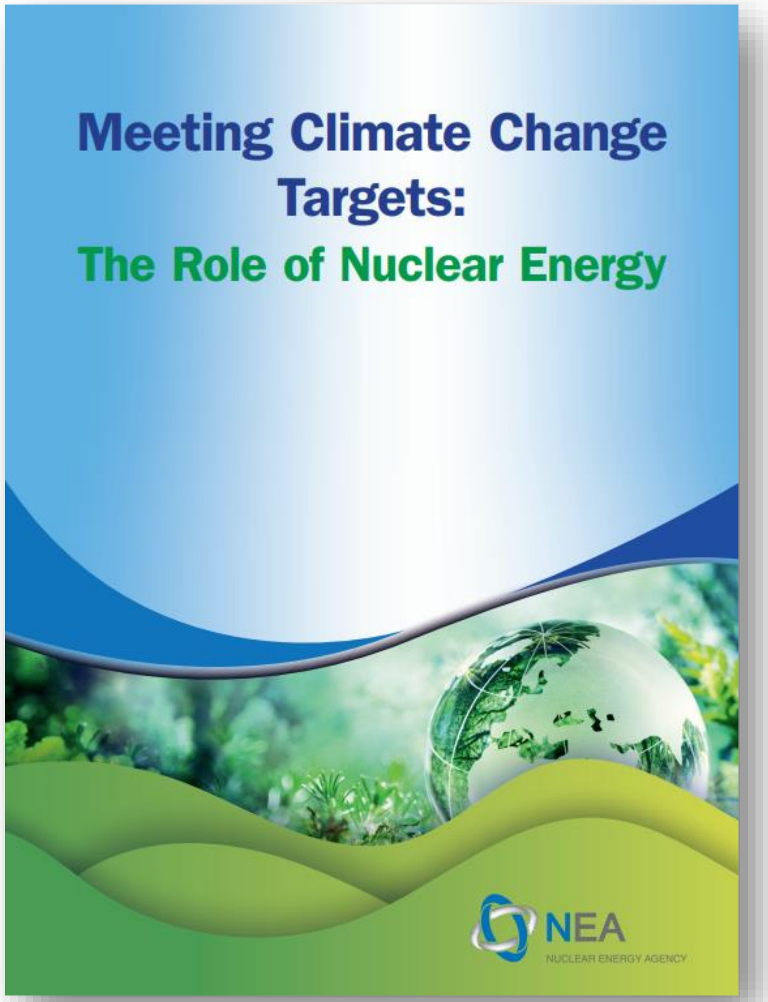
Nuclear Energy Faces Many Challenges

- **The nuclear sector must demonstrate that can deliver nuclear projects in more predictable manner 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

Thank you for your attention!

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





www.oecd-nea.org/nuclear-hydrogen

https://www.oecd-nea.org/climate-change-2022

ROLLS ROYCE SMR

Rolls-Royce SMR

Clean, Affordable, Energy For All

NNWI Forum 2022

Harry Keeling – Head of Industrial Markets

October 2022

Department for Business, Energy & Industrial Strategy

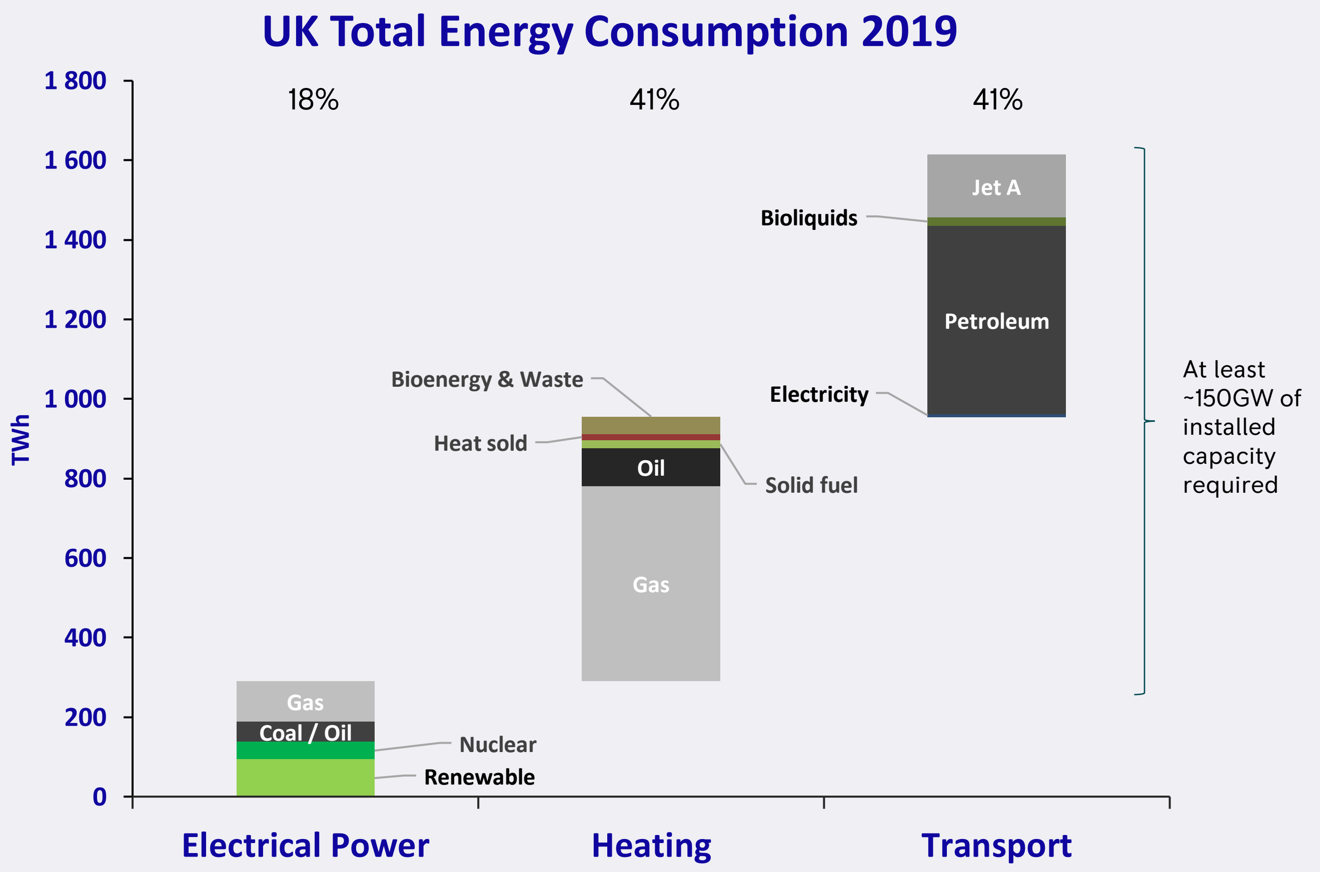
UK Research and Innovation

Achieving Net-Zero: Decarbonising the energy system

The Power/electricity sector has been the historic focus

Heating and Transport are a much greater challenge

All forms of decarbonisation will require more clean electricity



Source: https://www.gov.uk/government/statistics/energy-chapter-1-digest-of-united-kingdom-energy-statistics-dukes

ROLLS ROYCE SMR

Rolls-Royce's Nuclear Heritage

Strong nuclear heritage with roots in defence and civil development

Designing, manufacturing and supporting small reactors for over 60 years

Rolls-Royce is a globally recognised and trusted partner

Rolls-Royce is one of the world's **leading** industrial technology companies pioneering cutting-edge technologies that deliver **clean, safe and competitive** solutions

Civil Aerospace

Power Systems

Defence

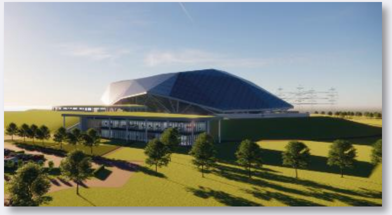
Strong nuclear heritage with roots in defence and civil development

Nuclear Business Experience

Civil Nuclear

Defence Nuclear

Rolls-Royce SMR



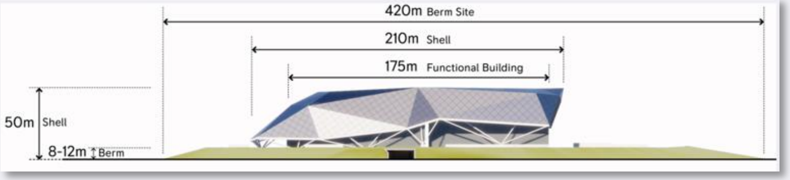
Innovation & Future Programs

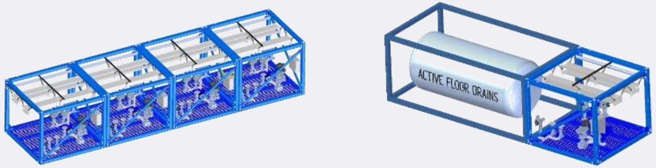
Submarines

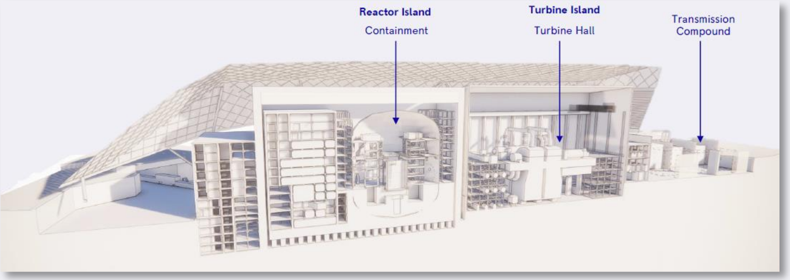
Not all SMRs are the same

To deliver cost reduction, schedule reduction, and certainty we must not reproduce a "small" large plant

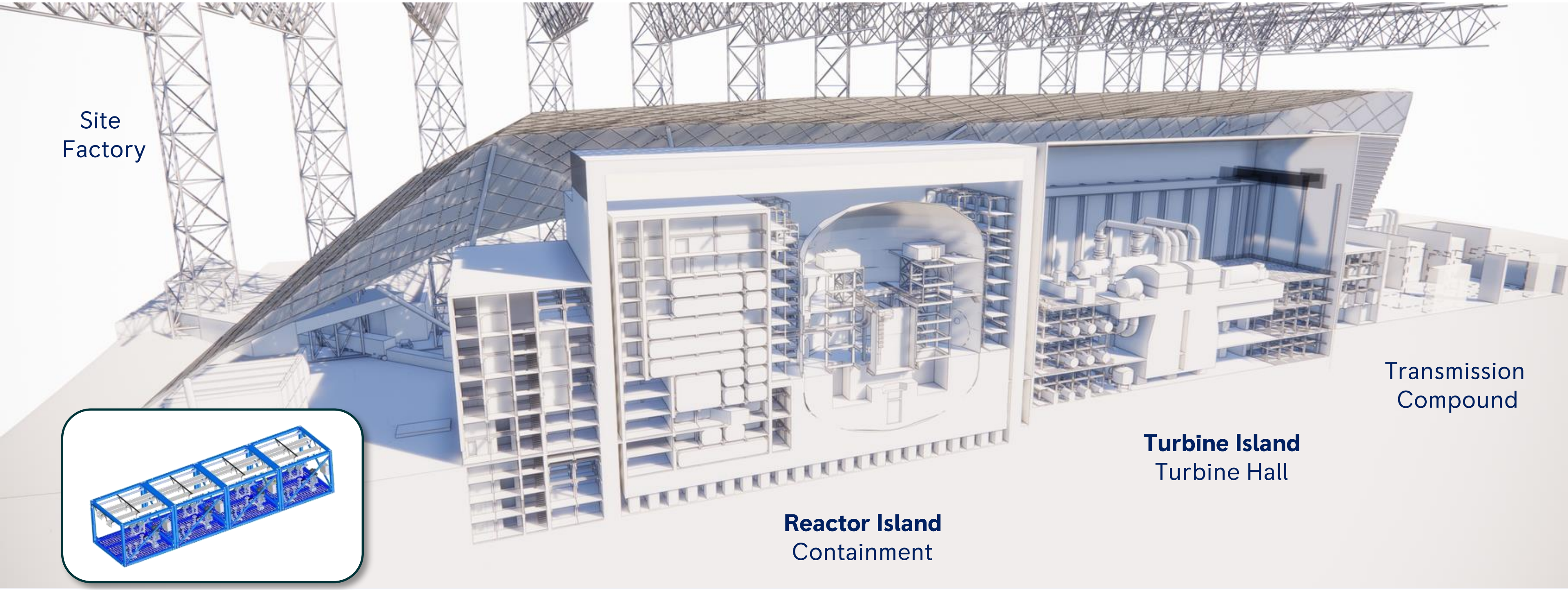
- **S**mall
  - Maximise power for physical constraints around manufacturability and transportability
  - Not about designing around an arbitrary power level
- **M**odular
  - Standardisation, factory repeatability in a production line approach.
  - Avoidance of large modules that must be disassembled for transportation - defeats the benefits of modularisation
  - Modules tested in factories to reduce site activity
- **R**eactor
  - RR provides the power plant, not just the reactor
  - Reactor is ~20-25% of the power plant by capital
  - Modularisation of the full power plant including civil construction
  - Enables delivery, by Rolls-Royce SMR under single EMA contract







A whole power plant approach focused on standardisation, repeatability, commoditisation where allowable



Turning nuclear into a product, not a one-off mega infrastructure project

✗ EPC (mega project)

Conventional EPC (e.g. Large nuclear)

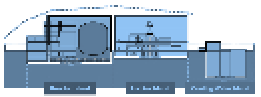
- Mega project GBP10bn+
- Reactor only, *not* whole plant
- Government driven
- Commercially complex

Reducing Project Risk

Designed for LCOE and simplicity of deployment

Factory product

Standardization



Schedule certainty

Commercial simplification

EMA (factory product)

✓ Engineering
Manufacturing
Assembly

- Much lower risk
- Reduced capital
- Shorter time to build

= Reduced financing cost

SMR

Decarbonisation of Society

There are many solutions to decarbonize

But most need clean electricity at a vast scale

Rolls-Royce SMR can provide the backbone to a stable and secure energy system


ROLLS
ROYCE
SMR

PAKS II.: A NUCLEAR NEW-BUILD PROJECT IN HUNGARY

NNWI Forum 2022: A Sustainable Future – Addressing the Energy Trilemma

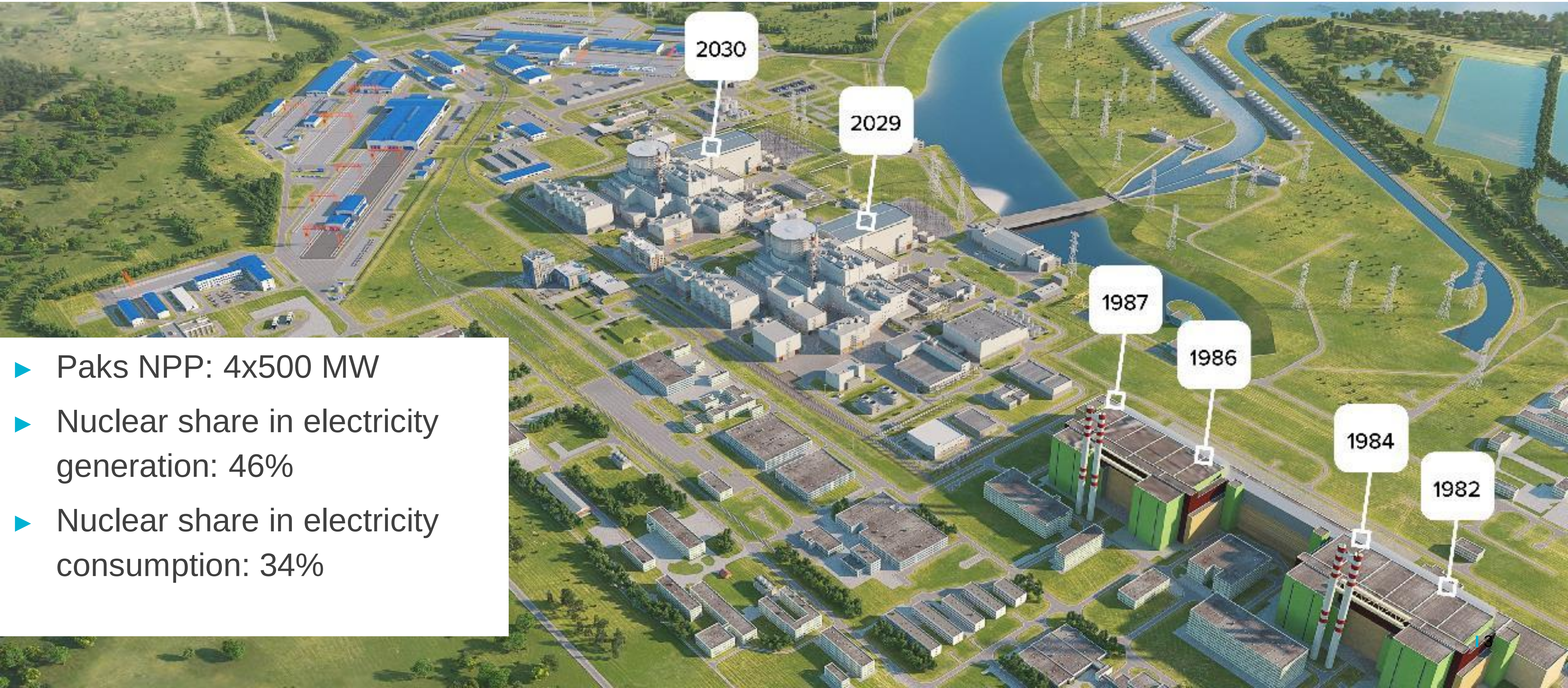
Attila HUGYECZ, Ph. D.
Chief economic advisor
Paks II. Ltd.

18th October 2022, London

HUNGARY

- Population: 10 million
- Area: 93 030 km^2

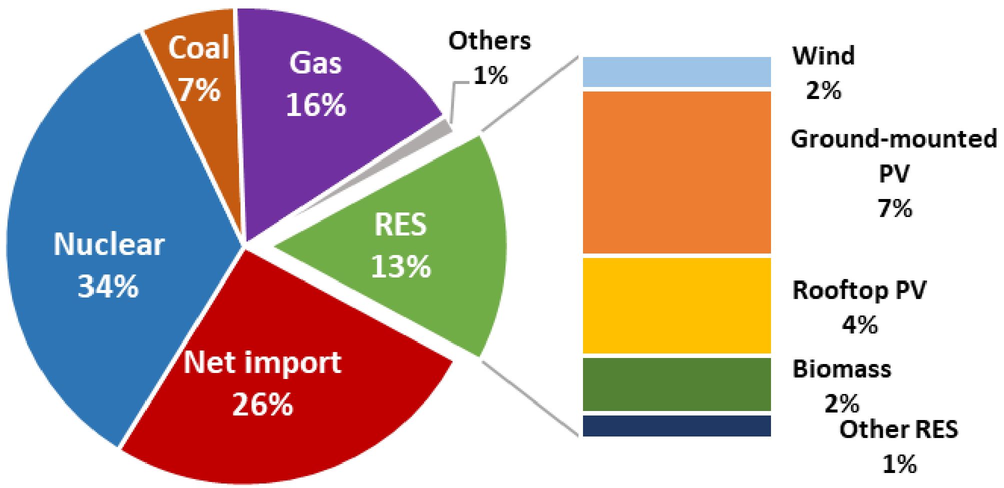
PAKS NPP



- Paks NPP: 4x500 MW
- Nuclear share in electricity generation: 46%
- Nuclear share in electricity consumption: 34%

ELECTRICITY MIX OF HUNGARY, 2022H1

Sources of Hungarian electricity CONSUMPTION in 2022H1

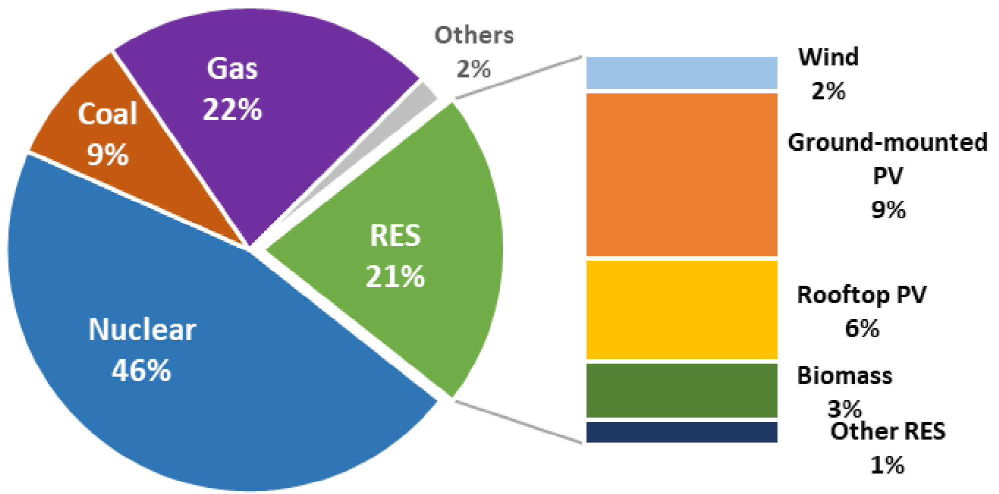


Source of data: MAVIR, MEKH

- Major data (2021):
  - Total gross consumption ≈ 47 TWh/a
  - Gross domestic generation ≈ 34 TWh/a
  - Net import ≈ 13 TWh/a
- Consumption growth rate: **1,35%/a** (2013-2021)
- Average load: 5400 MW (3,5-7,4 GW)
- Nuclear: 2000 MW
- PV + wind: 3820 MW

- Outstanding electricity import dependency
- Crucial role of nuclear (the major low-carbon source)

Sources of Hungarian electricity GENERATION in 2022H1



ELECTRICITY: CHALLENGES, OPTIONS

- Current **challenges**
  - High import dependency already today
  - New industrial needs of 2500 MW by 2030
  - Electrification of the space heating and transport sector
  - Aging power plant fleet
  - More and more intermittent generators in the system
  - Not too rosy future for conventional coal power plants
  - A questionable gas supply security

- What are our **options**?
  - Nuclear (?), hydro (?), wind (?), solar PV (?), biomass (?), biogas (?), geothermal (?)
  - Gas-fired power plants are needed in the next decades for balancing
  - Taxonomy: a changing attitude towards nuclear in Europe

PAKS II.: AN INTERNATIONAL PROJECT

PAKS II. LTD.

- **EPC requirements based on EUR, IAEA and WENRA requirements,** domestic and international standards
- **Commitment by the Russian Contractor to apply competitive tenders EU-wide**, results:
  - Russian primary circuit paired with a Western European turbine-generator set and I&C system
    - **a turbine-generator set from GE-Alstom** (USA-FR)
    - main and upper-level **I&C from Siemens-Framatome** (DE-FR)
- Soil improvement and cut of slurry wall construction by a German company (DE)
- Site preparation (earth) works by Duna Aszfalt (HU)
- CEB construction by KÉSZ Zrt. (HU)
- Containment prestressing system by PANNON-FREYSSINET (HU)

www.ge.com

framatome — PRESS RELEASE

RASU JSC and Framatome-Siemens consortium sign contract to supply automated process control systems for Hungarian Paks-2 Nuclear Power Plant

MOSCOW, Oct. 23, 2019 – Rusatom Automated Control Systems JSC (RASU JSC), a subsidiary of Rosatom State Corporation, and the Franco-German consortium Framatome-Siemens signed an agreement to manufacture, deliver and commission automated process control systems for the Paks Nuclear Power Plant Units 5 and 6, located in central Hungary. This award was based on the results of a competitive call for bids.

The document was signed by CEO of RASU JSC Andrei Butko, Managing Director of Framatome GmbH Carsten Haferkamp, Vice President Sales Nuclear I&C of Siemens AG Jens König, and Commercial Sales Director Nuclear I&C of Siemens AG Jens Bostelmann.

According to the signed agreement, the Framatome-Siemens consortium will manufacture and supply the equipment for automated process control systems, as well as conduct its certification and qualifications, including compliance with information security requirements.

"Framatome is proud to provide automated process control systems for Paks-2 in conjunction with our partner, Siemens," said Frédéric Lelièvre, senior executive vice president in charge of Sales, Regional Platforms and the Instrumentation and Control (I&C) Business Unit at Framatome. "Our high performing people have been commissioning automation systems at nuclear power plants in Russia for many years. With Paks-2, we are delighted to use our expertise in I&C for VVER reactors in Europe, and add to a long list of successful projects with Rosatom."

www.framatome.com

PAKS II.: CURRENT STATUS

- Already obtained: environmental licence, site licence, physical protection licence, construction licence, almost 1000 licences and permits
- Construction and erection base works going on
- Just finished: pit excavation to -5 m level
- To be started: soil improvement and slurry wall construction








PAKS II.: CURRENT STATUS

- Construction and erection base works

PAKS II.: CURRENT STATUS

- Construction and erection base works

PAKS II.: CURRENT STATUS

- Pit excavation to -5 m level

THANK YOU FOR YOUR ATTENTION!

NNWI Forum 2022

Environmental Sustainability Panel

Chaired by Saralyn Thomas, Chair, Nuclear Institute Young Generation Network

- Kirsty Gogan, Founder and Managing Partner, **TerraPraxis**
- Emilia Janisz, Director of Strategy, **European Nuclear Society**
- Rauli Partanen, Chief Executive Officer, **Think Atom**
- Shekhar Sumit, Head of Energy Transition, Sizewell C, **EDF Energy**
- Neil Hirst, Honorary Senior Research Fellow, **Grantham Institute, Imperial College London**

#NNWIForum2022

TERRAPRAXIS
BENDING THE EMISSIONS CURVE

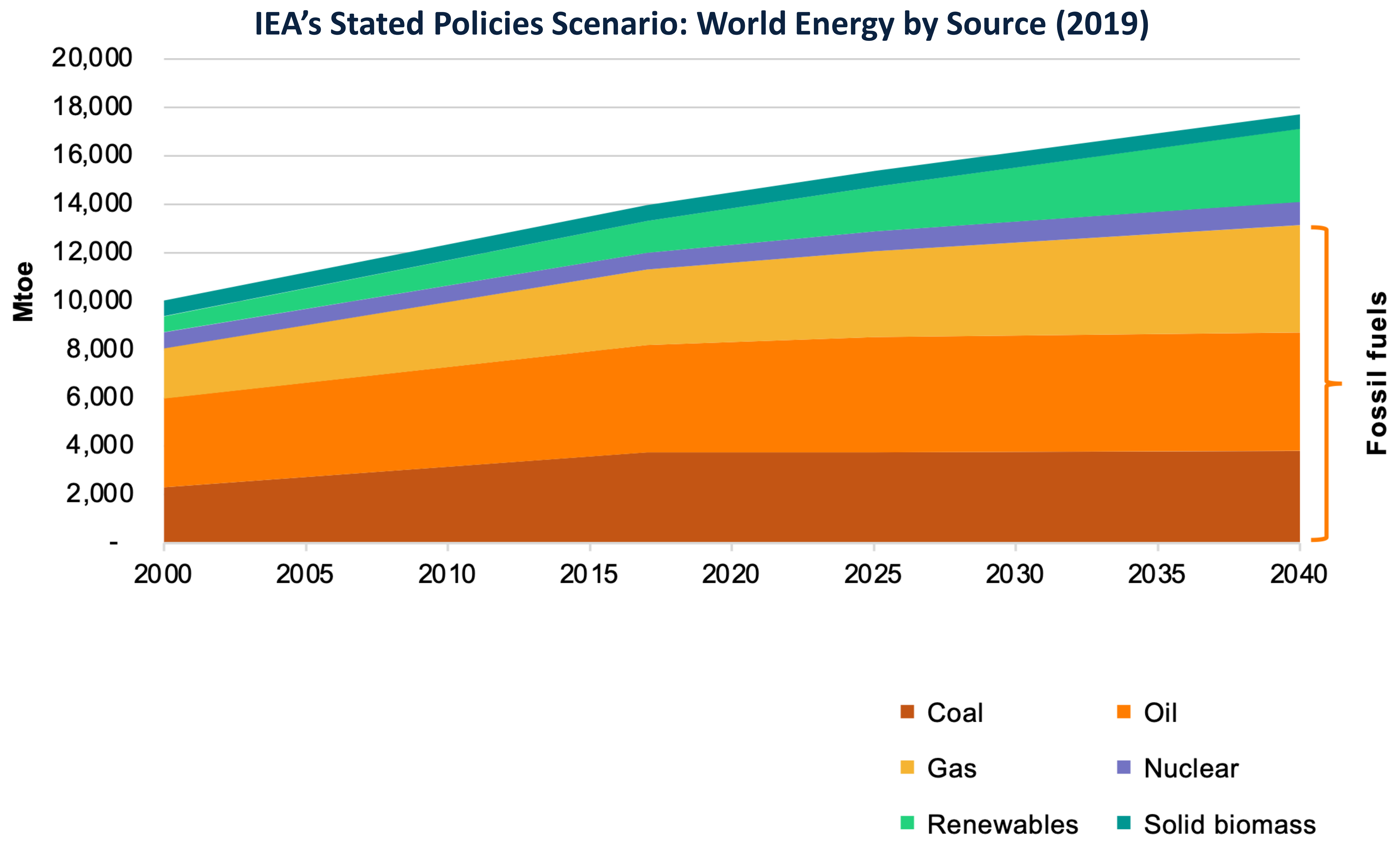
NEW NUCLEAR WATCH INSTITUTE

OCTOBER 2022

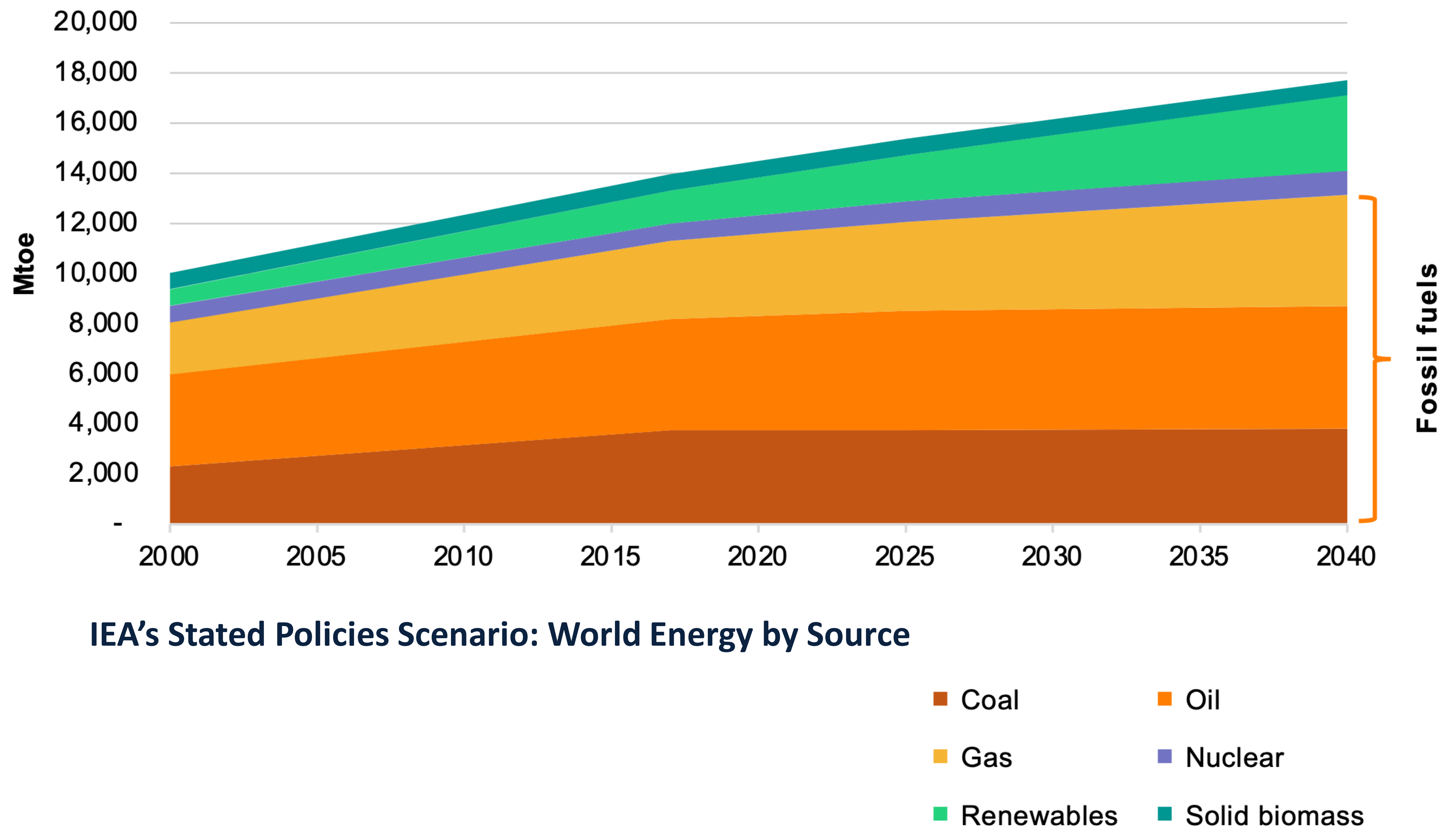
01 BENDING THE EMISSIONS CURVE

URGENCY AND SCALE

FIRST THE BAD NEWS: EMISSIONS ARE STILL GOING UP NOT DOWN



NEXT THE GOOD NEWS: WE HAVE NU WAYS TO BEND THE CURVE



- Coal plant conversion
- Clean hydrogen
- Synthetic fuels production

IEA's Stated Policies Scenario: World Energy by Source

01 SYNERGETIC

DEPLOYMENT ARCHITECTURE

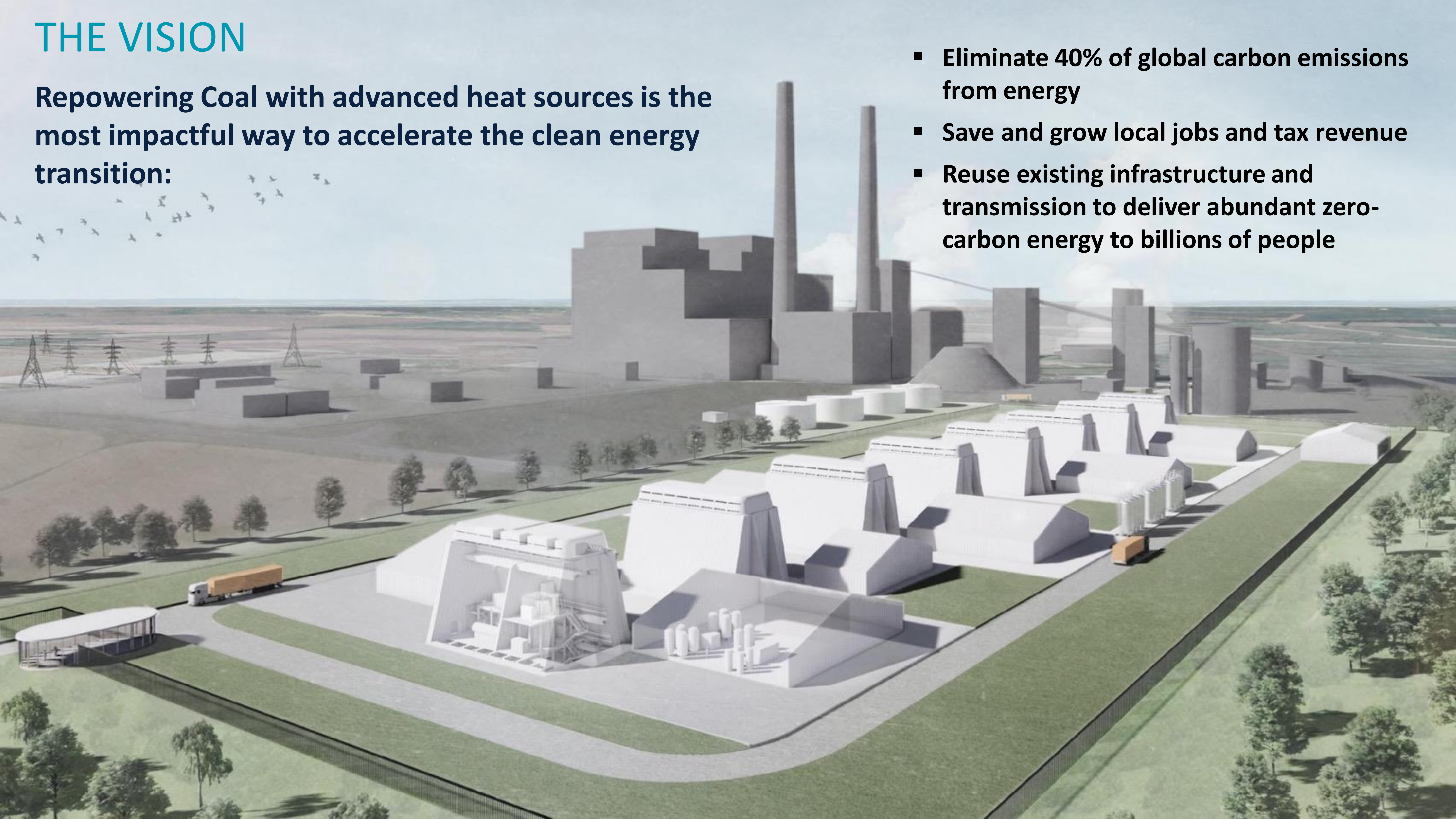
01 REPOWERING COAL

FAST, LOW COST, REPEATABLE

THE VISION

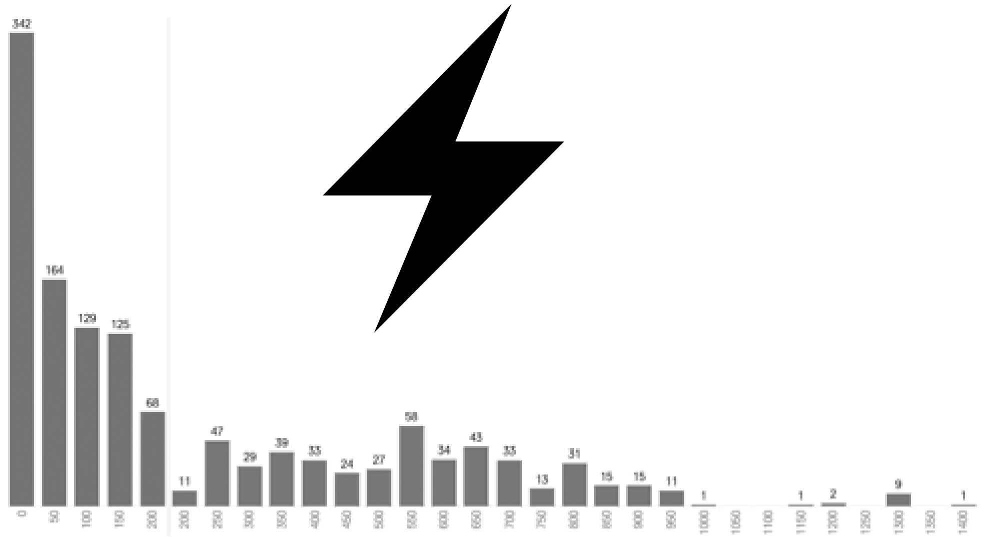
Repowering Coal with advanced heat sources is the most impactful way to accelerate the clean energy transition:

- **Eliminate 40% of global carbon emissions from energy**
- **Save and grow local jobs and tax revenue**
- **Reuse existing infrastructure and transmission to deliver abundant zero-carbon energy to billions of people**

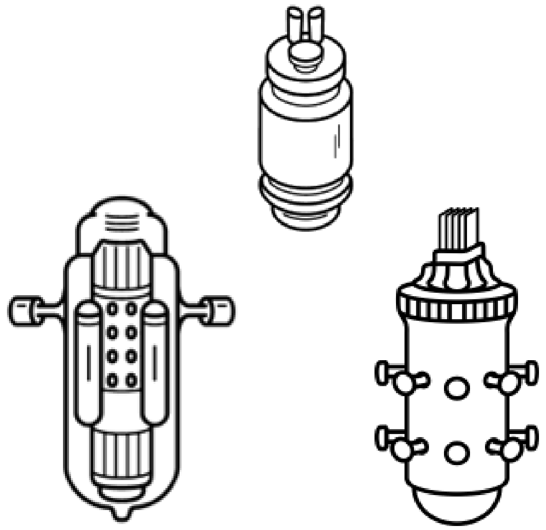


Standardization to Address Wide Variety of Requirements

2TWe
2050



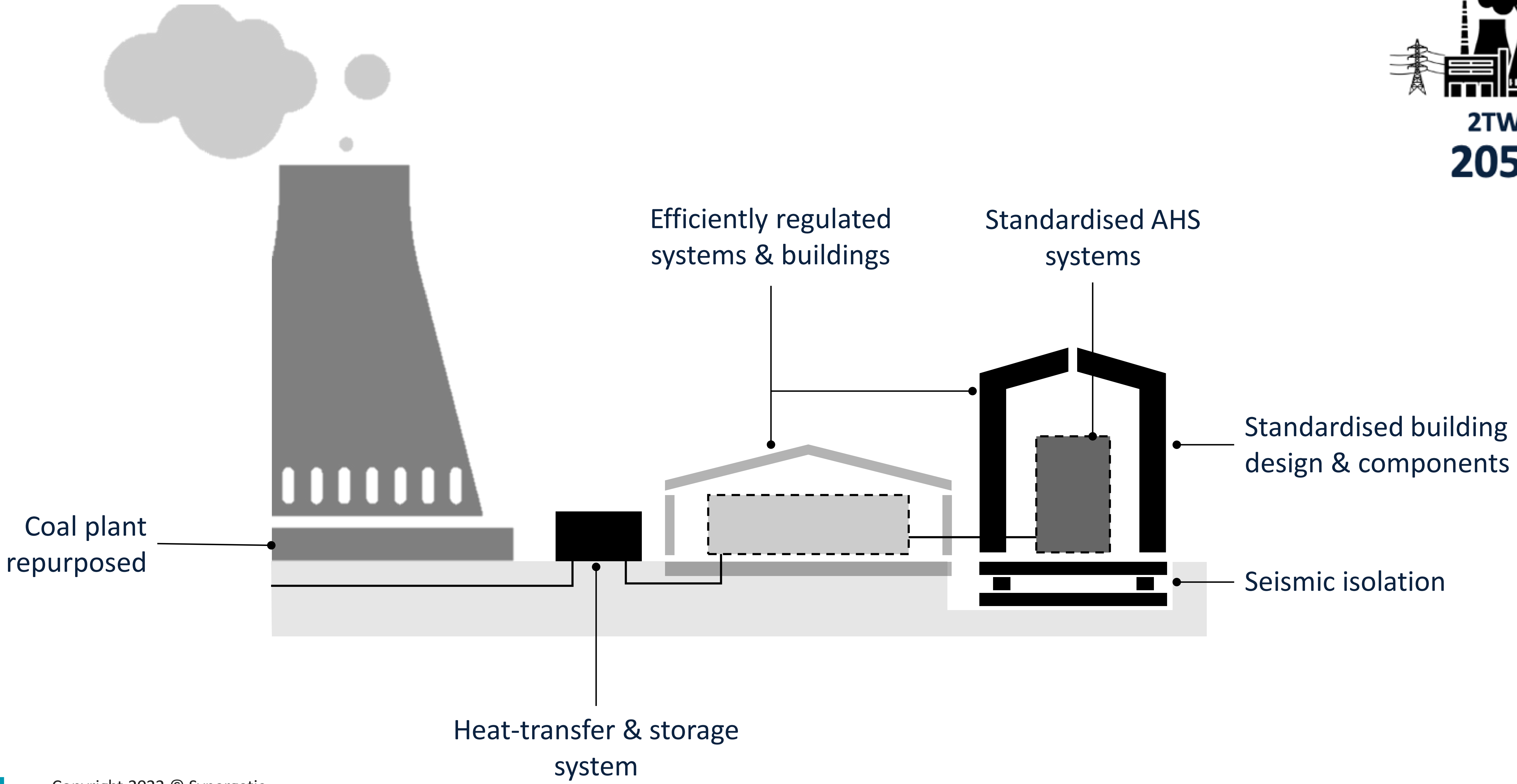
Different
Energy and heat requirements



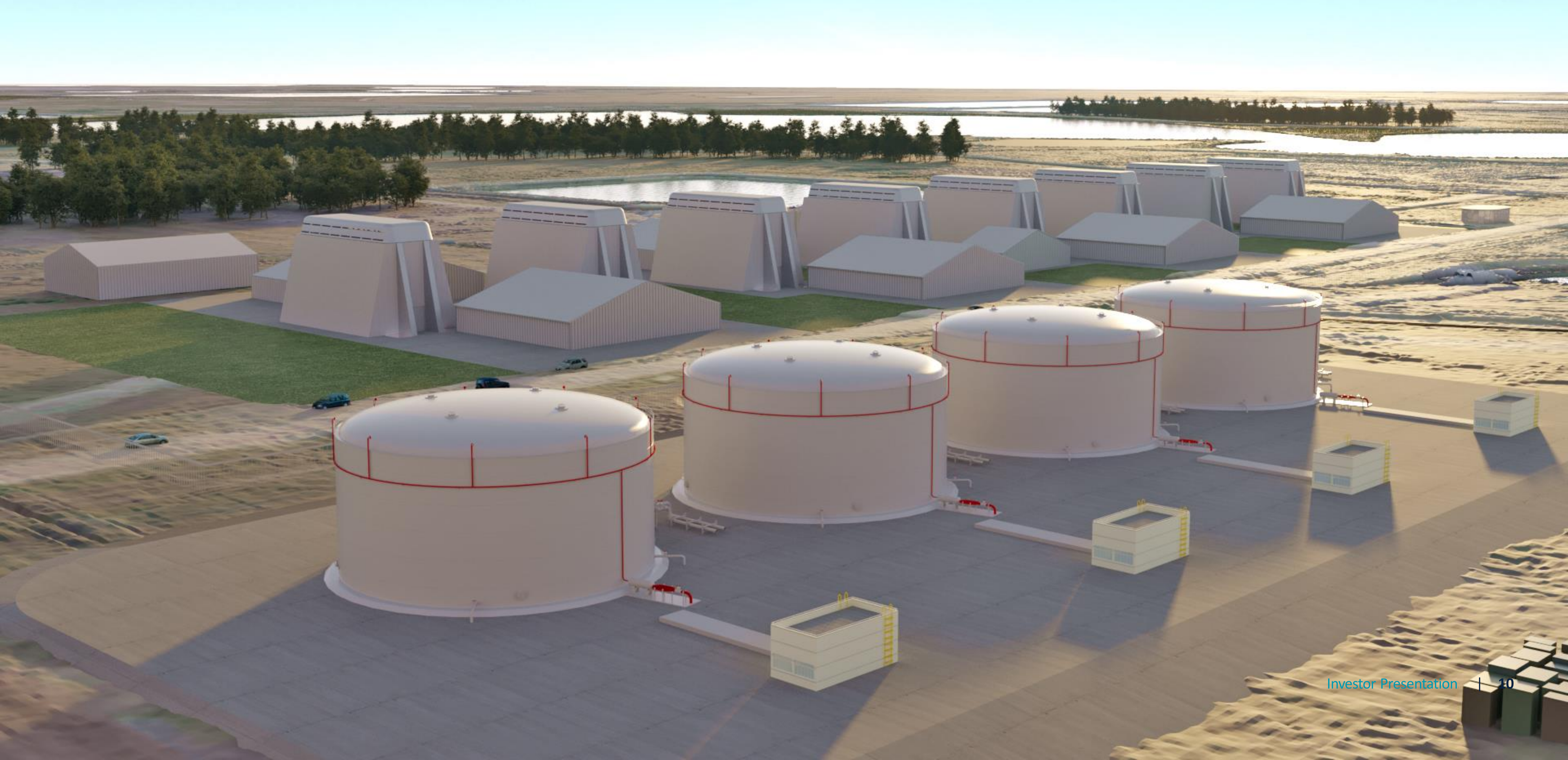
Different
Advanced heat-source (AHS) technologies

Different
Site layouts and local requirements

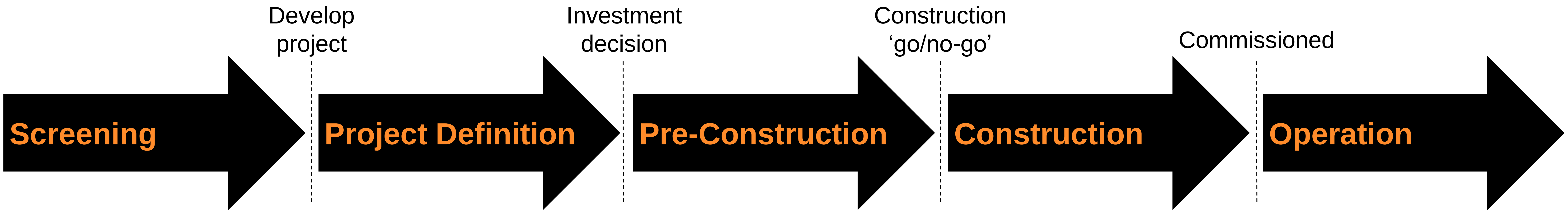
Built Systems Must Enable Scale and Speed



Thermal energy storage de-links the nuclear heat island safety case from the existing coal plant power island. This enables flexible generation and continued use of the existing plant.



DEFINING THE CUSTOMER JOURNEY TO ENABLE FAST, LOW COST AND REPEATABLE COAL PLANT REPOWERING



Is project viable?

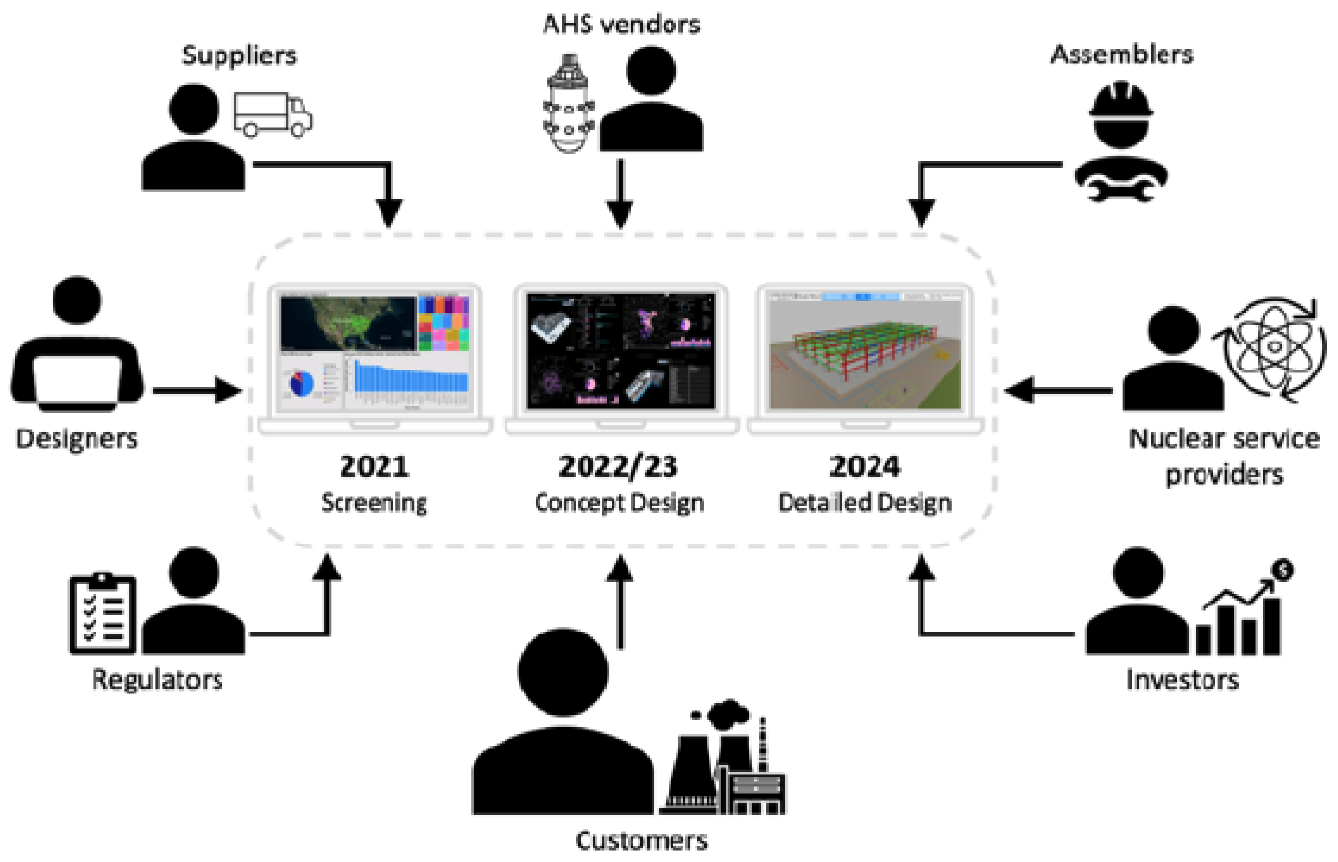
What is the best project?

Who will do key activities & how?

How to stay on schedule & budget?

How to profitably supply end-users?

Making Repowering Coal ‘Oven-Ready’ by 2025 to Deploy at Speed and Scale



2025 - 2030

- 100’s of Projects
- Global Market of Building Systems
- Advanced Heat Source Market
- 100’s of New Suppliers

Building and priming the market

Repowering Coal by 2050

SUPPORTED BY EXTRAORDINARY LEADERS

Brad Smith, President of Microsoft
"One of the greatest challenges of the 21st Century is really to cut the cord between power and carbon. And one of the most profoundly challenging areas of this is the world's reliance on coal to generate power.

"TerraPraxis, you all are at the absolute centre of the world's innovation to cut the cord while enabling the world to continue to rely on the power plants that have been built and the infrastructure that already exists so that the world doesn't have to go spend the money to recreate what already exists."

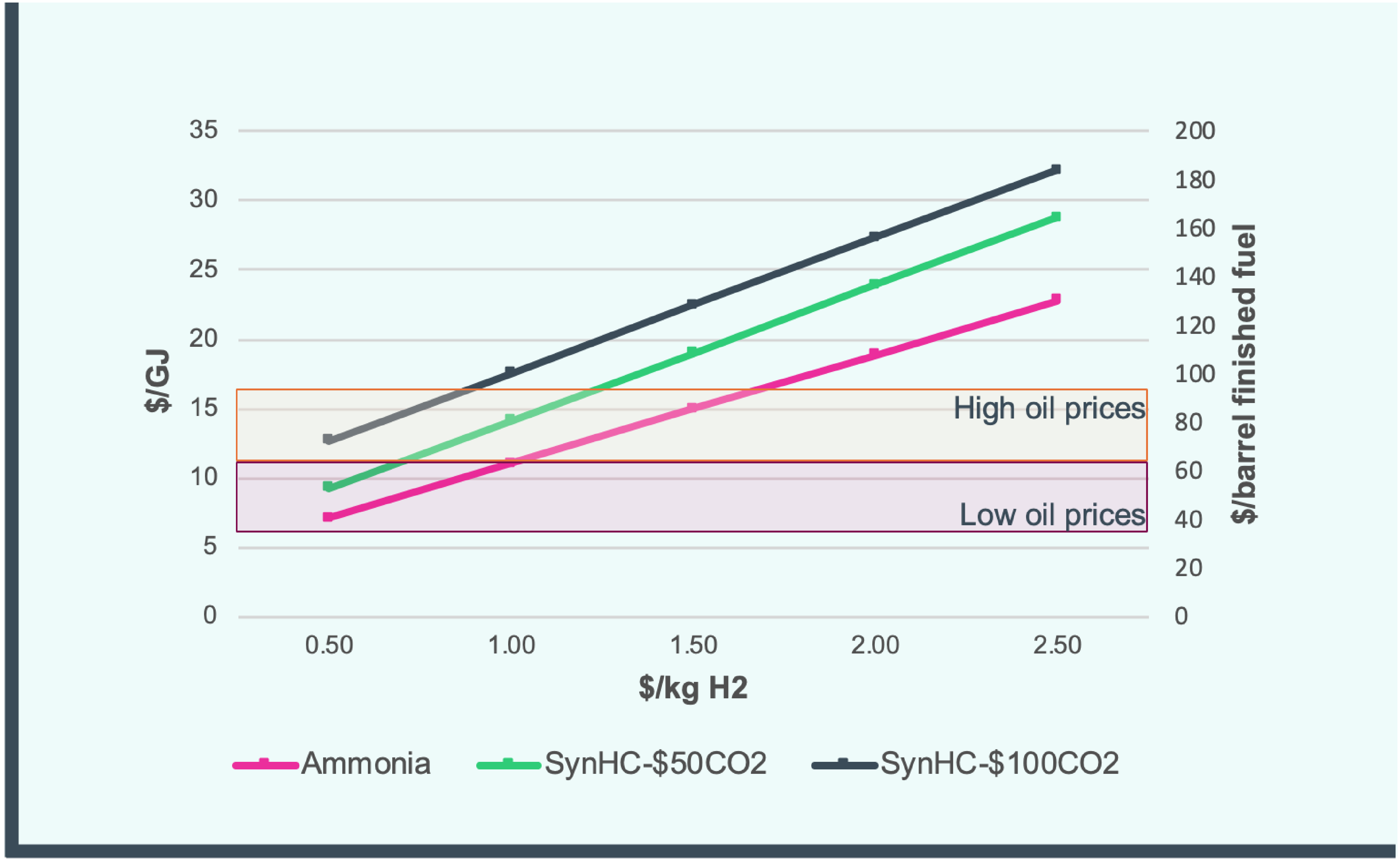
Repowered coal plants can protect jobs and energy security by continuing to operate for decades, supplying emissions-free, reliable, flexible, and cost-competitive electricity.

02

REFINERY-SCALE HYDROGEN GIGAFACTORY

BRING THE FACTORY TO THE PROJECT

COST COMPETITIVE SYNTHETIC FUELS REQUIRE LOW-COST CLEAN HYDROGEN



SYNFUELS COST AS A FUNCTION OF HYDROGEN INPUT COST

REFINERY-SCALE HYDROGEN GIGAFACTORY

03 SHIPYARD-MANUFACTURED CLEAN SYNTHETIC FUELS

BRING THE PROJECT TO THE FACTORY


SYNERGETIC AMMONIA FPSO
NH3
12k boe/d
1.2 GWe

SYNERGETIC: ACHIEVING SCALE

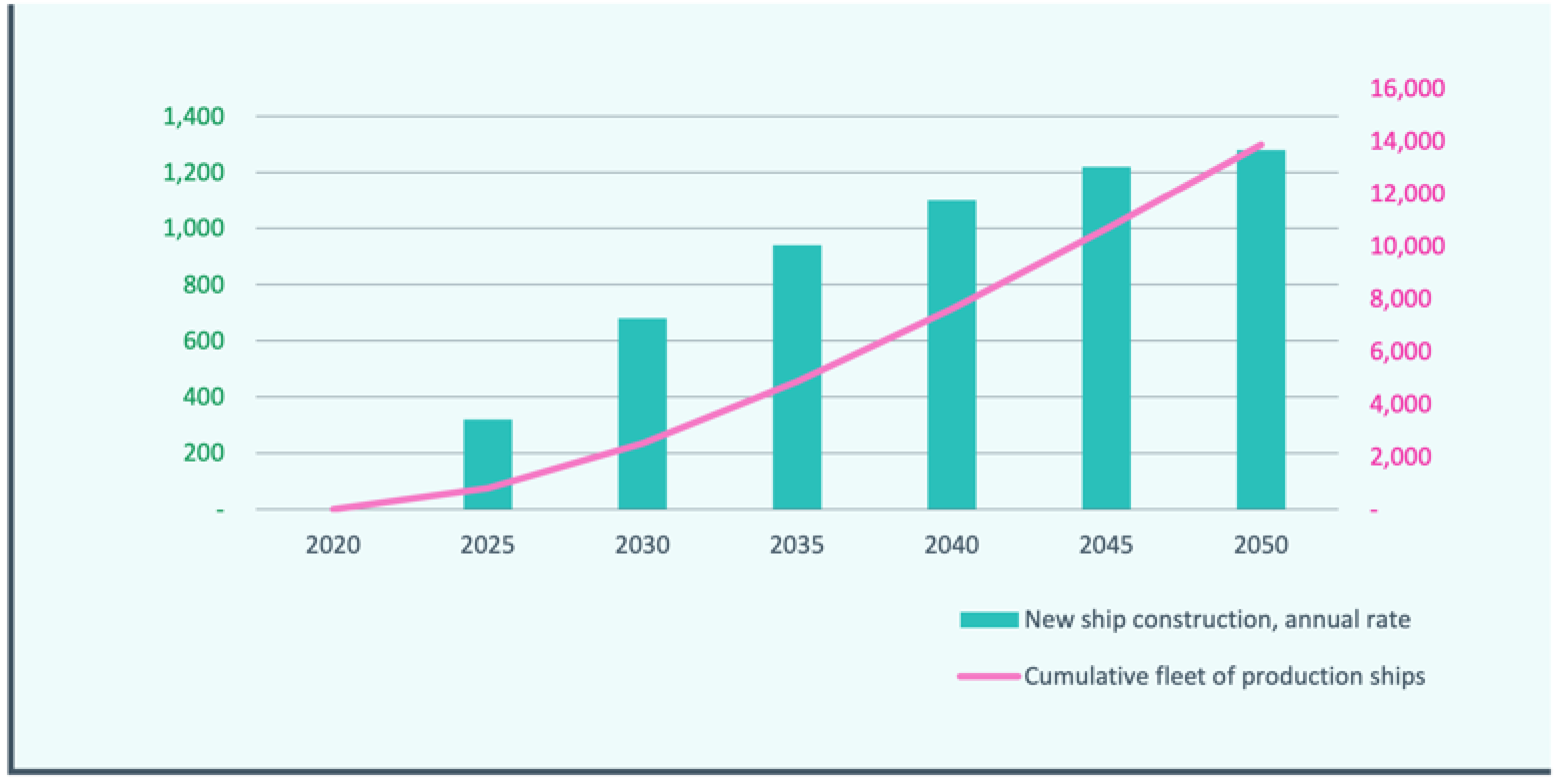
Seven FPSO platforms each producing 1.2 million tonnes per year of the world's lowest cost zero-carbon ammonia would be the equivalent to 5% of total global ammonia production.

03 SYNERGETIC

TRANSFORMING OIL PRODUCERS INTO CLEAN FUELS SUPPLIERS

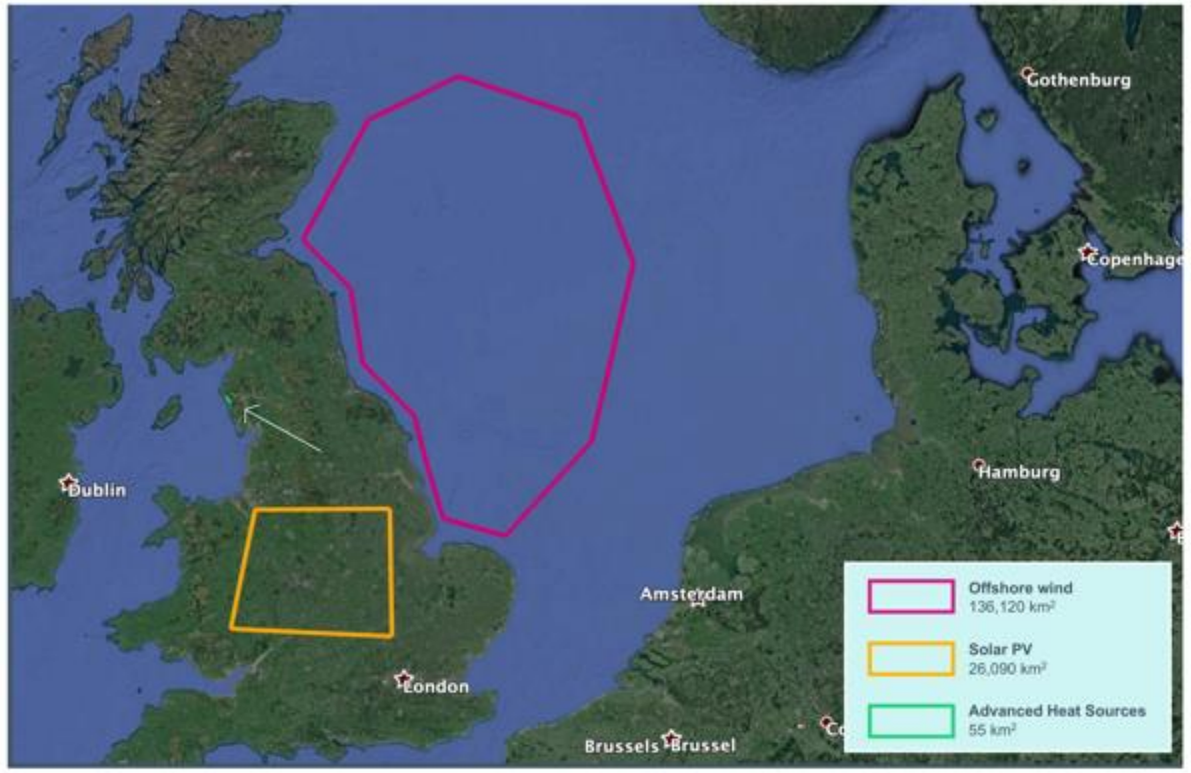
TRANSFORMING MAJOR OIL PRODUCERS INTO GLOBAL SUPPLIERS OF CLEAN LIQUID FUELS

- 100 million Barrels of Oil per day = ~10,000 FPSOs
- Currently ~ 60,000 large ships operating
- Shipyards: 281 operating in 2019

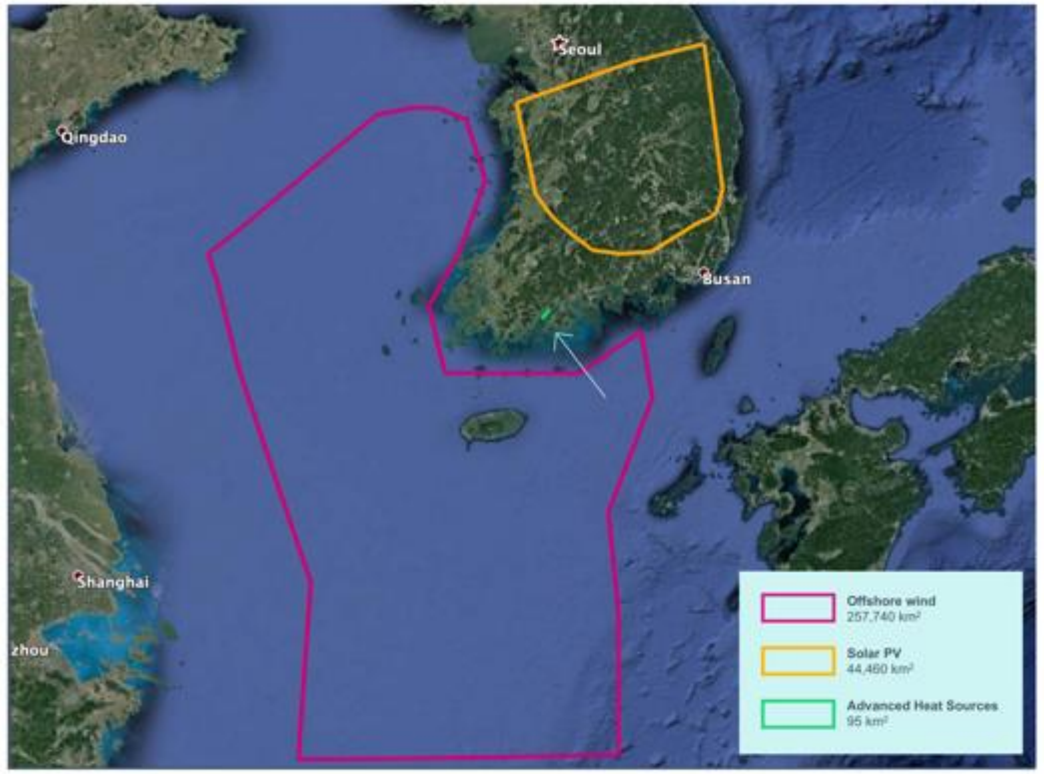


EXXON/Mobil	4,000,000	334
Shell	3,700,000	308
ADNOC	3,000,000	250
Equinor	2,000,000	167

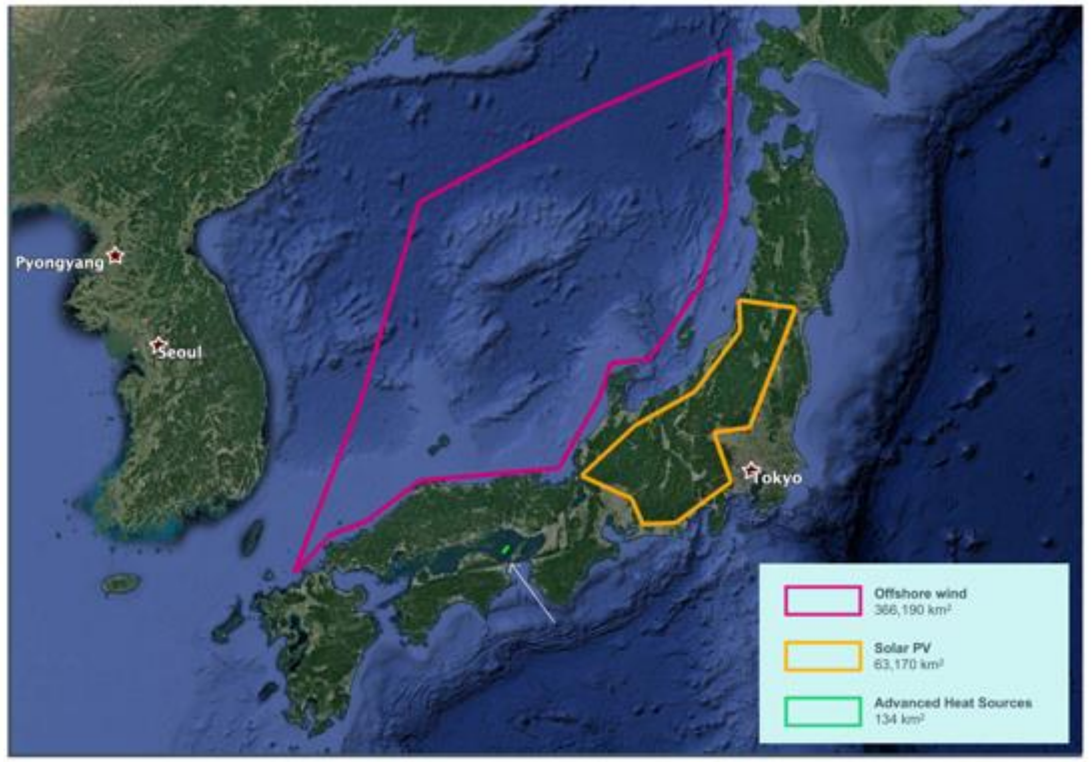
ADVANCED HEAT SOURCES WILL DELIVER CLEAN FUELS, COST-COMPETITIVELY, AT THE SCALE OF OIL AND GAS



Each colored outline represents the total area that would be required for the siting of each type of resource if it were to be the only one used to generate enough hydrogen to replace current oil consumption in the UK.



Each colored outline represents the total area that would be required for the siting of each type of resource if it were to be the only one used to generate enough hydrogen to replace current oil consumption in South Korea.



Each colored outline represents the total area that would be required for the siting of each type of resource if it were to be the only one used to generate enough hydrogen to replace current oil consumption in Japan.

IF WE CAN:

Repower 2 TWe of coal

Deliver refinery-scale hydrogen

Substitute 100M barrels of oil per day

WHAT DO WE HAVE?

NEW (NU) PRIMARY ENERGY

FUELLING A LIVABLE CLIMATE

ENS

Presentation

The evolution of nuclear advocacy

Nuclear for Climate Initiative

London, 18th October 2022

NNWI Forum 2022

Nuclear for CLIMATE

European Nuclear Society

Who we are?

Founded in 1975, ENS is the largest society for nuclear science, research and industry in Europe.

ENS gathers 21 nuclear societies and more 12,000 professionals in Europe.

ENS promotes the development of nuclear science and technology and the understanding of peaceful nuclear applications.

Supporting Scientific Excellence

30 Corporate Members

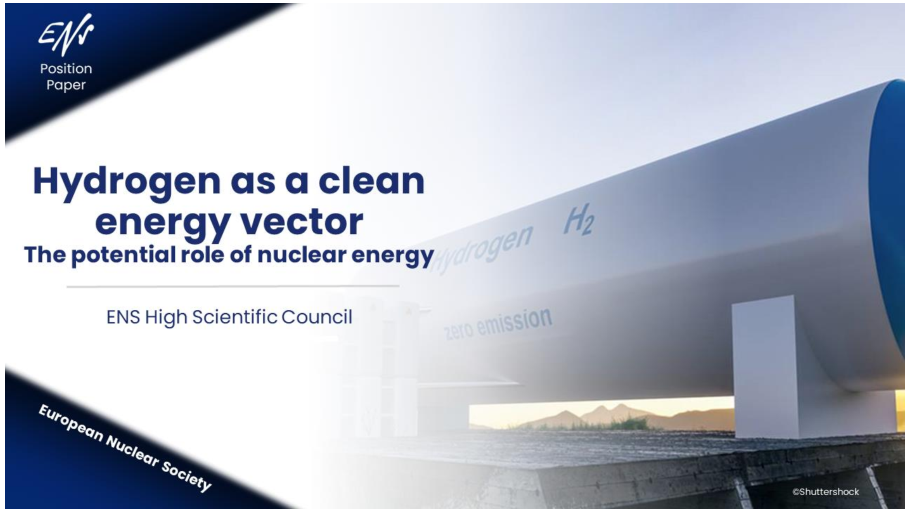
Presentation

The ENS High Scientific Council

23 scientists of high repute from 16 European Countries

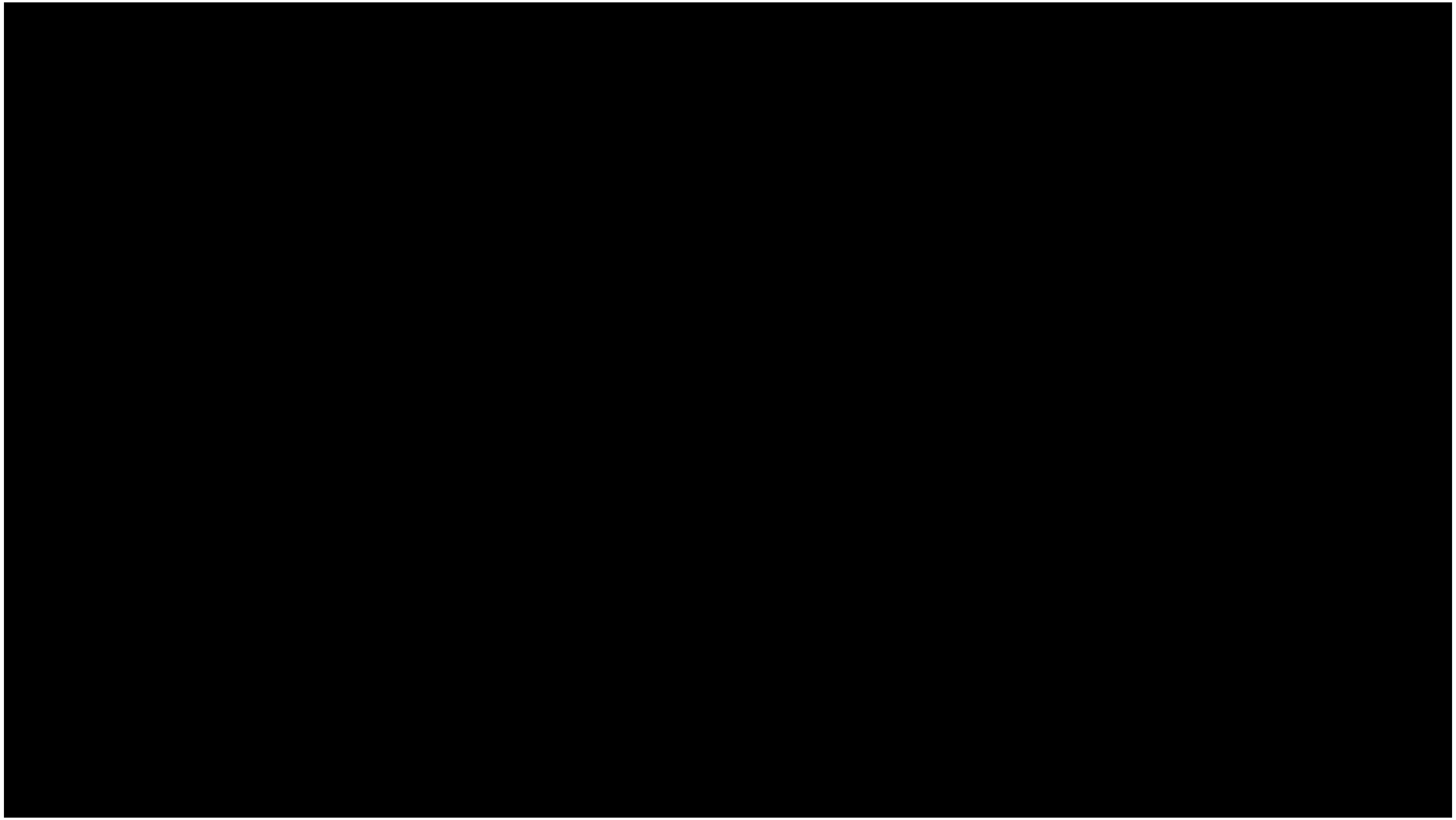
ENS PhD Award

Position Papers



Presentation

What is Nuclear for Climate?



An impressive growth

Since 2015 …

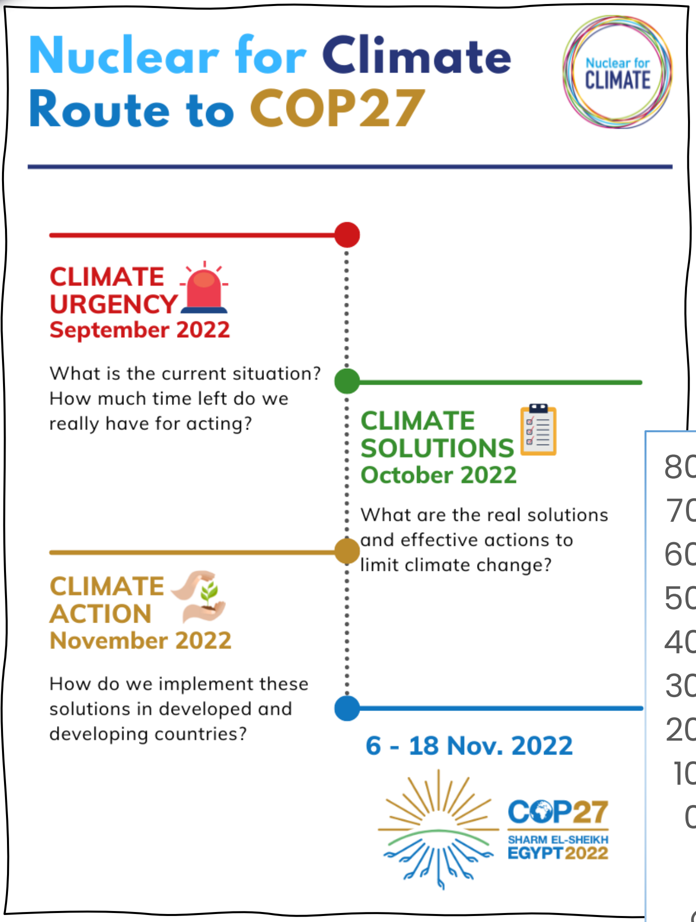
- From a one-time event **to a global recognised initiative**

- **Growing visibility,** at COPs, on media and online…
  → **more effective impact, wider audience and networks**

  → **attractiveness, increasing engagement** of neutral and non-nuclear NGOs

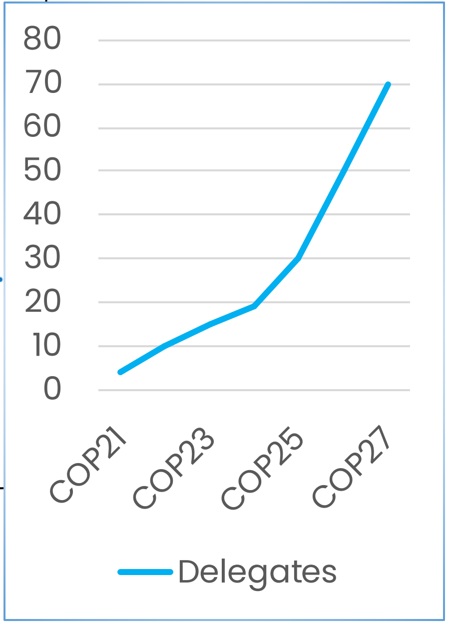
Presentation

- Over 100 associations (+80,000 people) undersigned and support last **N4C Position Papers** and **Petition**



- **Successful PreCOP Campaigns →** Route to COP27 3-webinars series, 400 tickets sold, +70k online impressions

- **Growing number of N4C delegates** at COPs from all over the world



- **Massive coverage on social media**

+8,000	+33,000	+2,500	+127,000
Followers	Views	Likes during last COP	Impressions during last COP

Presentation

N4C Nuclear Advocacy – What did we achieve?

Increasing engagement, proactive advocacy, growing visibility led to great achievements at several levels:

- **NGOs**
  increasing participation of volunteers, delegates and associations // attractiveness of neutral, non-nuclear NGOs
- **Industry**
  Rethink nuclear beyond energy - climate targets, SDGs, multipurpose applications → renewed companies' agenda and plans // new sponsorships and interest in N4C advocacy activities
- **Policy**
  Voice N4C Message + Greater support and visibility → Pressing on political agendas (e.g. COP24 Katowice → Polish NPPs Plan; COP26 Glasgow → UK Gov. Nuclear Plans)

N4C Nuclear Advocacy – Messaging

- Nuclear is part of the solution
- Only by combining renewables with nuclear energy, can we still deliver on Paris Agreement commitments
- Together is Better
- Net Zero Needs Nuclear
- We call for technology –neutral approach for all low carbon technologies – equal access to financing

Presentation

Support Nuclear for Climate at COP27

Follow us on Twitter and LinkedIn

Nuclear for CLIMATE

Thank you for your attention

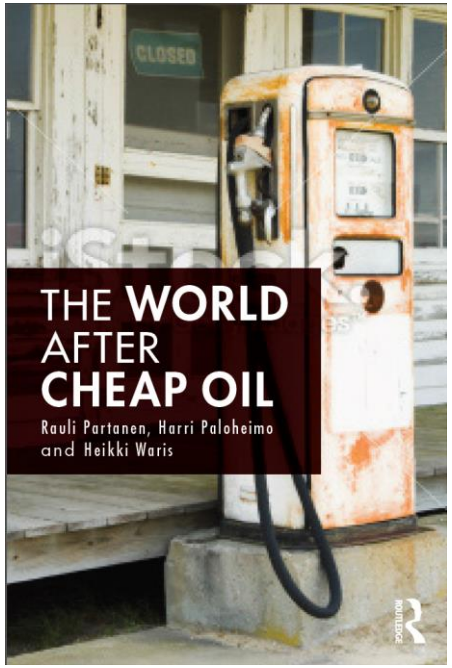
BEAUTIFUL NUCLEAR

LONDON, UK, 2022

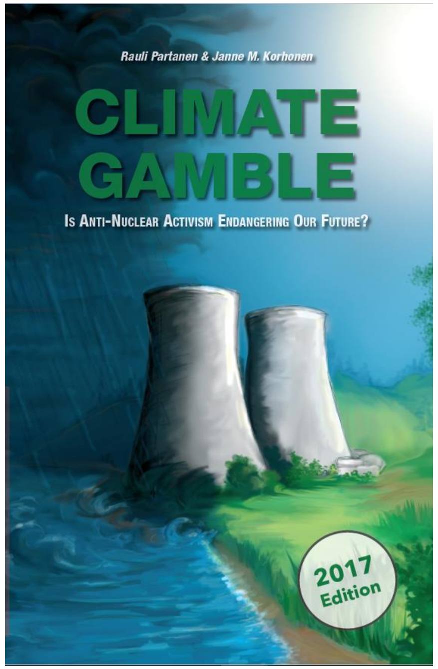
THINKATOM

RAULI WHO?

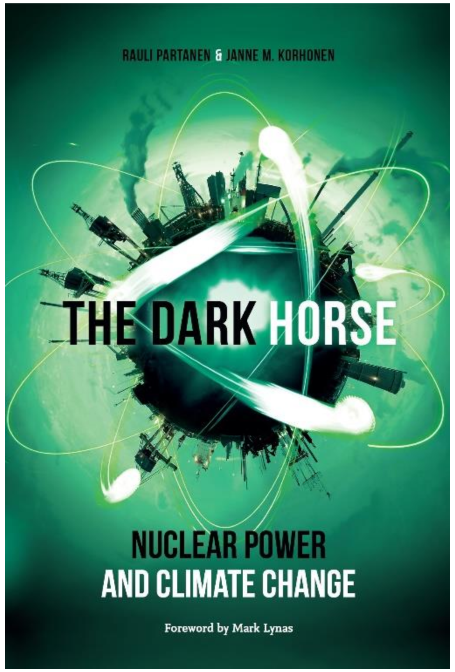
- Science writer, analyst, and communicator
- Environmental activist (Ecomodernist Society of Finland, RePlanet)
- Co-founder & CEO of Think Atom



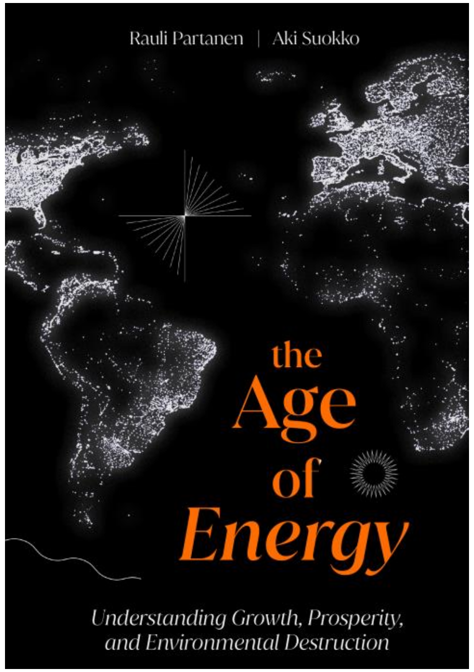
2014



2015



2020

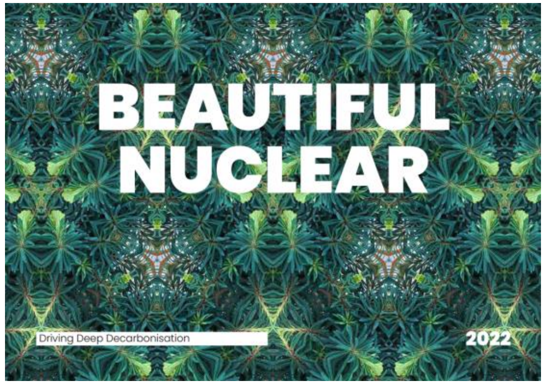


2022

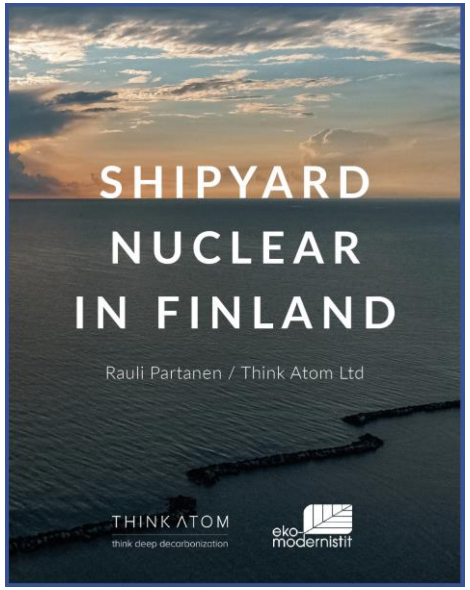
THINK ATOM

A non-profit, independent think tank

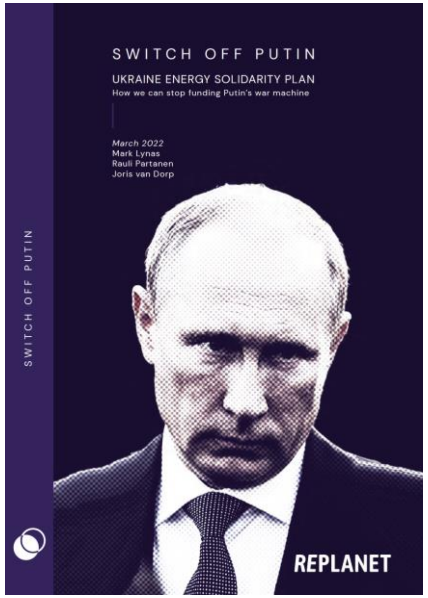
Thinkatom.net/publications



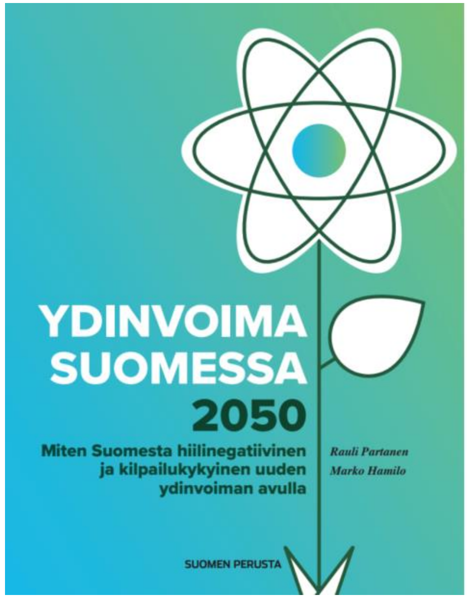
2022



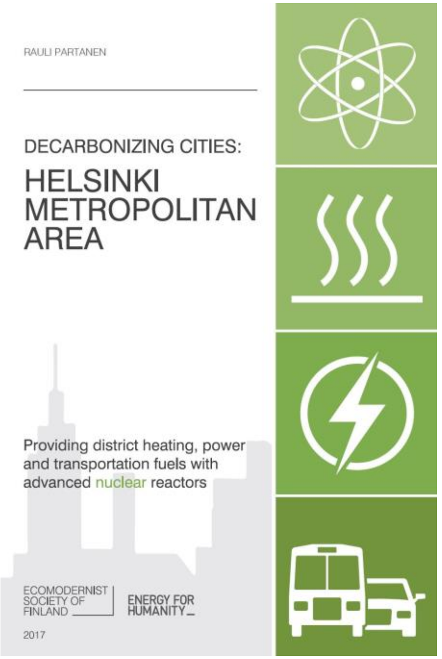
2022



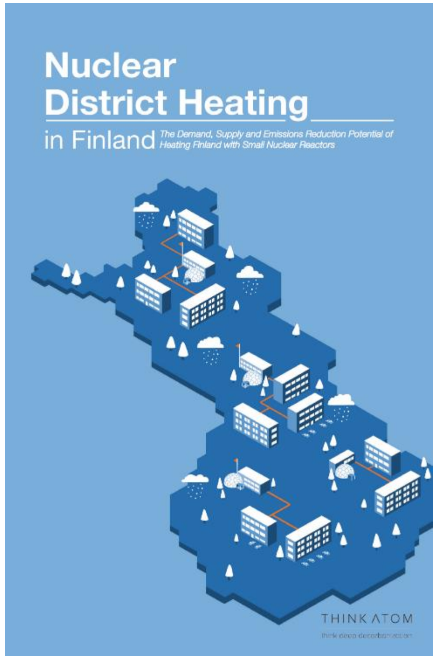
2022



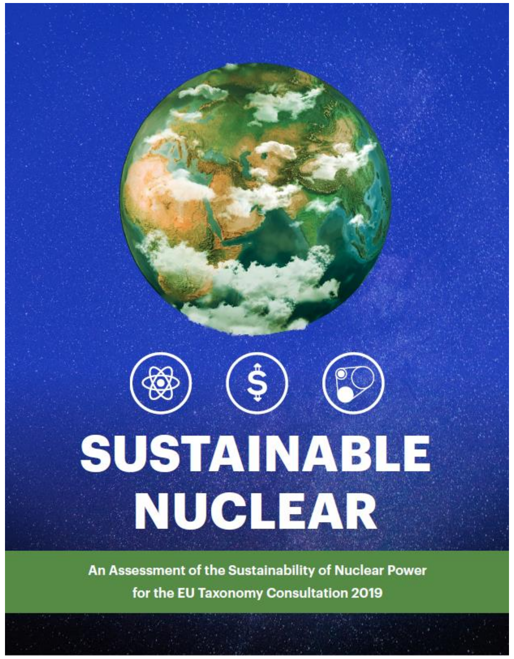
2021



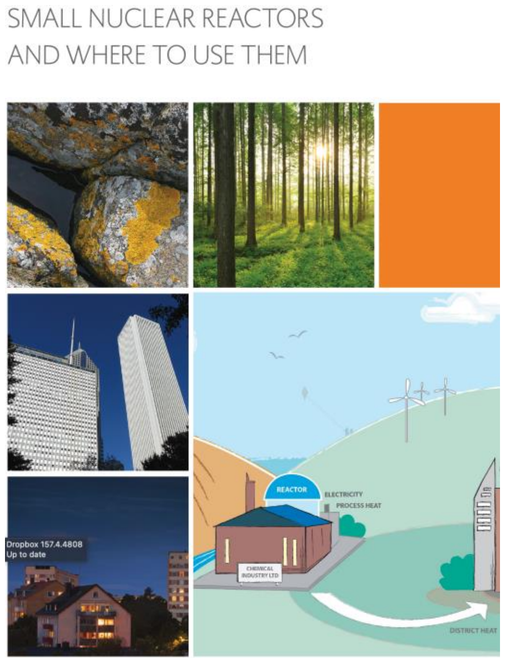
2017



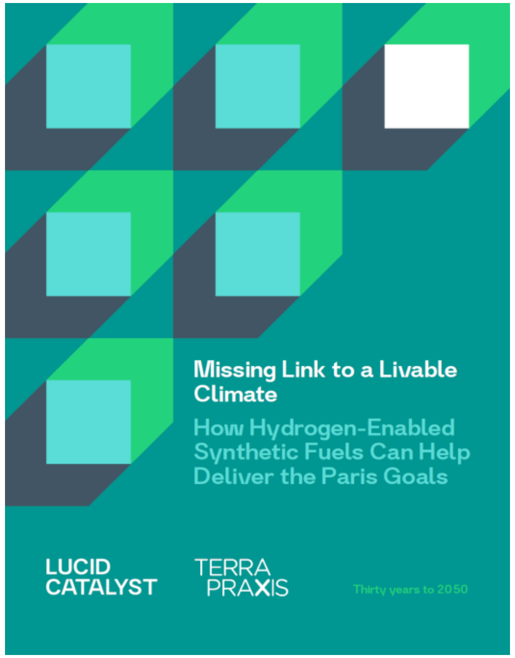
2019



2019



2020



2020

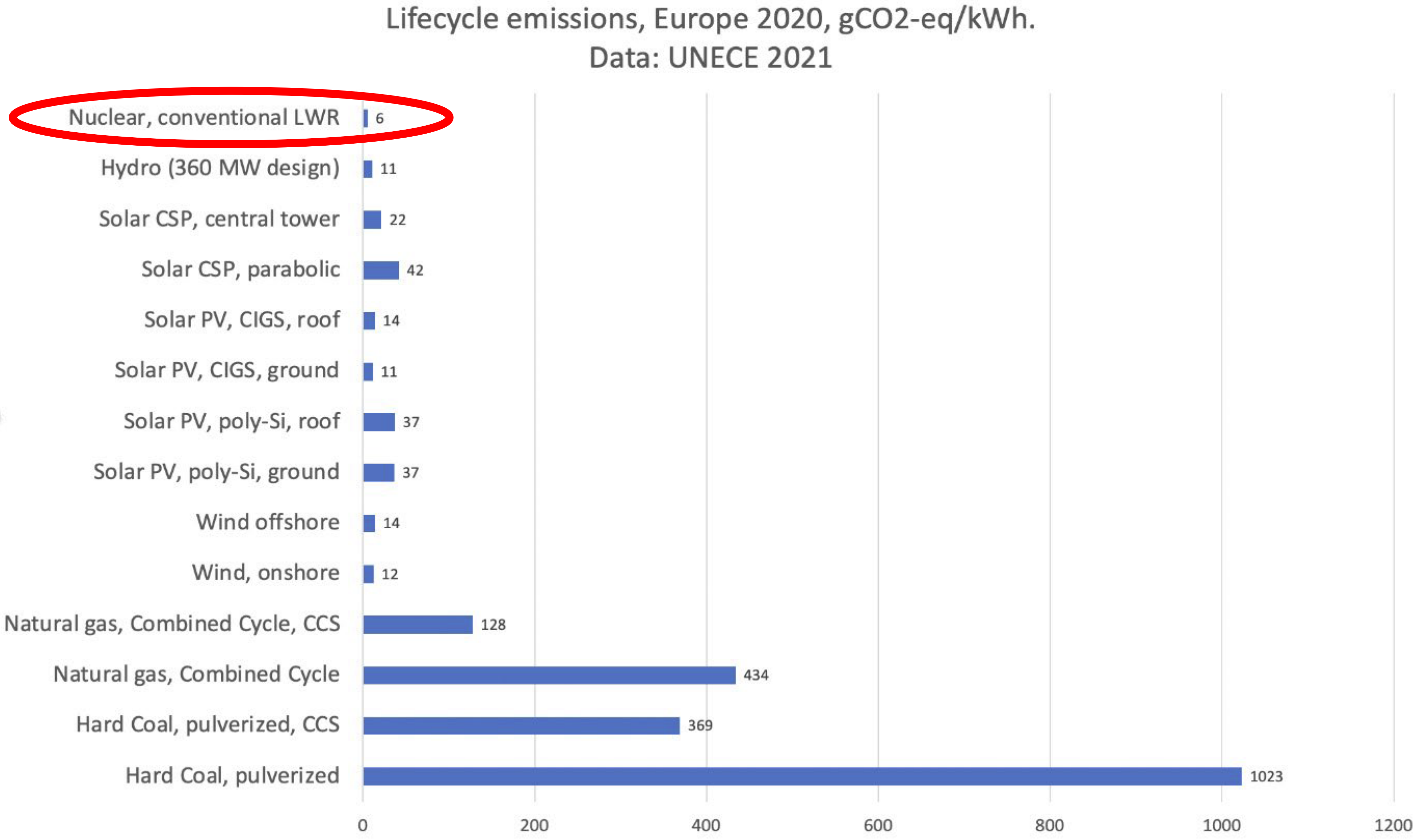
Why nuclear is beautiful?

“Nuclear is beautiful because its tiny land use and lifecycle footprint protects nature and delivers civilisation-scale, abundant clean energy.” - Kirsty Gogan

SUSTAINABLE DEVELOPMENT

- Nuclear technology contributes to **EVERY SINGLE ONE** of the 17 UN Sustainable Development Goals

NUCLEAR IS THE LOWEST CARBON



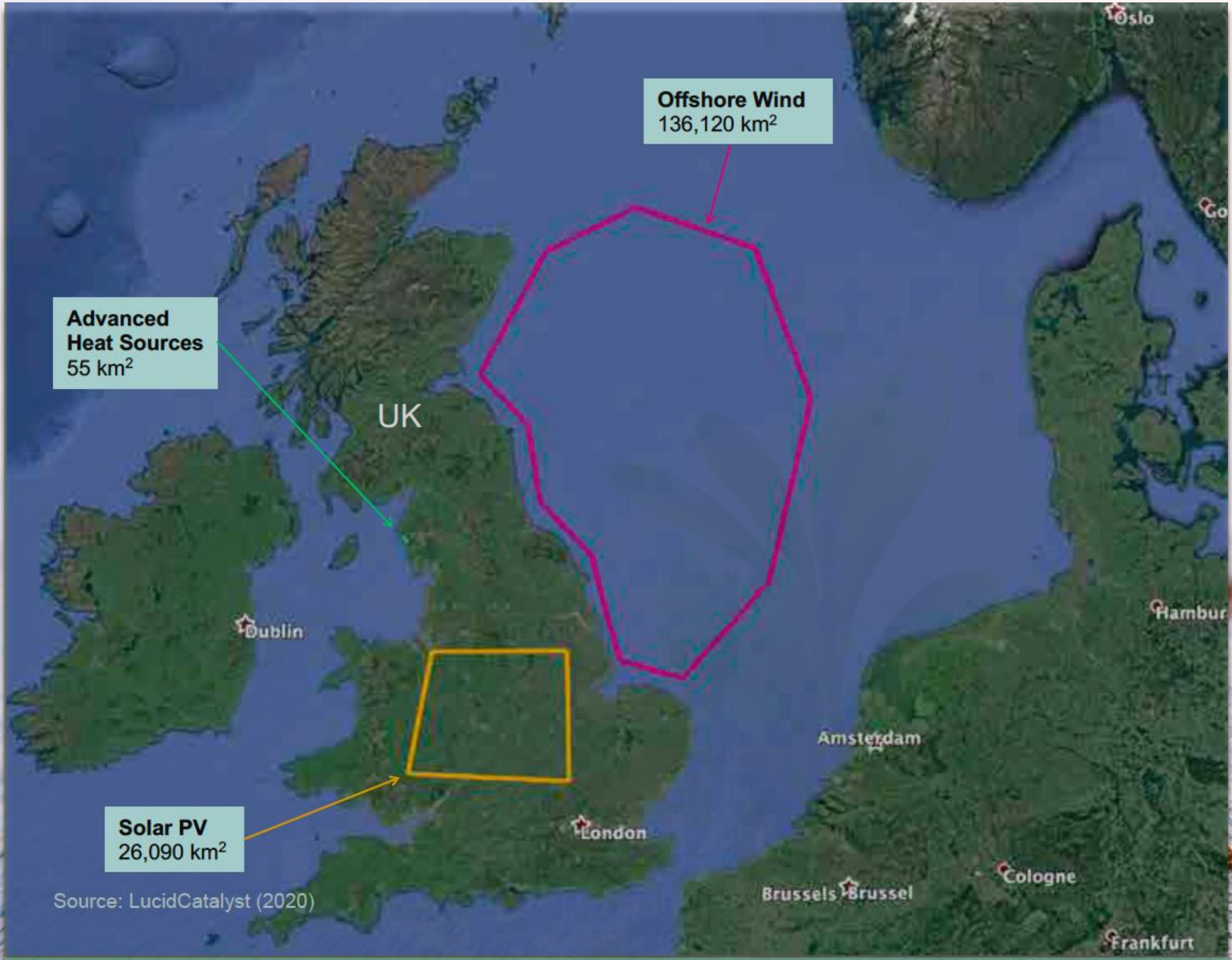
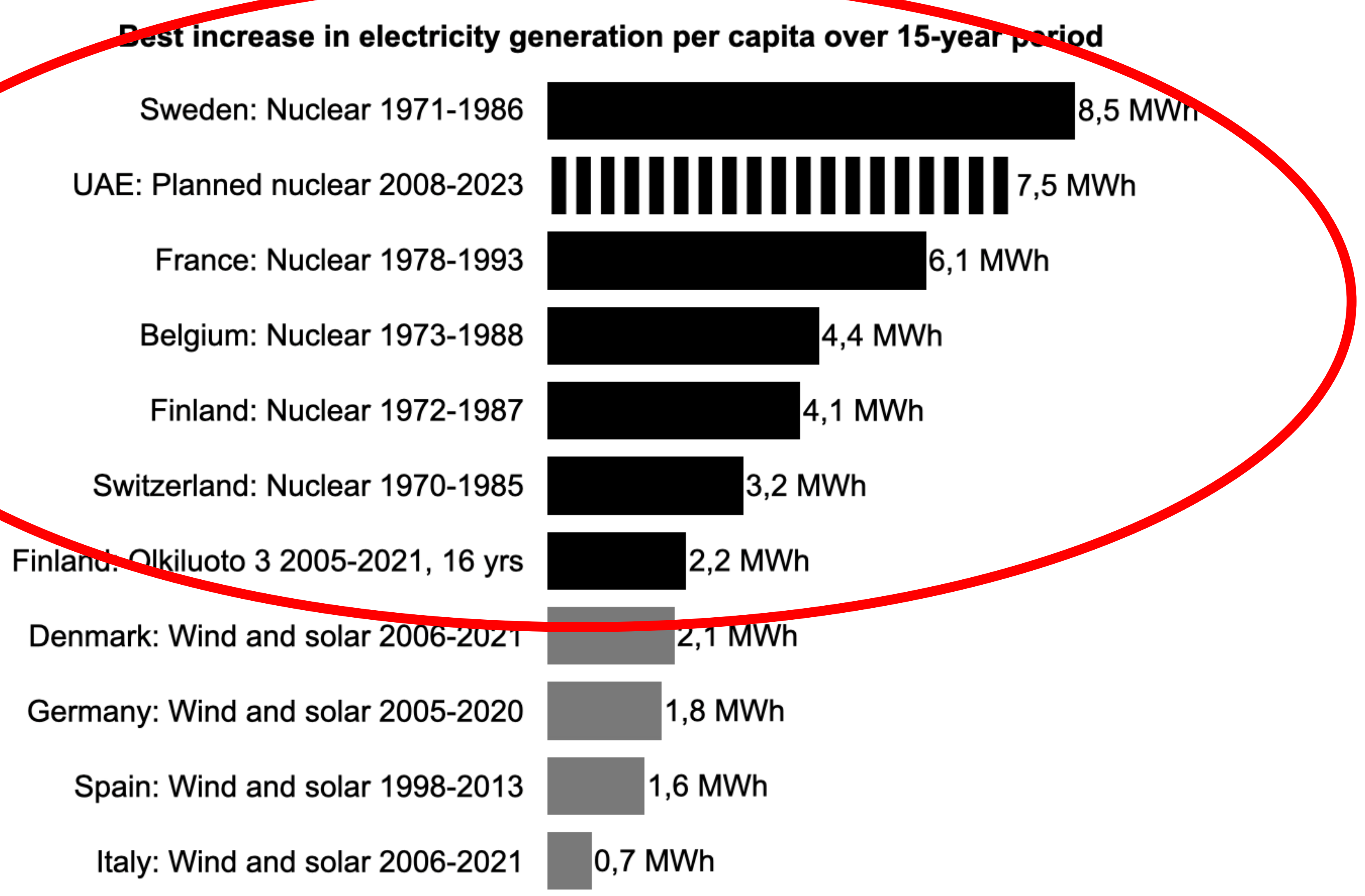


Figure 28. **Area required to replace UK's current oil consumption with hydrogen**

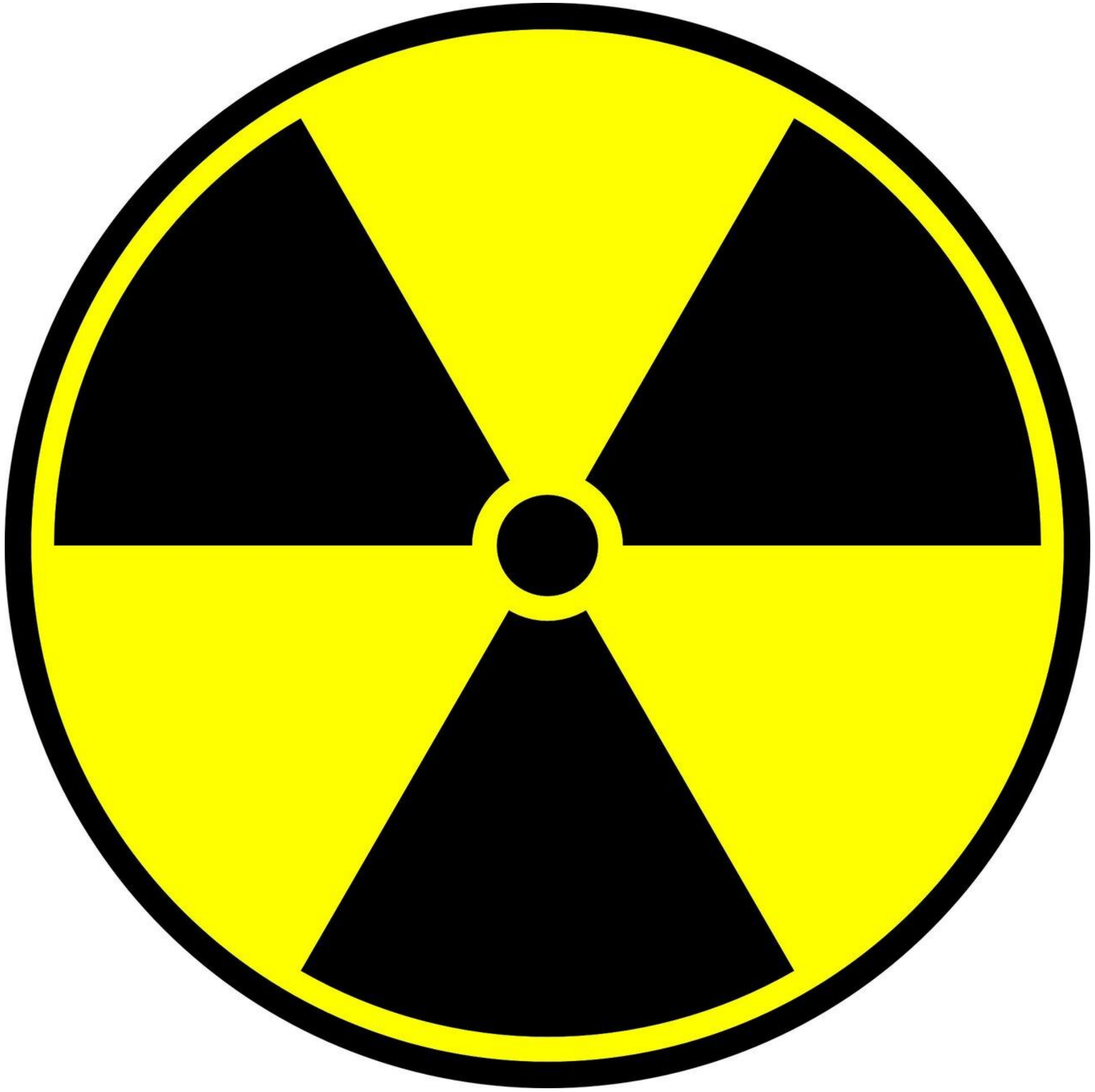
NUCLEAR HAS THE SMALLEST ENVIRONMENTAL FOOTPRINT

"No other carbon-neutral electricity source has been expanded anywhere near as fast as nuclear."

Barry Brook & Staffan Qvist



THE WORRIES



WHAT ABOUT RADIATION?

- The industry and our society has utterly failed to communicate the scale of the matter.

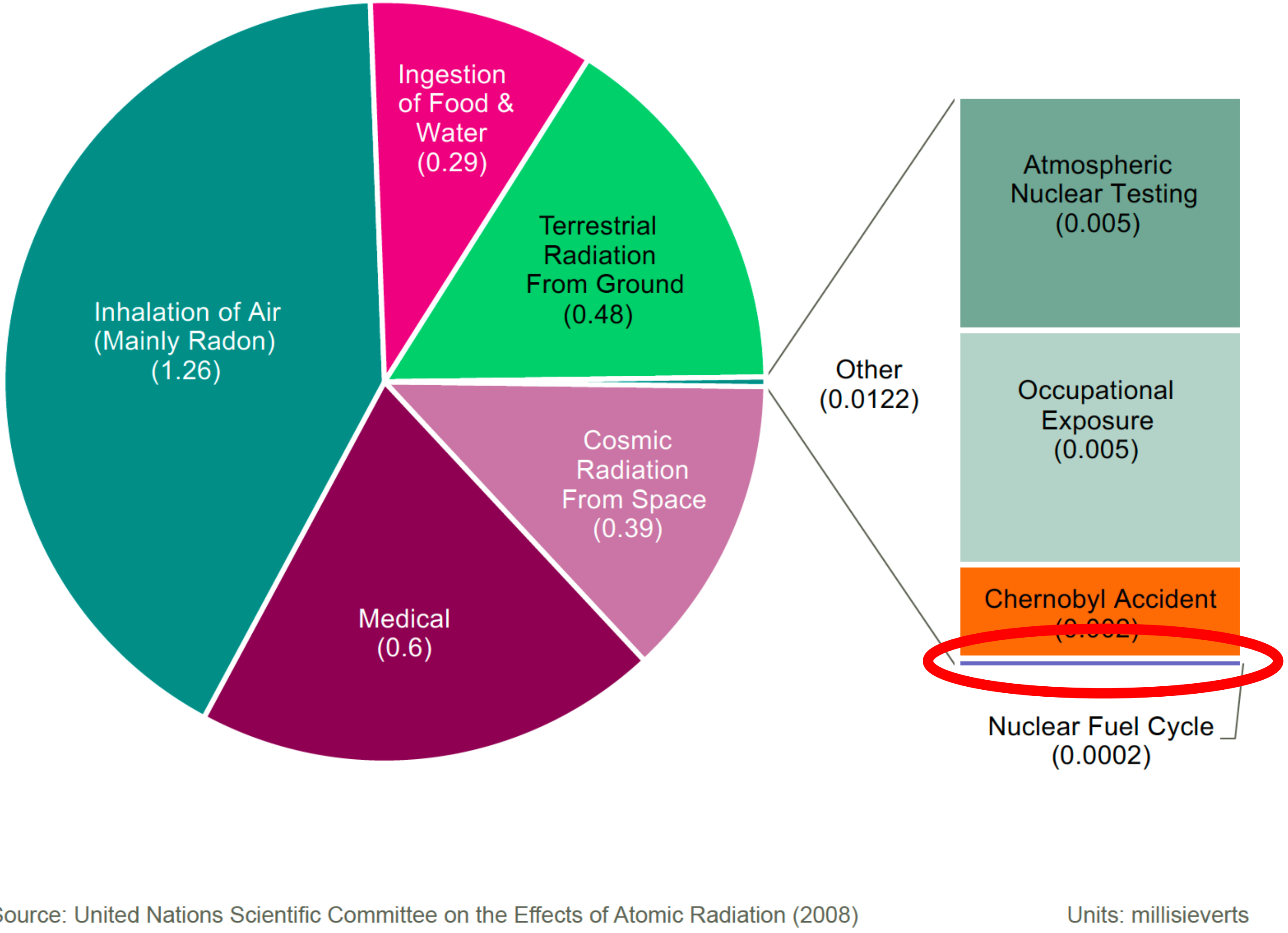


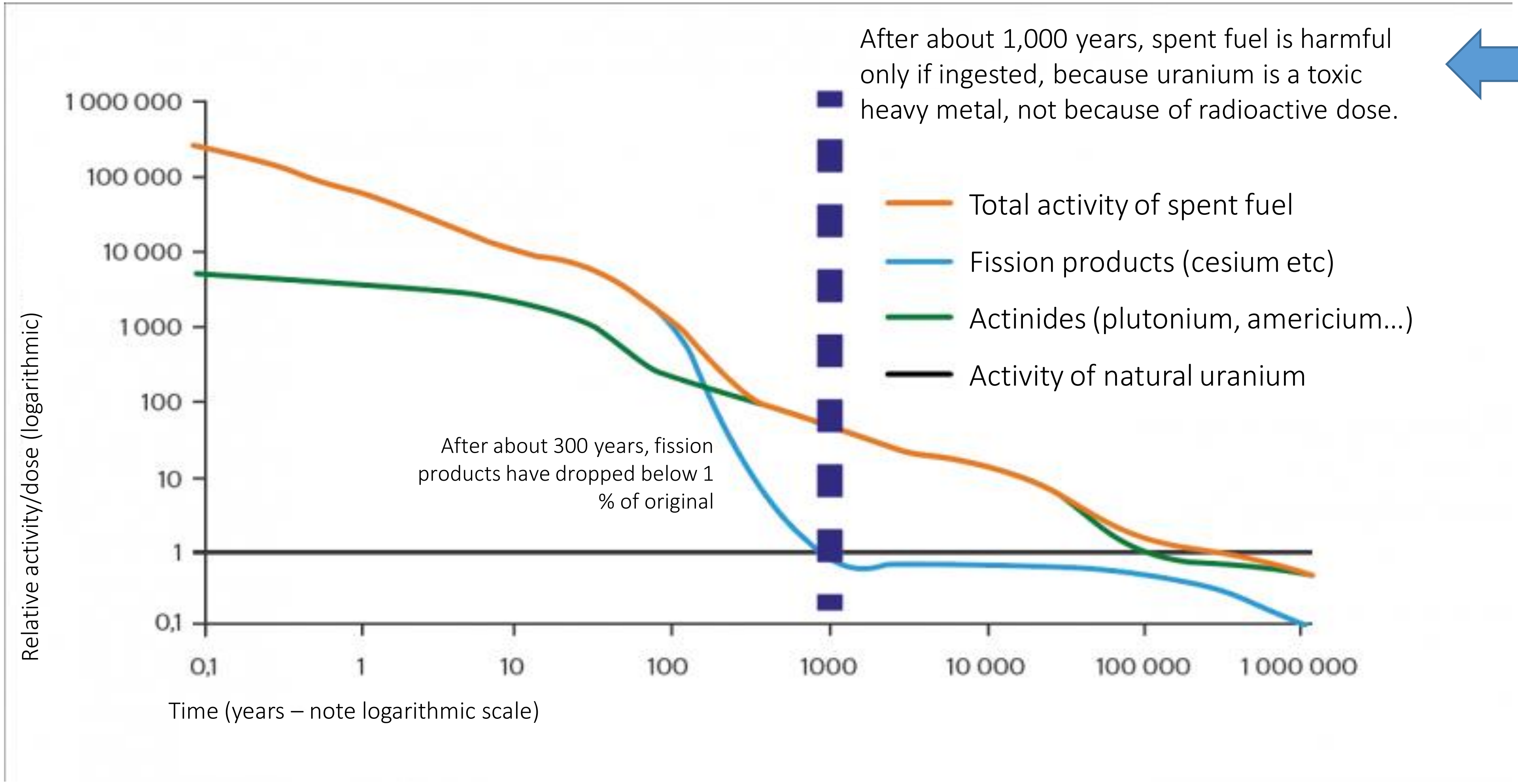
Figure 32. **Sources of global radiation, average annual dose from all sources**

…AND SPENT FUEL?

- Spent fuel is so well managed that it has never hurt anyone.
- It gets less harmful with time.
- Deep geological storage has a safety margin of roughly one million times:
  - Worst-case scenario, max dose: 0.00018 mSv/year*
  - Threshold for health hazard:
    100+ mSv / year

* Based on Onkalo Deep Repository's environmental assessment.
https://inis.iaea.org/search/search.aspx?orig_q=RN:45087737

GOING SCIENTIFIC ON SPENT FUEL…



Why nobody says this aloud?

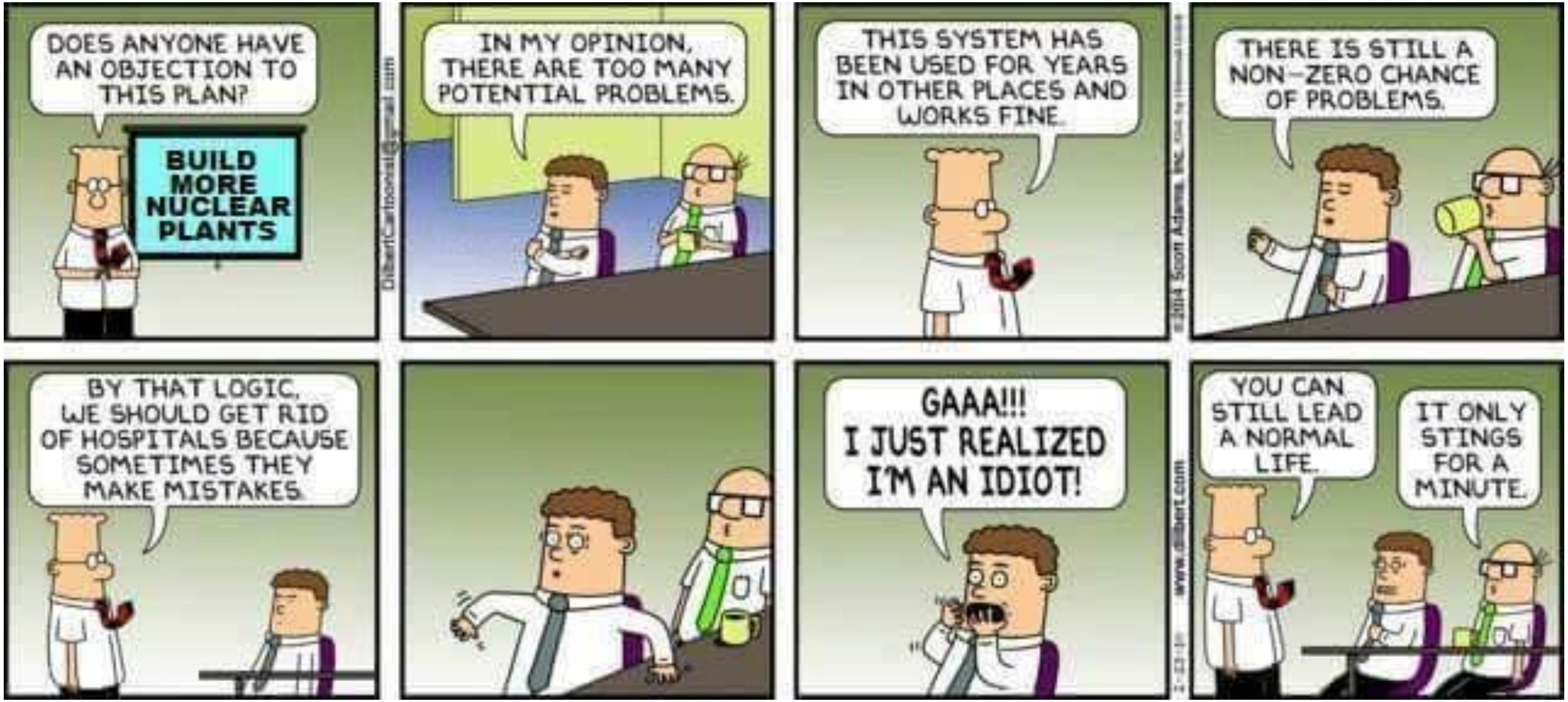
THINK ATOM

"I think we're going to look back and ask ourselves how did we let at least five million people die from air pollution every year? It's totally obscene."

Isabelle Boemeke, isodope; science communicator

Climate is a big challenge.

Nuclear is a big, beautiful solution.



THINK ATOM

think deep decarbonization

THANK YOU.

RAULI PARTANEN

Sizewell C – A Sustainable Clean Energy Transition

Shekhar Sumit
(Head of Energy Transition, Sizewell C)

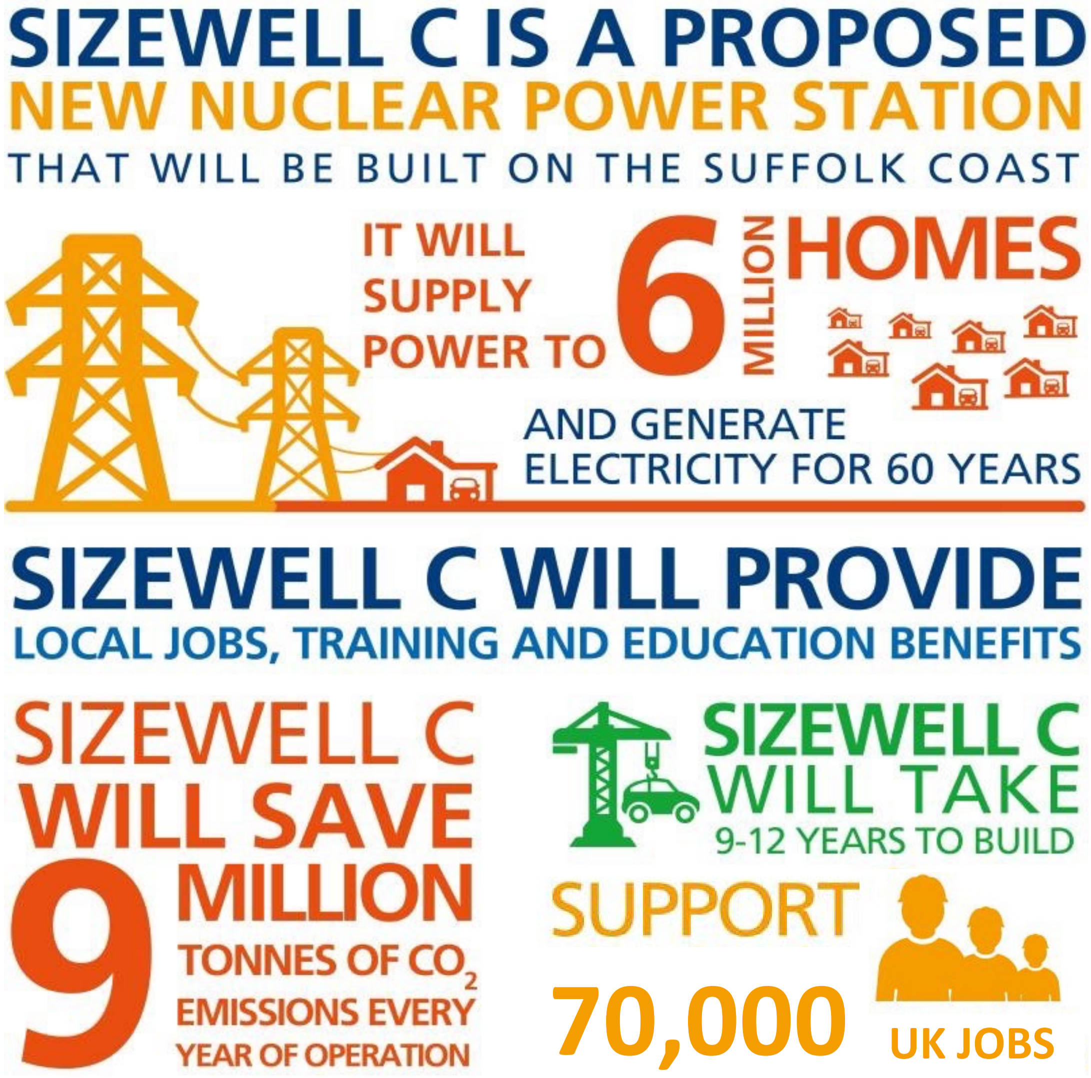
October 2022

SizewellC
Doing the power of good for Britain

Sizewell C is ready to go

Where are we with Sizewell C?

- **Detailed buildable design**.
- Will replicate the **Hinkley Point C** nuclear power station currently being constructed in Somerset.
- **Discussions with Government** on the project are progressing well.
- After 8 years of consultation, have received a **positive Development Consent Order**.
- Applied for a **Nuclear Site License** and have applied for **environment consents** – positive response from regulators.

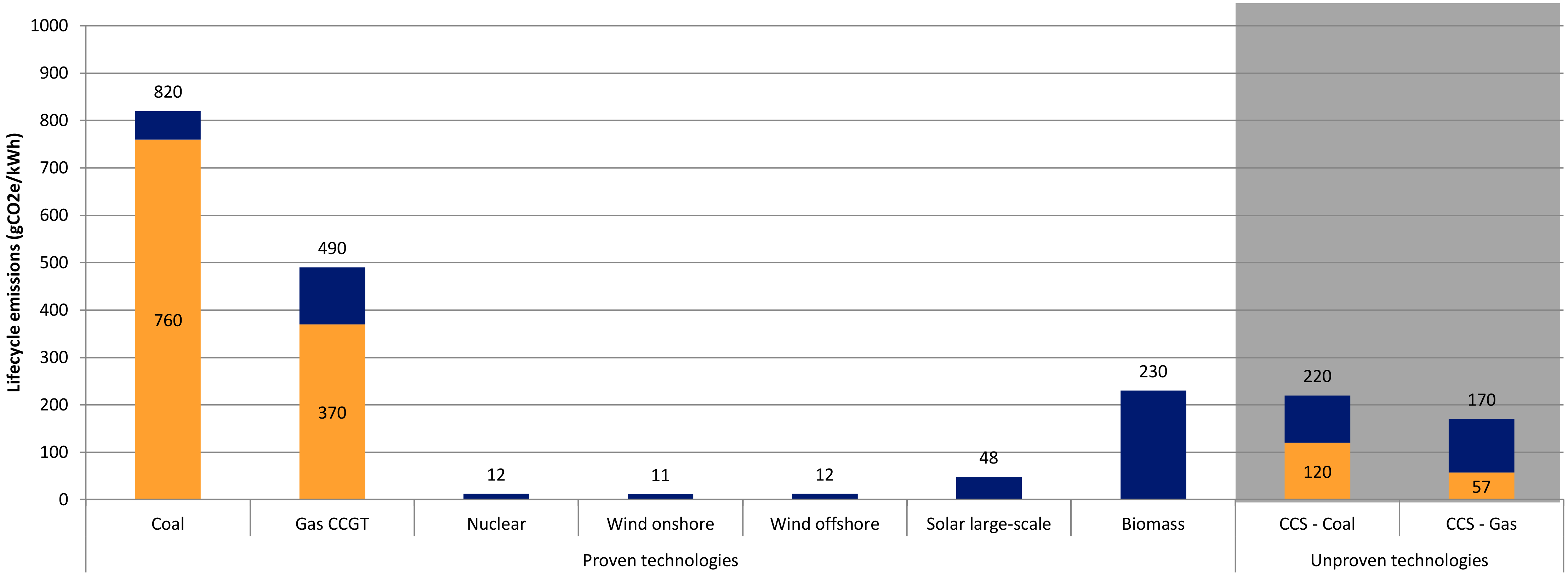


SizewellC

Nuclear is one of the lowest carbon generating technologies

Approximate lifetime greenhouse gas emissions per technology

- **Direct** (i.e. Combustion) emissions (in grams of CO_2 produced per kilowatt hour generated)
- **Other lifecycle emissions** (construction; maintenance; fuel extraction, processing; transport; leakage; decommissioning and disposal)



Source: IPCC 5th assessment report, median values from Annex III, Table A.III.2
*Based on a third party verified carbon lifecycle assessment (May 2021)

Sizewell C and the Environment

Nuclear provides more energy on a fraction of the land than wind & solar

300
MWh per acre
per year

300,000
MWh per acre
per year

100
MWh per acre
per year

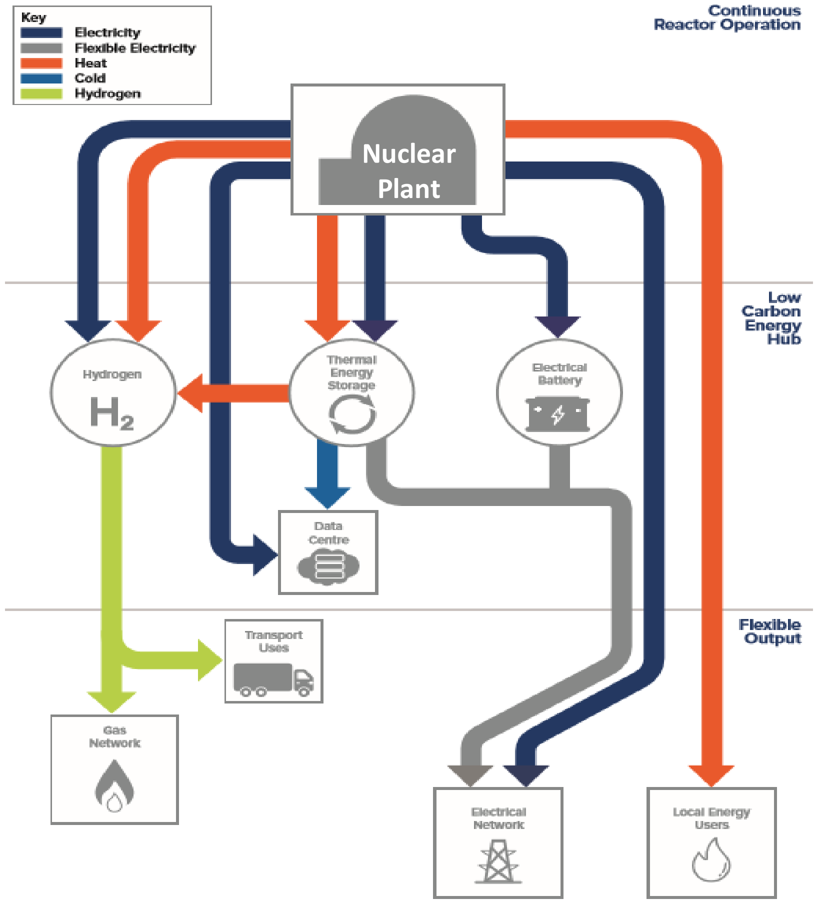
Sizewell C aims to leave a positive legacy, including a net gain in biodiversity

Aldhurst Farm: We have created 67 hectares of new habitat, benefitting a variety of wildlife as well as rare plants.

SizewellC edf CGN

Sizewell C Energy Hub

As part of an Energy Hub, Sizewell C can make an even greater contribution to the UK's net zero ambition, helping to decarbonise industry, transport and heating



Source: Mott MacDonald

Sizewell C has the potential to produce:

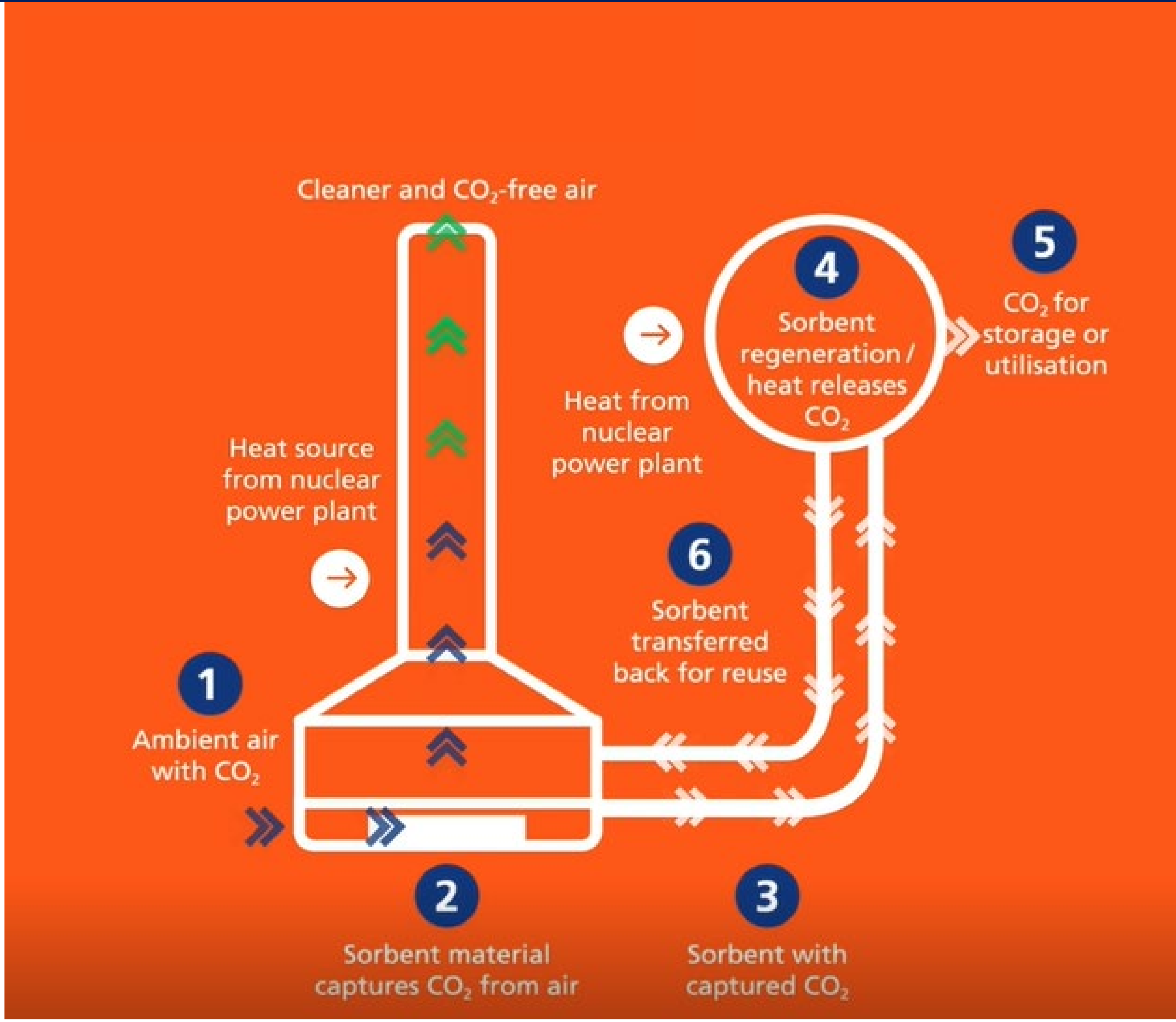
- **Low carbon hydrogen** – Using heat to make electrolysis more efficient
- **Direct Air Capture**, making Sizewell C **carbon negative**
- **Clean fuels** for shipping and aviation
- Clean heat for industrial processes and for **district heating**
- **Cooling data centres**
- Working with **freeports** to provide clean heat and power

SizewellC edf CGN

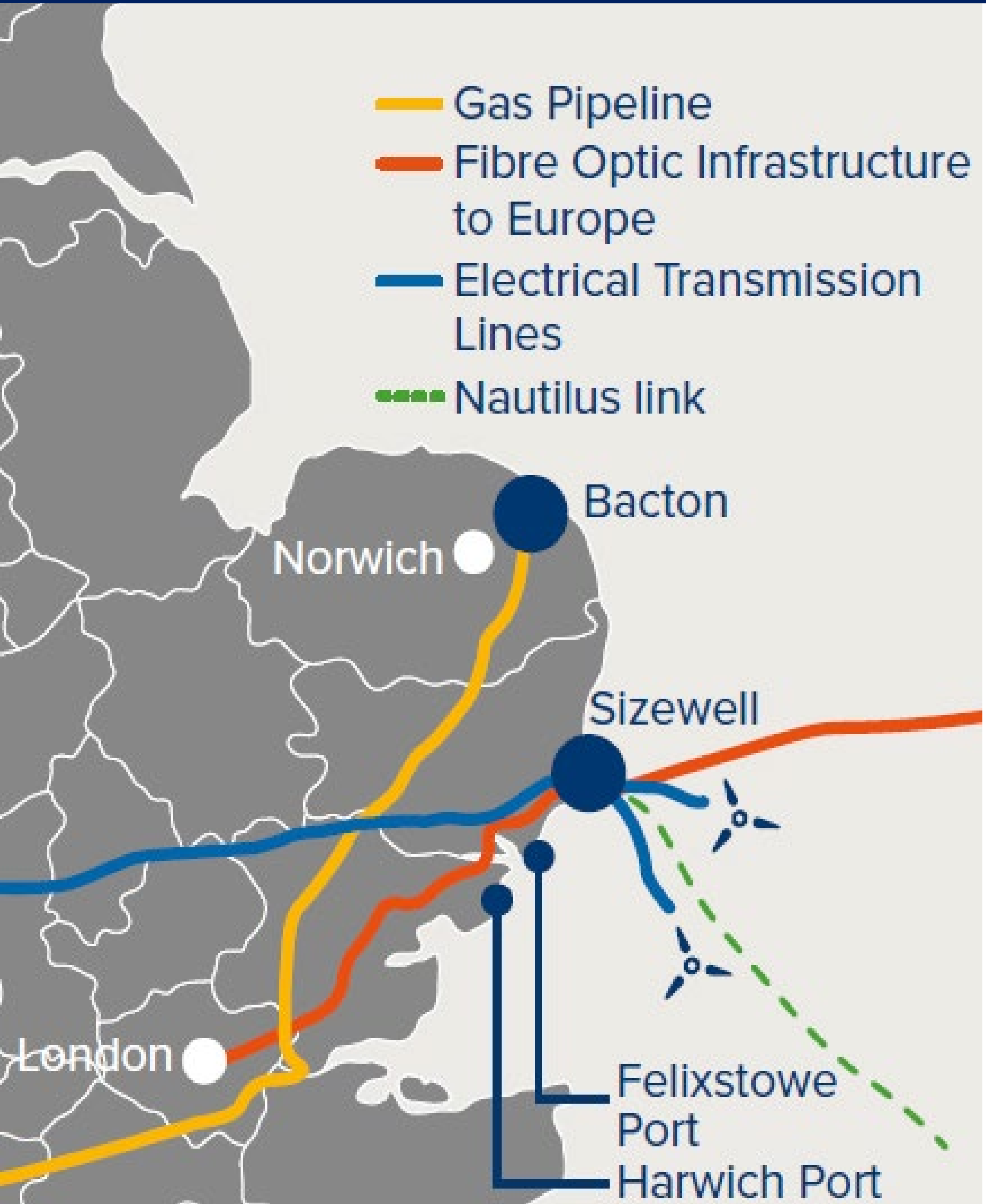
Direct Air Capture at Sizewell C

Consortium led by Sizewell C developing plans for Direct Air Capture (DAC) powered by low-carbon heat:

- A small-scale demonstrator DAC system would be capable of capturing **100 tonnes of CO2 per year.**
- A scaled-up version could capture 1.5m tonnes of CO2 per year - enough to **almost offset the annual emissions of the UK's rail network**.
- The carbon captured by DAC can be combined with hydrogen produced by electrolysis to make net zero hydrocarbons and **synthetic aviation fuels.**



Hydrogen and Sizewell C



Exploring the opportunity to kickstart the hydrogen economy in the East of England

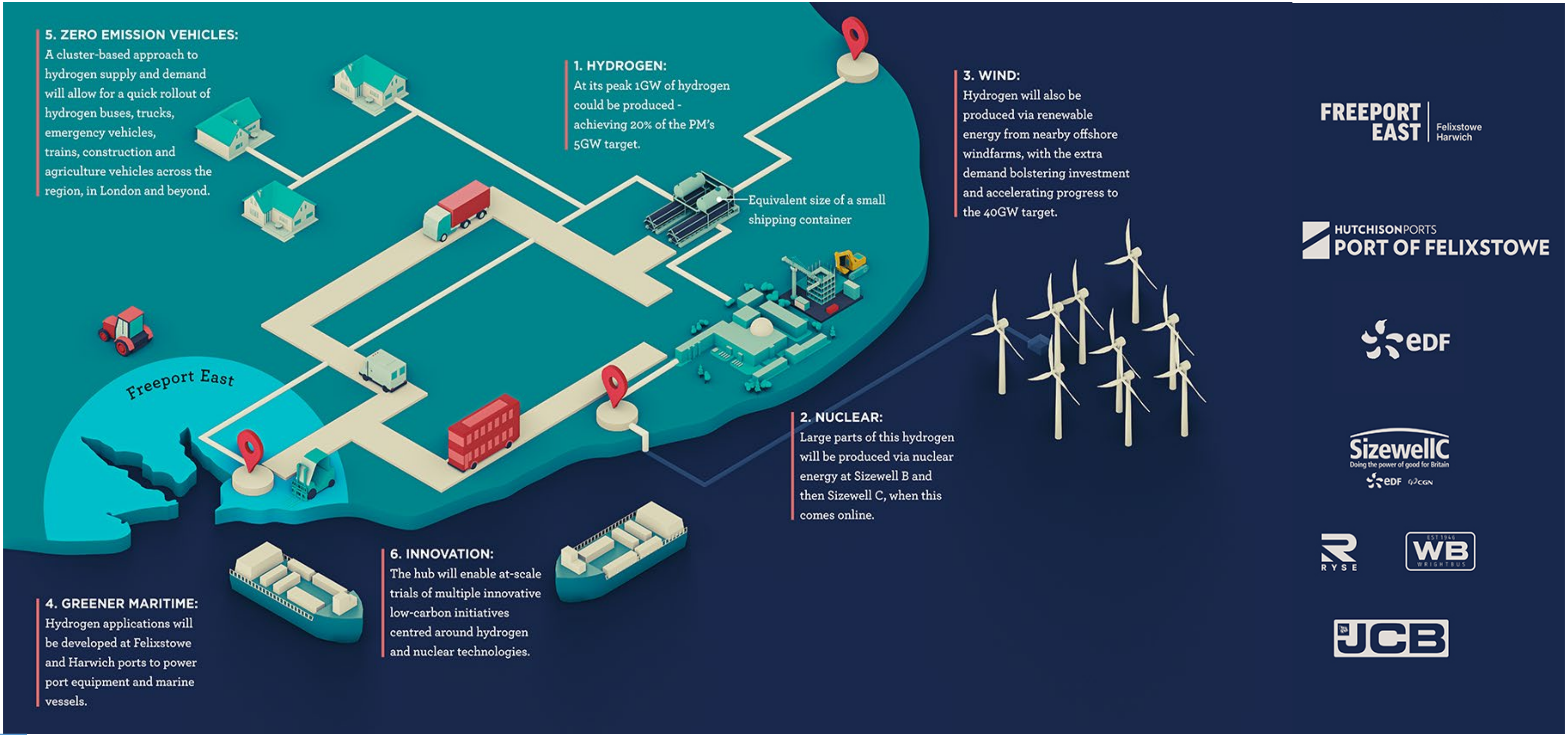
- <u>Short Term</u>: Using hydrogen buses / construction equipment to **decarbonise Sizewell C construction** and serving as a **regional hydrogen demand aggregator and catalyst**.

- <u>Long Term</u>: Sizewell C can make hydrogen production **more efficient using low carbon heat**.

- <u>Location</u>: **Sizewell C is ideally located** close to the Bacton terminal / ports such as Felixstowe / opportunities to work with offshore wind.

Freeport East Hydrogen Hub

First-of-a-Kind Nuclear, Renewables and Hydrogen Project



SizewellC eDF CGN

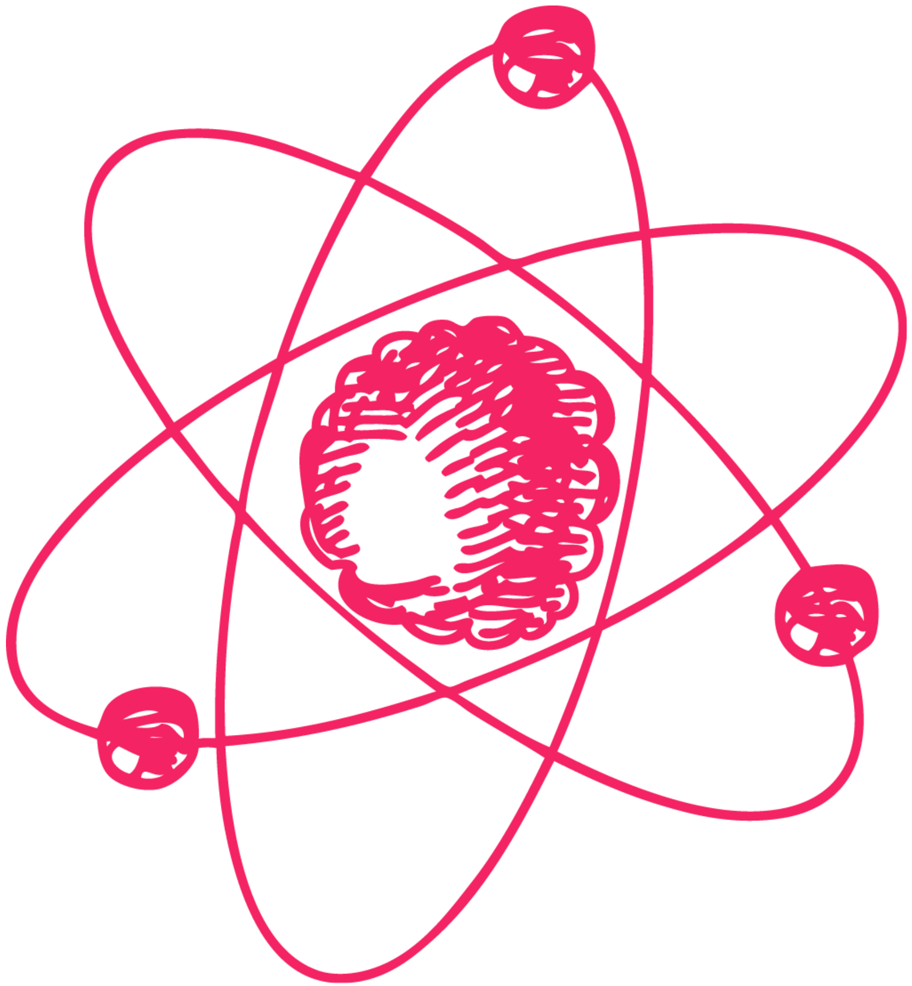
Thank you

Sizewell C
Doing the power of good for Britain
EDF CGN

NNWI Forum 2022

Environmental Sustainability Panel

Neil Hirst
Honorary Senior Research Fellow
Grantham Institute
Imperial College London



#NNWIForum2022

NUCLEAR 21®
PERSPECTIVE FOR YOUR DECISIONS

Let’s Energise Sustainability

WE ARE NUCLEAR-21:

An independent expert cabinet providing bankable decision support driving policy, strategies and business development towards optimised nuclear-based solutions

| WE EXIST THANKS TO NUCLEAR …
LET'S USE IT WISELY TO PROVIDE A FUTURE TO US ALL NOW AND FOREVER

18 October 2022 - London

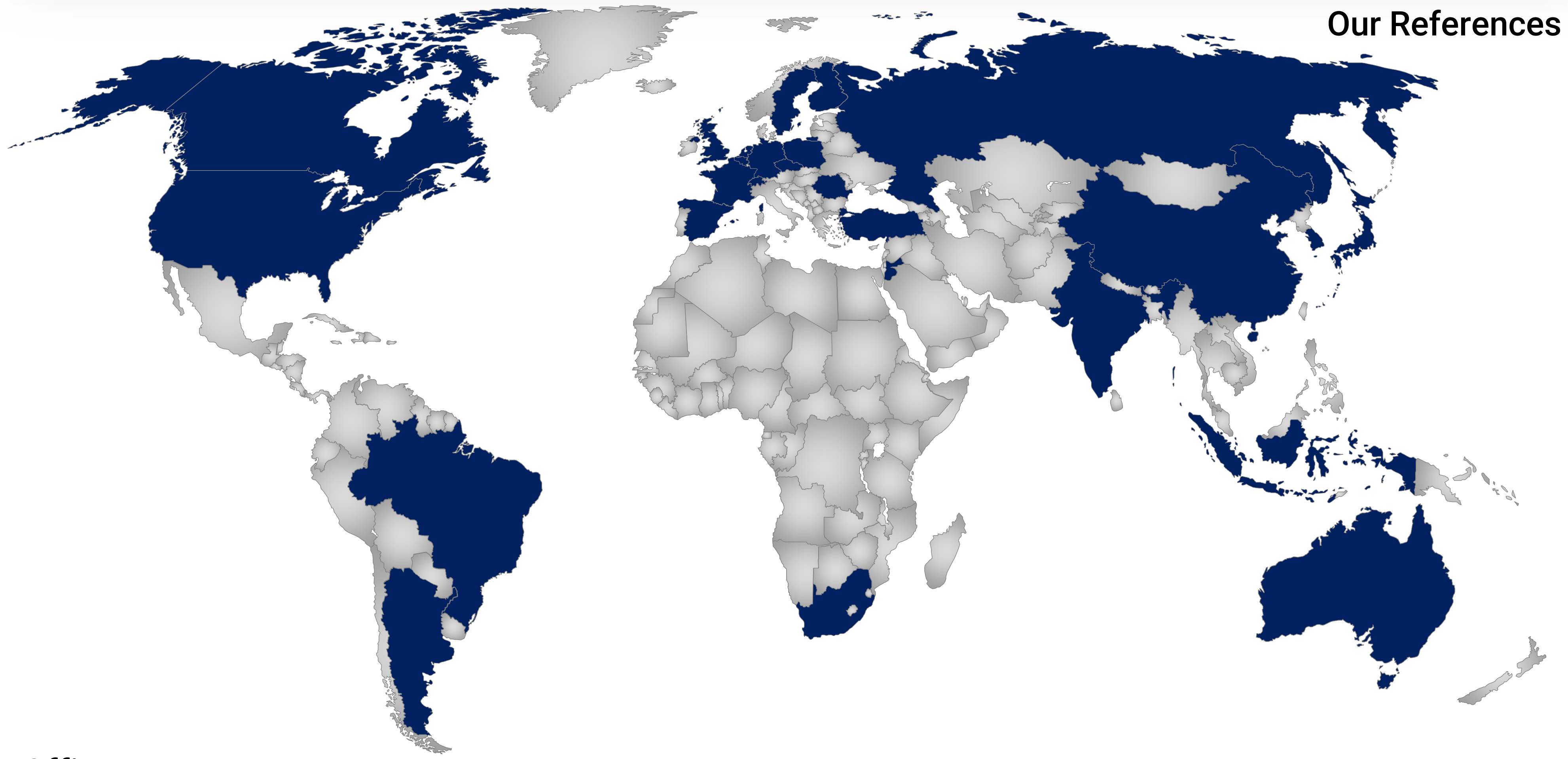
NNWI Forum

OUR SERVICES AIM TO:

1. Identify and analyse the challenges our customers face in developing and using nuclear science & technology based solutions
2. Enrich policy, strategy and business options
3. Support our customers in their policy, strategy and business development activities
4. Recommend decisions based on proven, sector-specific expertise and quantitative, best practice methodologies
5. Broker solutions-focused international partnerships
6. Ensure compliance with international and national requirements and regulations

Nuclear-21
is an independent expert cabinet providing bankable decision support driving policy, strategies and business development towards optimised nuclear based solutions

Our References



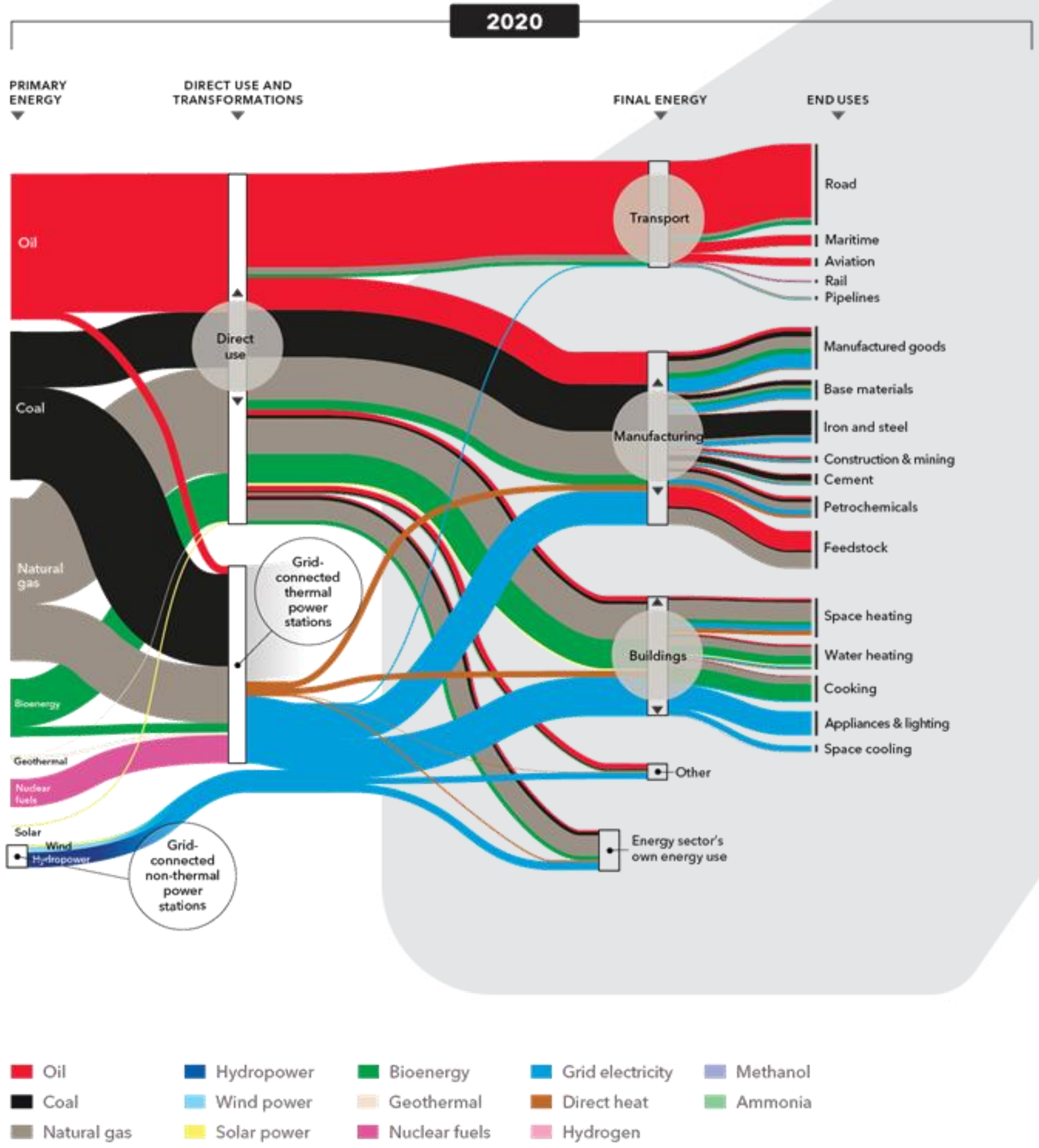
Offices:

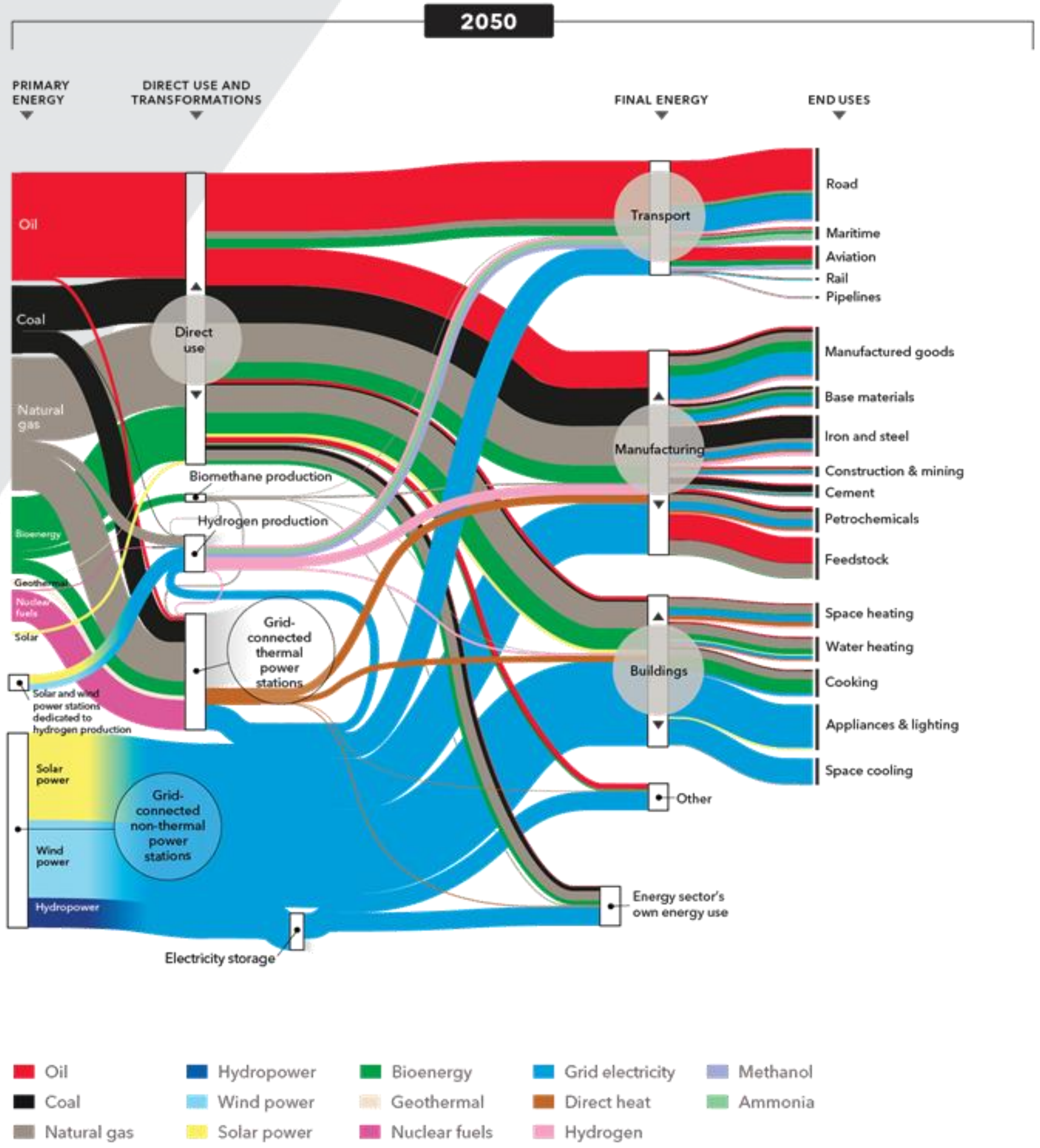
Gent – Belgium
Paris – France
London – UK
The Hague – The Netherlands

MAJOR TRENDS IN ENERGY SYSTEMS WORLDWIDE

AN ENERGY SYSTEMS VIEW IS ESSENTIAL ...

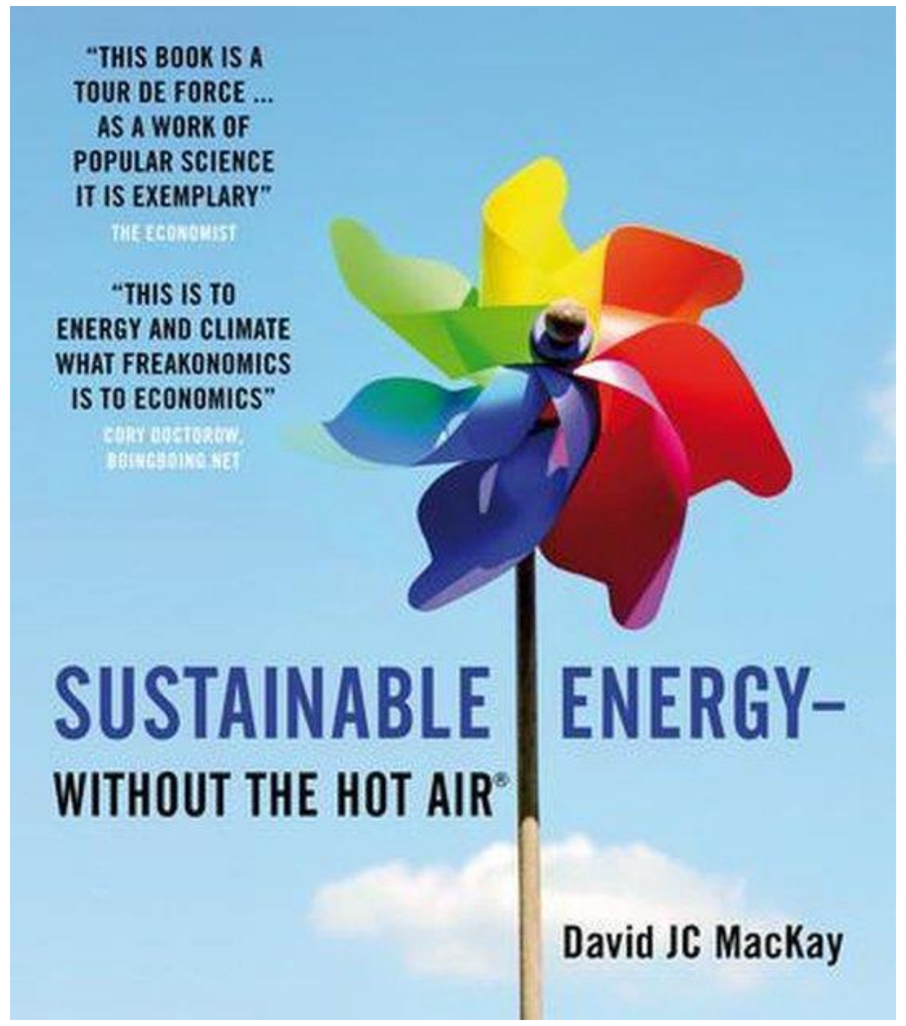
IDEALLY WITH A POLICY SPANNING MULTIPLE DECADES

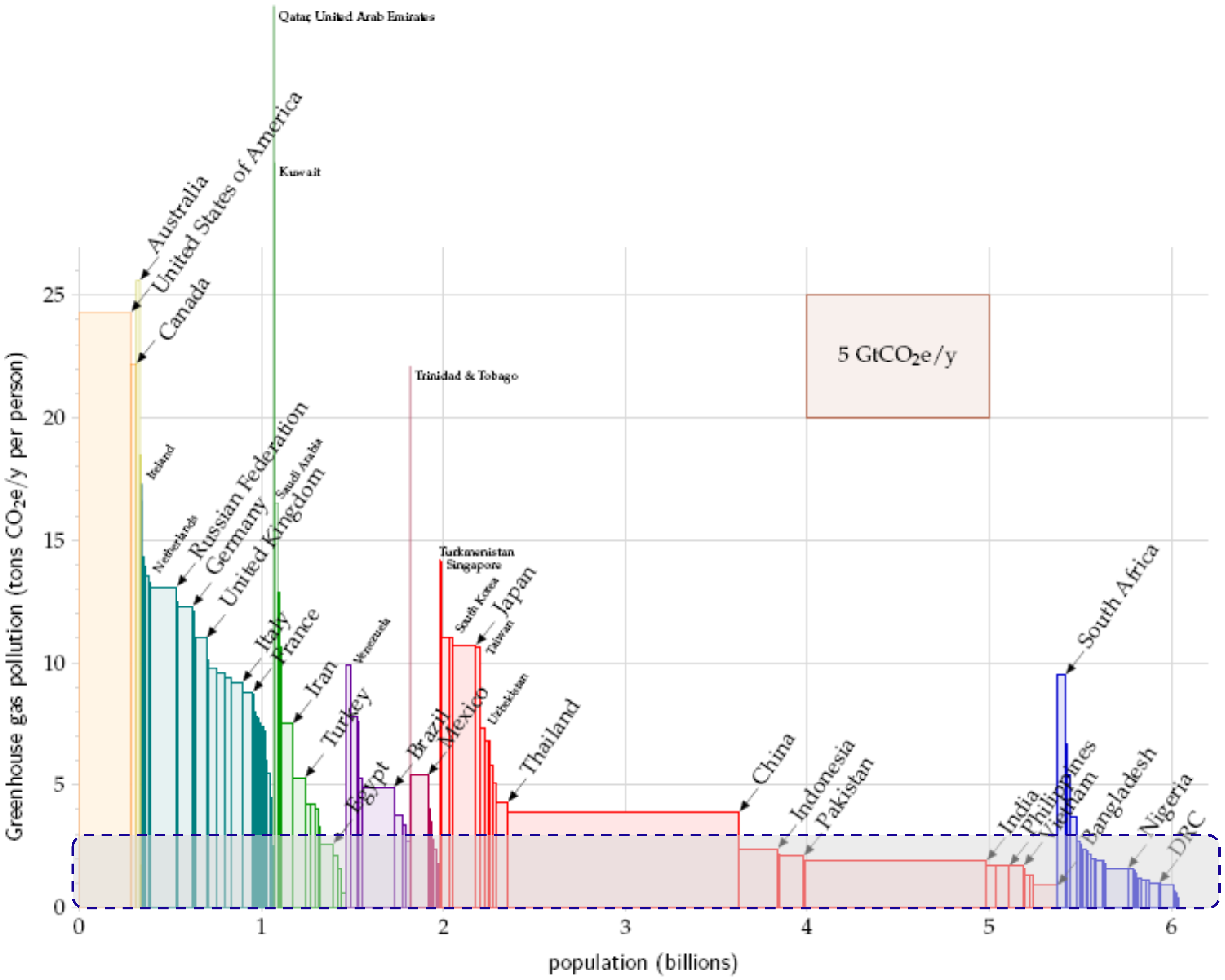




Ref. DNV GL Energy Transition Outlook 2022

AND TIME IS PRESSING





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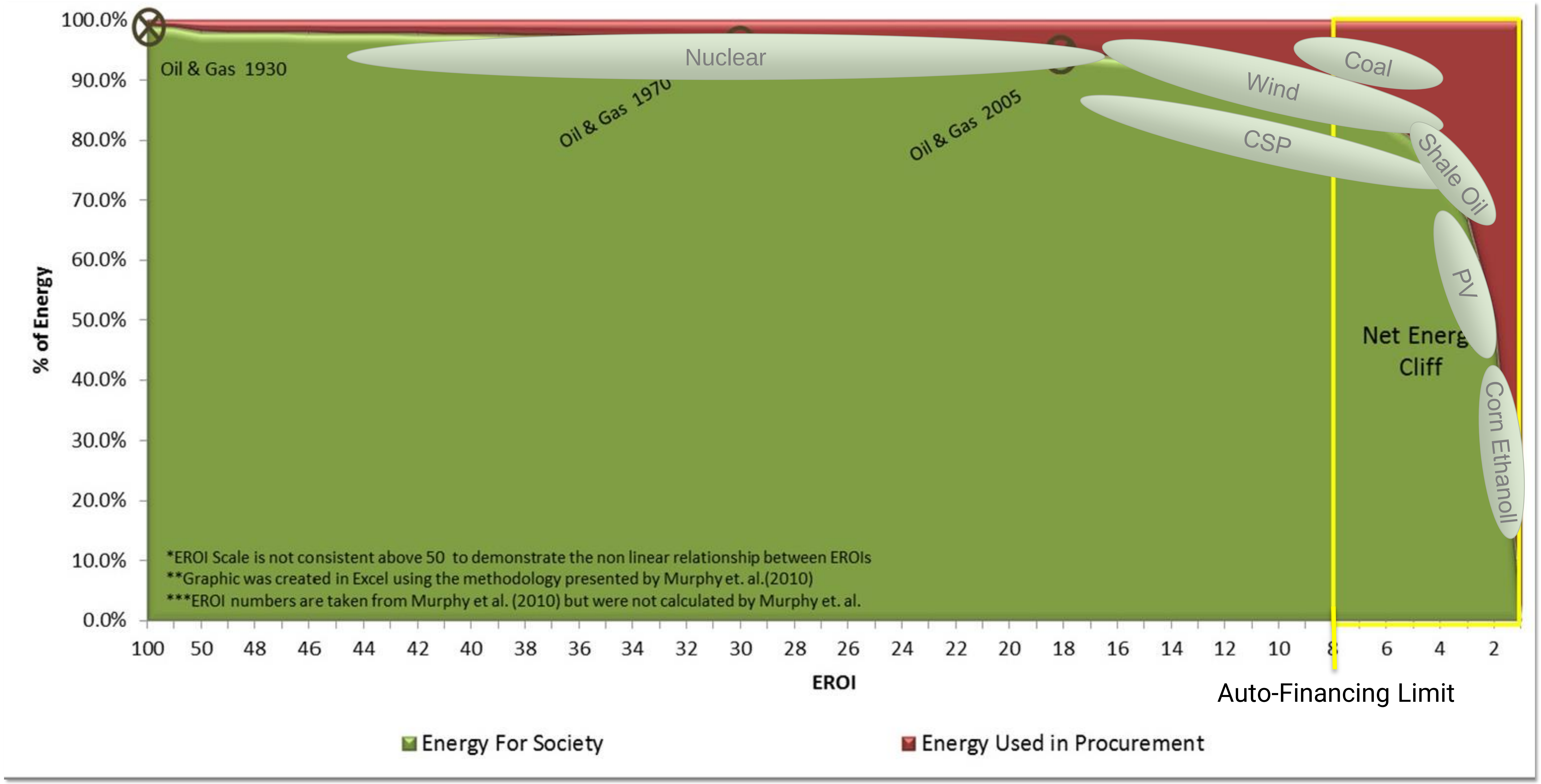
THE INCREASING « ENERGY CLIFF DILEMMA »



Complementarity of low-carbon energy options is a necessity and will demand synergies between regional, typically higher EROEI, with local, typically lower EROEI, energy solutions

ON THE FUTURE OF NUCLEAR ENERGY

- Our challenge
  - Positioning nuclear energy in a constantly changing energy market
    - After a liberalisation and deregulation wave since the end of last century challenging the nuclear energy competitiveness,
    - And after an euphoric transition period in favour of renewables
    - A global decarbonisation wave is developing in consideration of the contribution of energy to climate change and related States commitments
    - Tomorrow, post-COVID a “back-to-basics” wave, i.e. resilience of the energy system and a more holistic systems approach into energy systems may find its place? (this dates from a period before … Ukraine)

- Tomorrow’s sustainable energy market will demand a nuclear energy even better suited to
  - Serve various energy market segments as reliable energy conversion source
  - Remaining competitive
  - Guaranteeing safety, security and safeguards performance
  - Guarantee that all reasonably recoverable materials are optimally managed and waste responsibly disposed of
  - Reducing the waste amount and long-term stewardship requirements
  - and, gradually, using less natural resources

CENTRAL QUESTION

How do we get nuclear energy "bankable" again … without doubt …

→ ***Be performant throughout the life cycle***

→ ***Be essential for energy systems***

→ ***Bring solutions to world problems***

→ ***Be sustainable***

This presentation addresses parts of an ongoing study by Nuclear-21

"Let's Energise Sustainability", i.e.

We need to act on sustainability and thus energise the process towards such future

Sustainability requires energy resources that comply with the key principle: answer the demand minimising the burden to future generations

Nuclear is the only current known technology providing this perspective

OUR APPROACH

- *A systems view on*
  - The role for nuclear energy in today's and tomorrow's (energy) systems
  - The key criteria to deliver on nuclear energy
  - The intra-nuclear options ensuring and facilitating to deliver on nuclear energy
  - How to provide a decisional framework fully valuing the (long-term) merits of nuclear energy ?
  - How to get this decisional framework used ?

Scenario Analysis

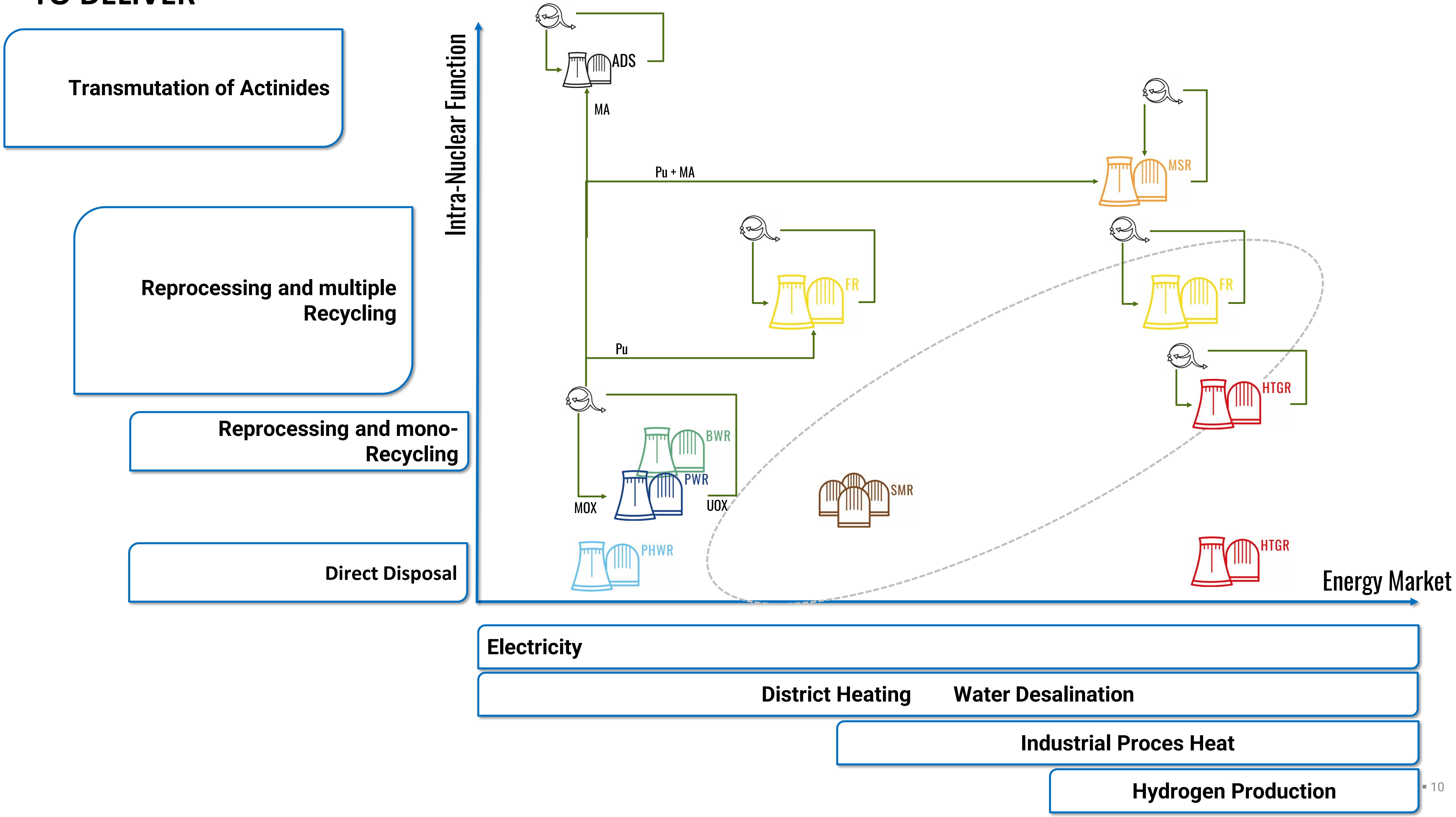
Real Options Valuation

" I make money with electrons

De-risk my neutrons"

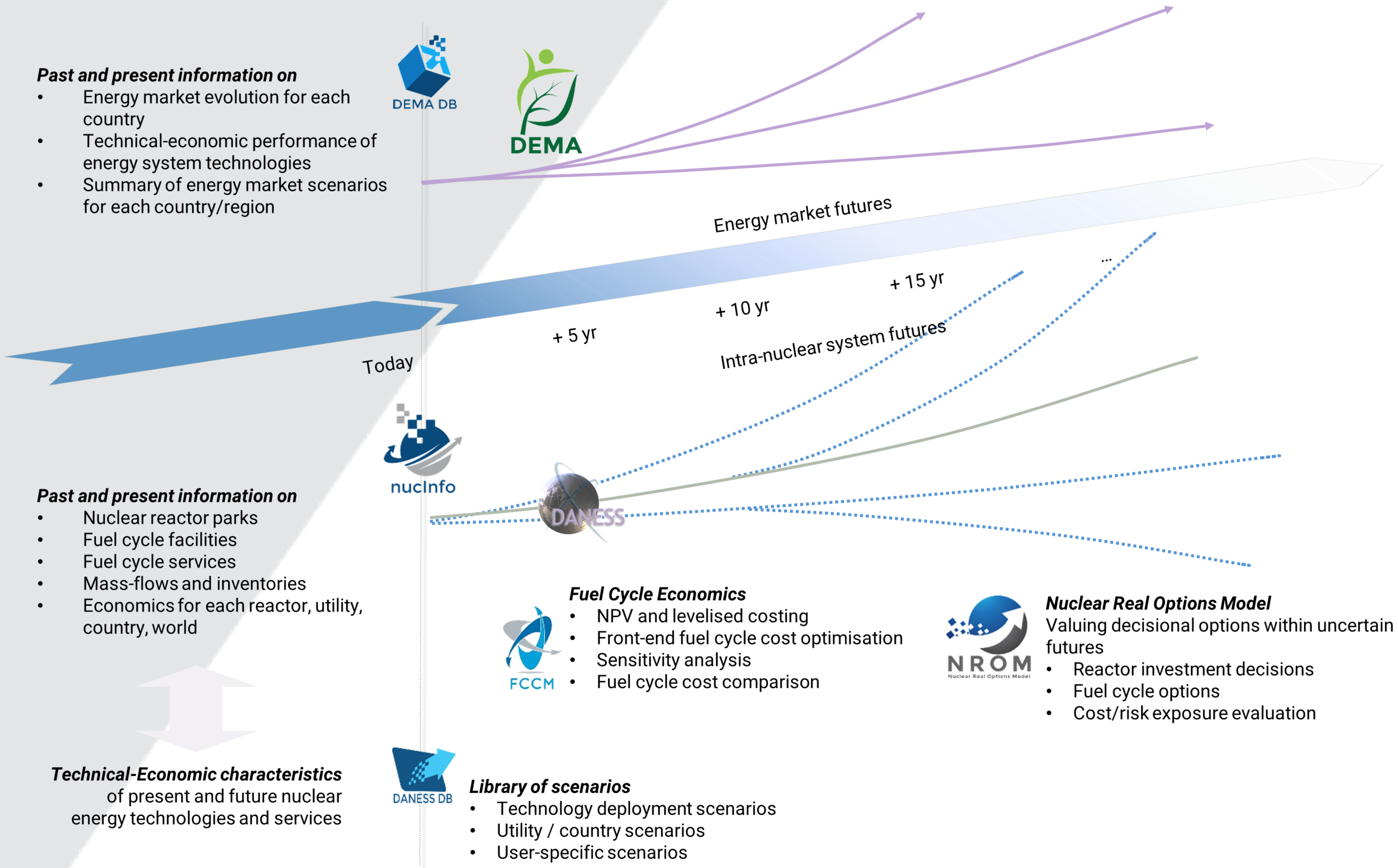
CFO Utility

WE DO NOT LACK OPTIONS TO ANSWER THE DEMANDS … NOW AND TOMORROW … BUT LET'S FOCUS TO DELIVER



| OUR ENERGY MARKET MODELLING TOOLBOX
ASSESSING WHY, WHEN AND WHICH NUCLEAR ? (SOME OF THE KEY QUESTIONS)

- ***Why?***
  - What are the societal developments and needs for energy?
  - Which industrial / residential / service development is envisaged?
  - How is energy contributing to a sustainable and equitable society?
  - Which role for nuclear energy and associated broad economic impact?
- ***When?***
  - What is maturity of skills base and supply chain?
  - When to replace and/or prepare for increase in net energy services demand?
  - When can bankability be optimised?
  - Roadmap for nuclear programe deployment?
- ***Which?***
  - Balancing energy demand versus supply
  - Beyond electricity demand?
  - Siting potential and synergies with energy-intensive energy needs
  - Large LWR or SMRs or AMRs?



Nuclear-21 has undertaken such assessment for a variety of clients and developed a best-practice base methodology and toolbox supporting such assessment

This presentation being a summary of a comprehensive global study on assessing the market prospects for nuclear energy

FOUR REPRESENTATIVE NUCLEAR ENERGY PROSPECTS GROUPING POTENTIAL FUTURES

- Complementary to the variety of energy demand scenarios by authoritative studies, Nuclear-21 defines four illustrative scenarios according to two main dimensions deemed structuring for market potential for nuclear energy
    - ***The degree of decarbonisation of the overall energy system***
        - ***being the main driver towards the overall demand for nuclear energy***
    - ***The degree of worldwide systems approach in designing the future, more sustainable, energy systems including circular economy thinking***
        - ***defining the potential for worldwide intra-nuclear system options with increased synergies between NPP-technologies and fuel cycle options***

Degree of Decarbonisation

Degree of Systems Approach

Stated Policies Commitment Nuc-BAU

- *COP Commitment Policies by States*
- *Increasing decarbonisation with essentially large countries and newcomer countries using nuclear*
    - *Pro-Nuclear: Asia, Russia, North-America, Africa, Latin-America*
    - *Phase-out and Renewed Nuclear: Europe*
- *Business-as-Usual for nuclear, i.e. mainly LWR-technology based deployment providing electricity*
    - *Some largely LWR-technology based SMR's making the market*
- *Business-as-Usual in fuel cycle policies*

Let's Energise Sustainability

- *Effective Circular economy driving policies*
- *Increasing decarbonisation with essentially nuclear + renewables synergies*
- *Nuclear energy accepted for increasing number of energy services*
    - *SMR's providing various energy services being additional market-segment for nuclear*
- *World integrated view on fuel cycle optimisation of nuclear materials and waste minimisation*

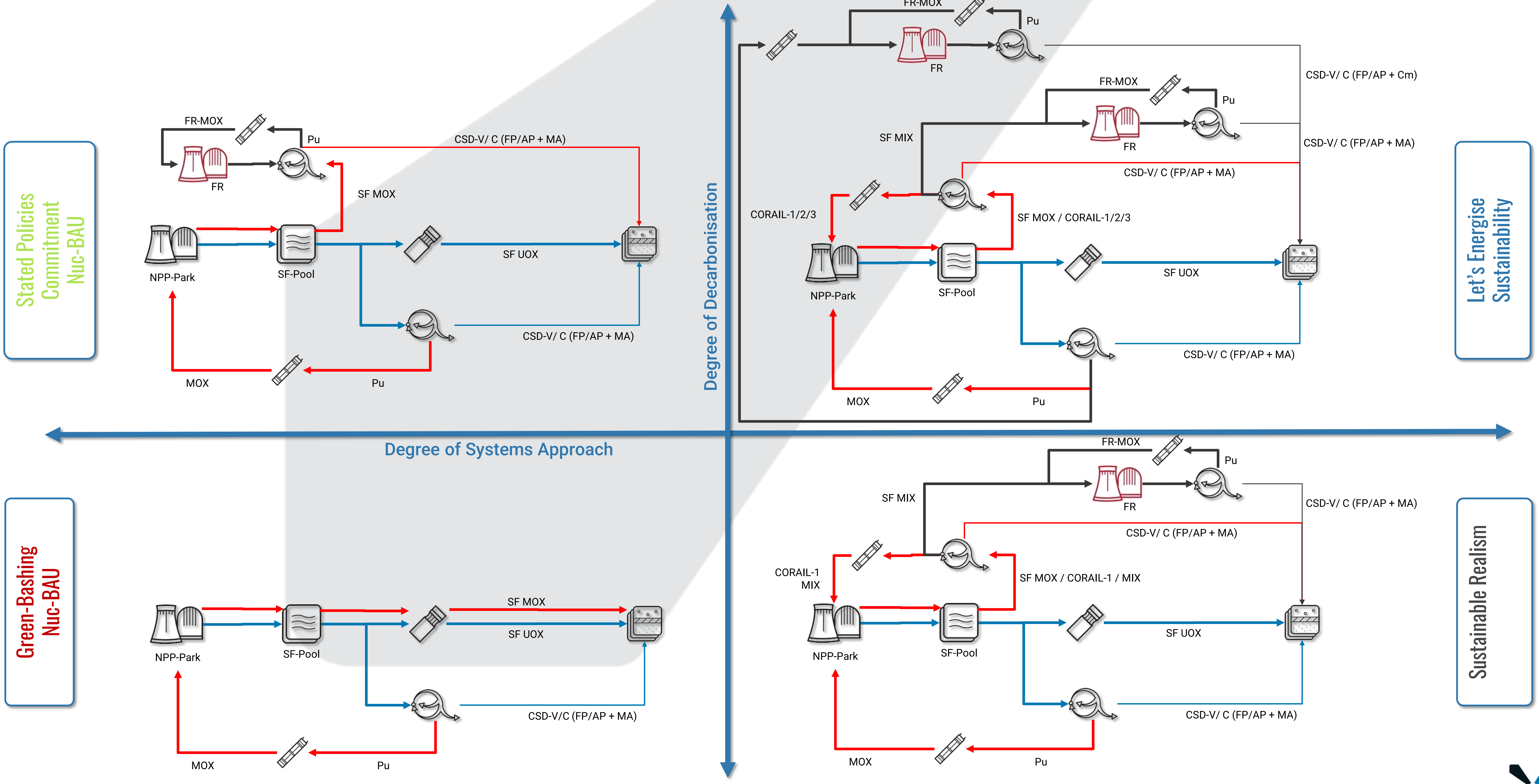
Green-Bashing Nuc-BAU

- *Weak and non-coordinated energy policies*
- *A lot of ideological promises but effective decarbonisation remains marginal*
- *Shorter-term investment horizon*
- *Business-as-Usual for nuclear, i.e.*
    - *mainly LWR-technology based deployment providing electricity*
    - *phase-out in most OECD-countries and newbuild in certain regions*
- *Business-as-Usual in fuel cycle policies*

Sustainable Realism

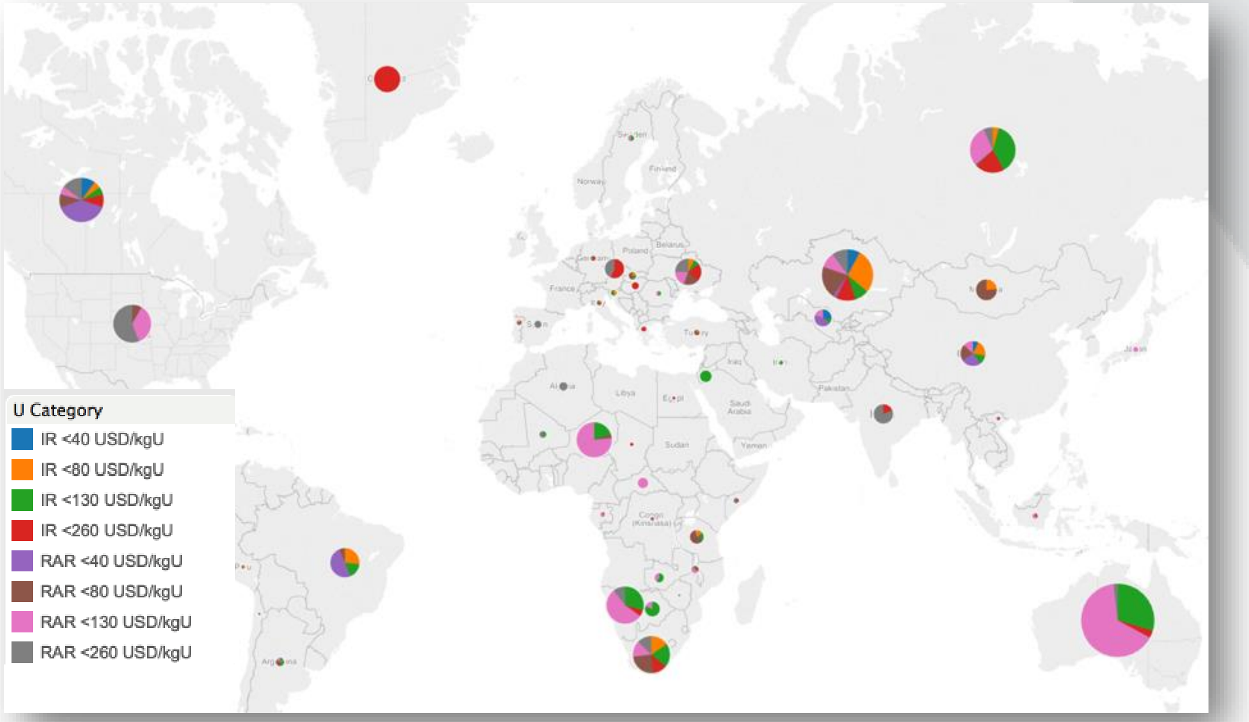
- *Stronger longer-term decarbonisation vision-driven policies*
- *Energy policies mainly inspired by industry with increasing realism and opportunity for synergies*
- *Nuclear increasingly considered for various energy services*
    - *primarily LWR-technology with increasing HTGR / Gen-IV deployment*
    - *SMR's*
- *Increasing synergistic recycling options deployed, i.e. both inter-park as inter-NPP-technology options*

INTRA-NUCLEAR OPTIONS PROVIDE SCALABILITY AND ADAPTABILITY TO SUSTAINABLE ENERGY NEEDS



TRANSITIONAL PERIOD FOR NUCLEAR ENERGY
FROM LEGACY-WASTE DRIVEN TOWARDS GLOBAL SUSTAINABLE SYSTEM?

Uranium Resources (Red Book 2013)



Separated civil Pu-inventory (2014)

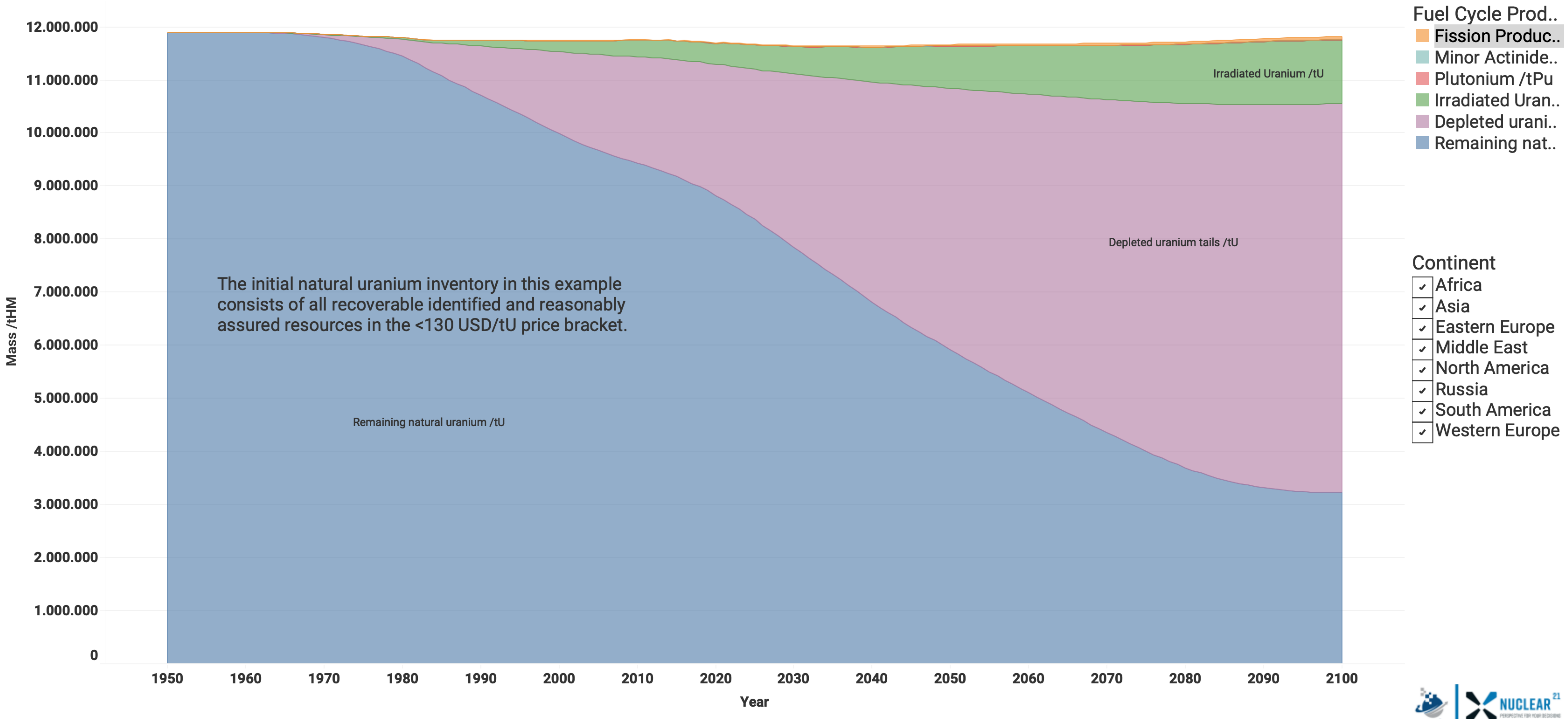
Separated REPU-inventory (2014)

- ***Nuclear energy's future***
  - **Will not be hampered by shortage of natural uranium at least until mid-century**
  - **Depends (mainly?) on how to manage effectively today's 300 000 tonnes of Spent Fuel worldwide**
    - **Geological disposal options socio-politically delayed**
      - Increasing security and financial risks in (very) long-term interim stored spent fuel
    - **Reprocessing of spent fuel has remained a limited option as requesting a 'captive' market**
      - 'Captive' = backed by government strategy, recycling policy to reduce geological disposal needs and increasing U_{nat}-independency
      - Today some 320 tonnes of separated Pu in store
      - Still an option to cope with spent fuel integrity on the long term and related safety, security, safeguards and financial risks
        - Support economic predictability and long term competitiveness for SF-owners
        - Internationally safeguarded and reducing proliferation risk for global nuclear energy system overall

“A MILLENNIUM VIEW ON SUSTAINABLE NUCLEAR ENERGY”

(LUC VAN DEN DURPEL, INSAC 2009, CHENNAI, INDIA)

A Millenium View on Nuclear Sustainability



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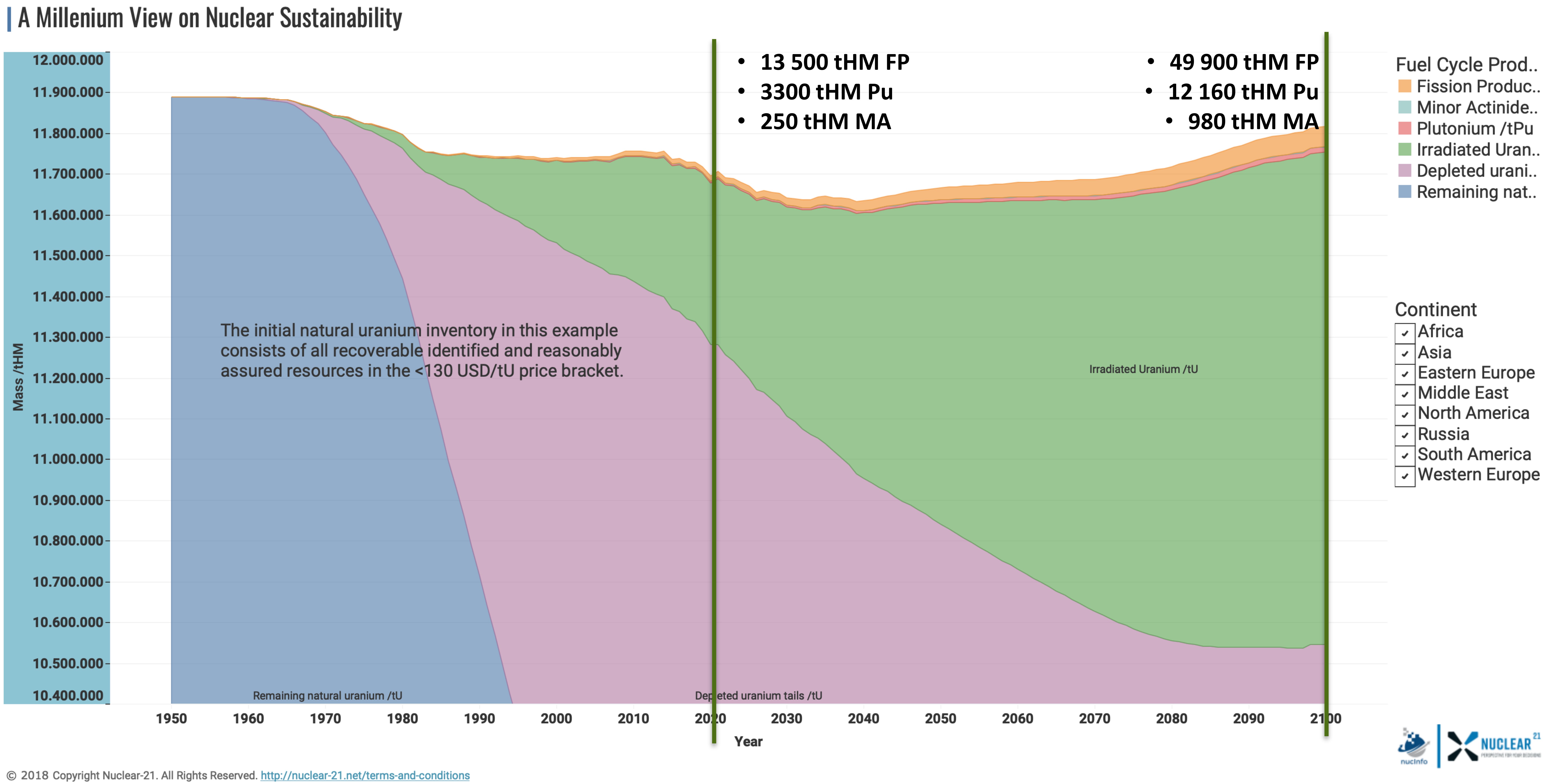
"A MILLENNIUM VIEW ON SUSTAINABLE NUCLEAR ENERGY"

Zoom on what 'bothers' us … SF, Pu, MA, FP/AP



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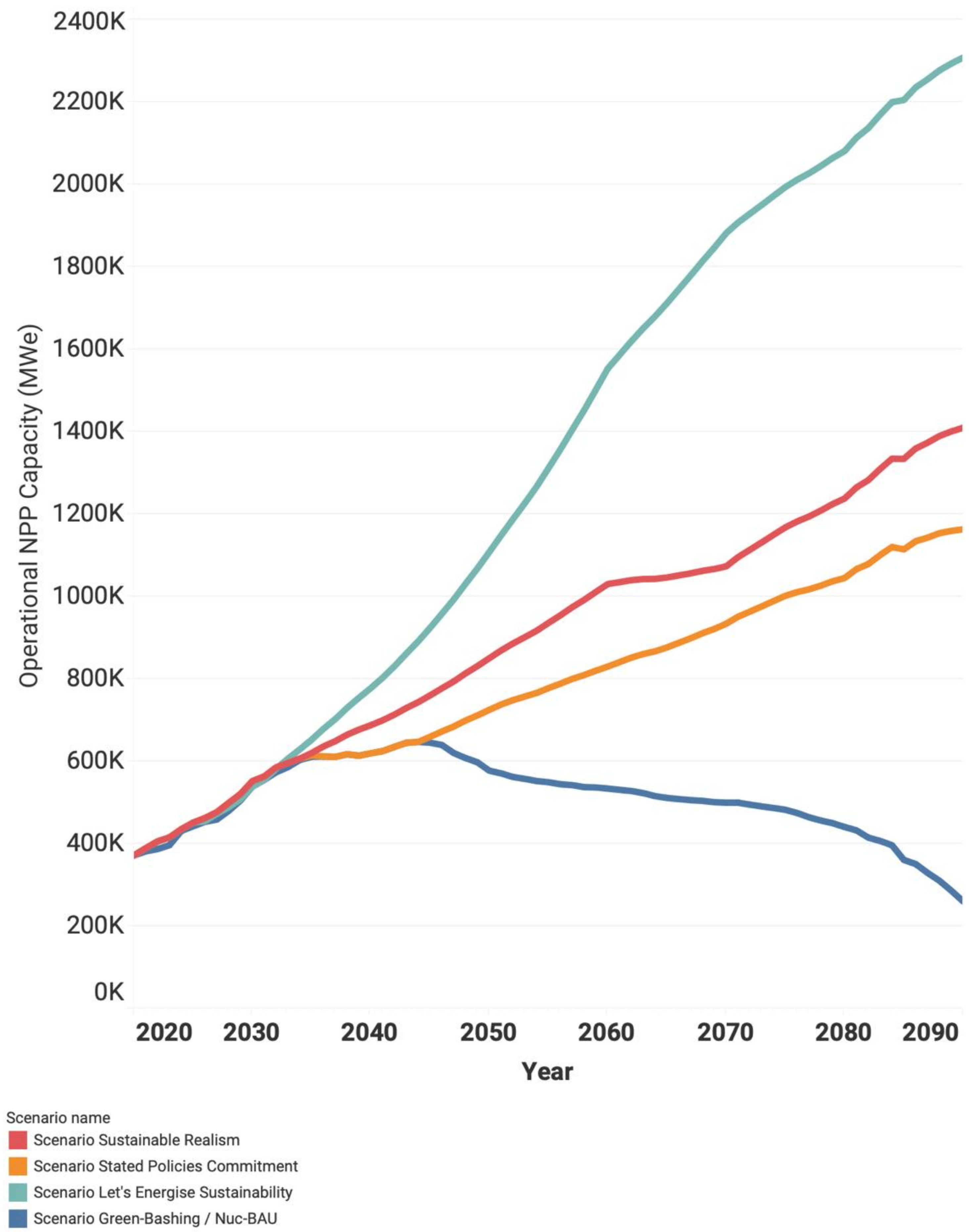
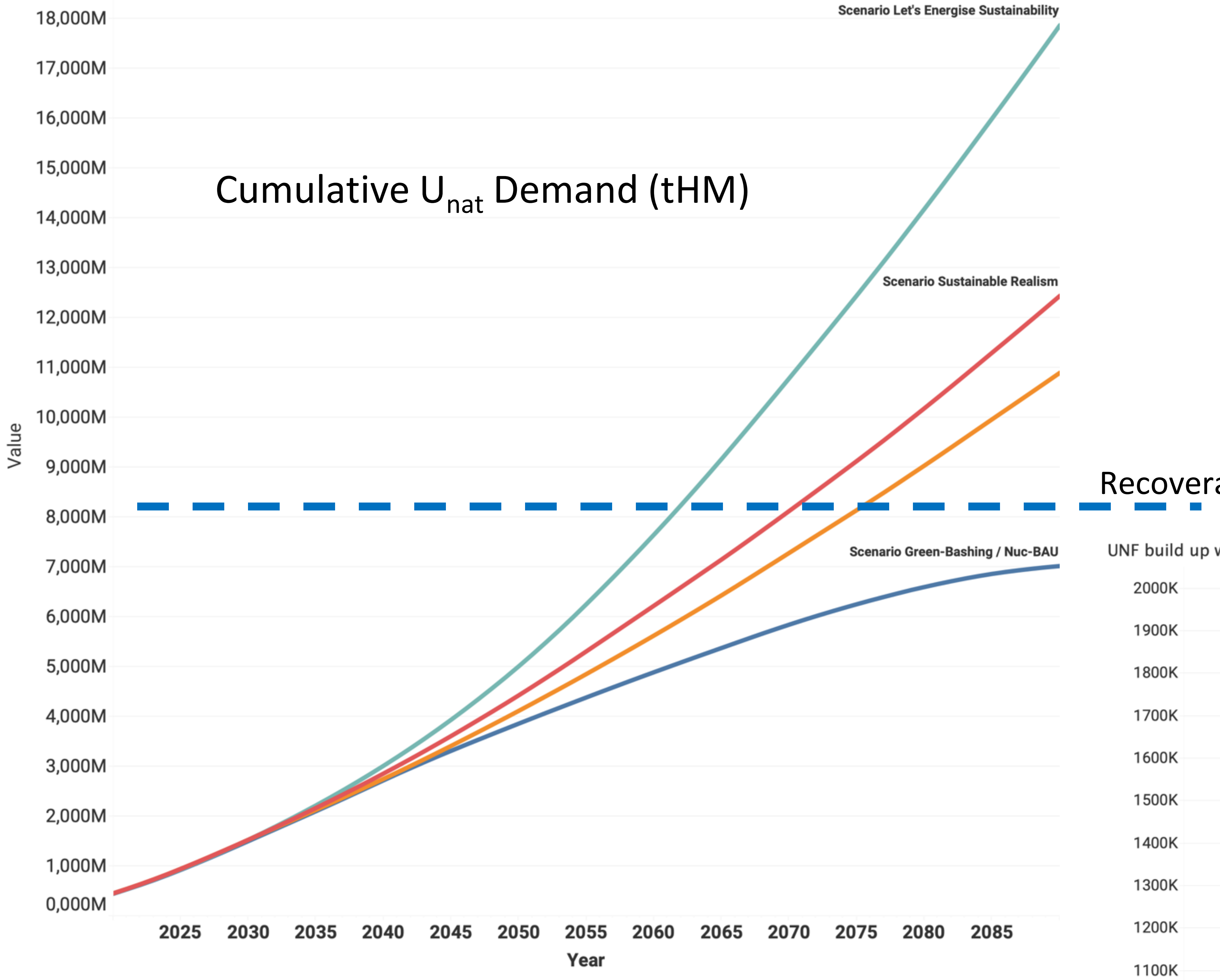
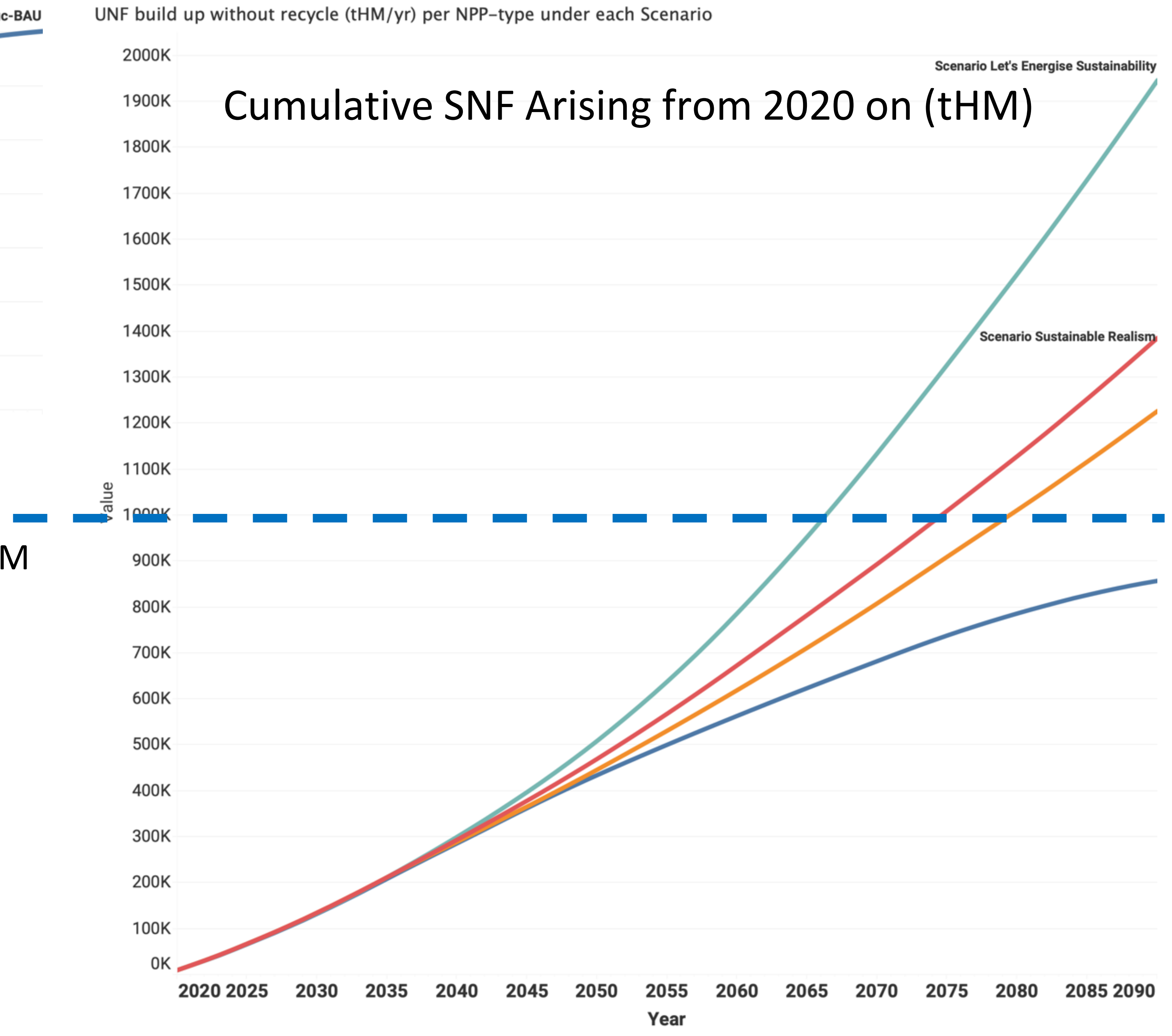
RESULTING NUCLEAR ENERGY PARK PROSPECTS

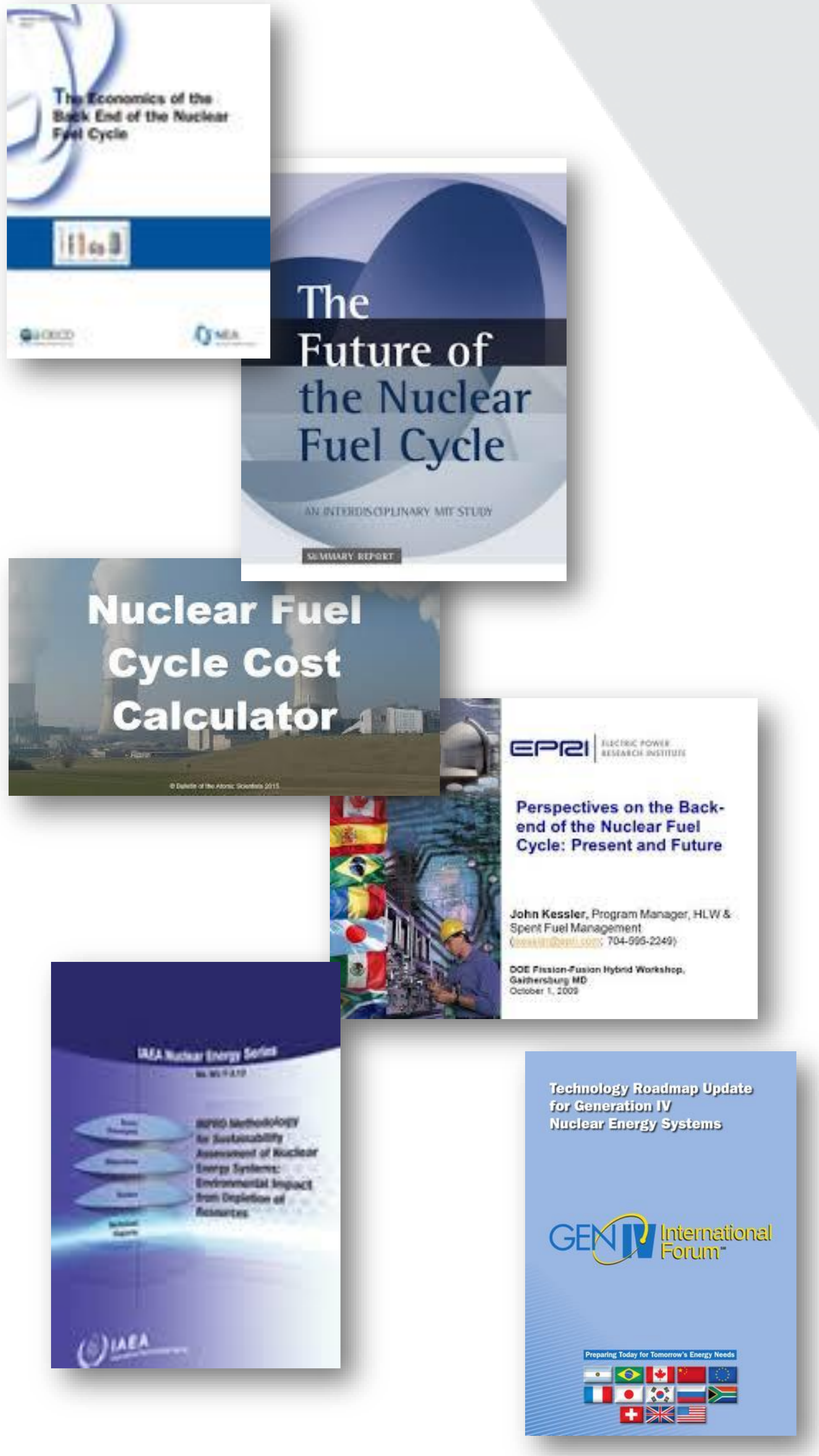
Future Scenarios for Nuclear Energy Systems







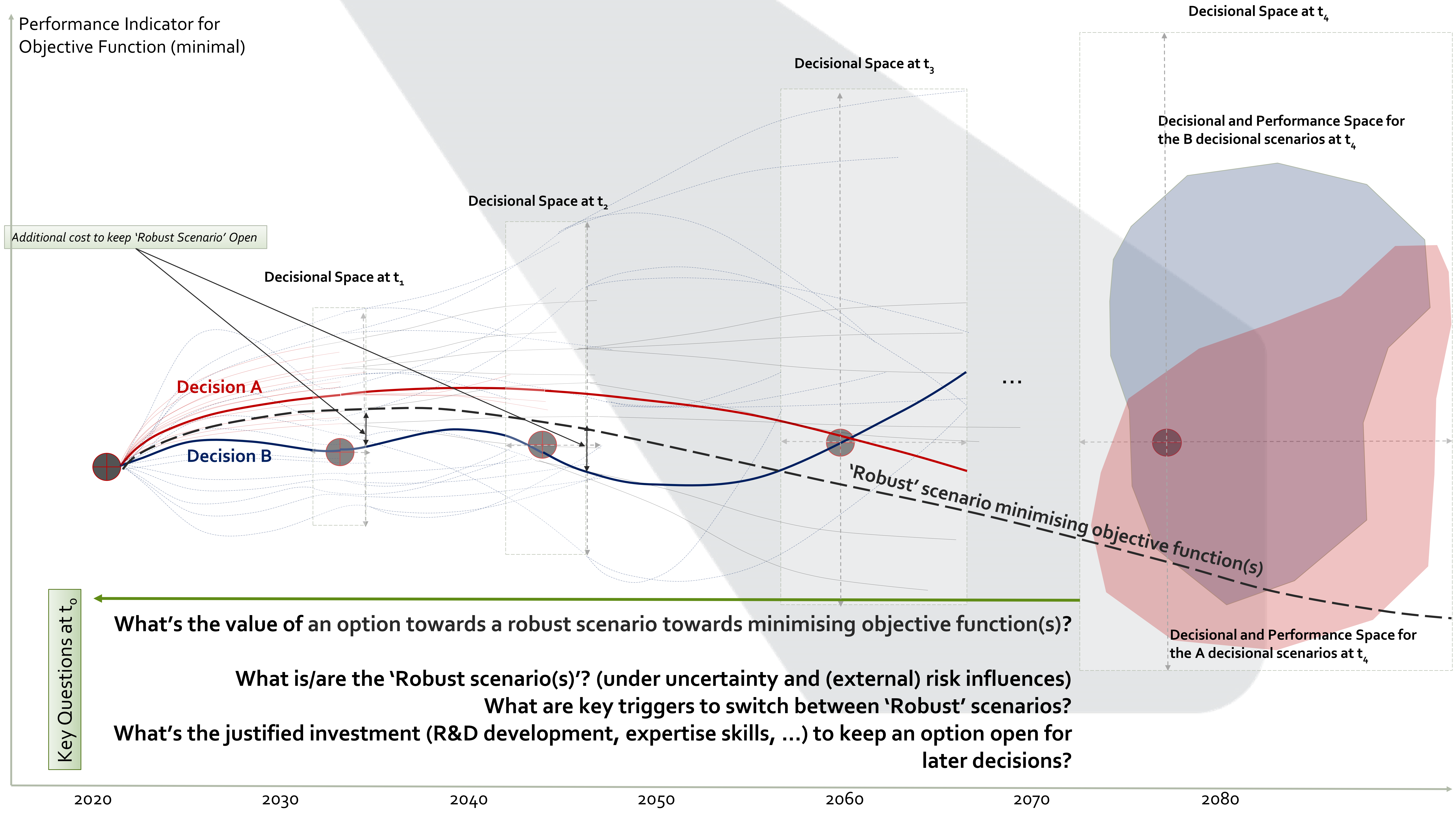
| CURRENT ASSESSMENT-FRAMEWORKS FOR NUCLEAR ENERGY OPTIONS TOO BIASED ON SHORT-TERM COST ANALYSIS



- **Today's framework on nuclear energy assessment is mainly based on Discounted Cash-Flow (DCF) / Net-Present-Value (NPV) or Levelised-Cost-of-Energy (LCOE) methodologies, i.e.:**
  - *All costs assumed known at 't$_o$';*
    - *Sensitivity analysis on cost values to assess uncertainty range for NPV/LCOE*
  - *Discounting of future cost-components at a specified discount rate r*
    - *Given high sensitivity of NPV/LCOE-results to r, again sensitivity analysis applied*
  - *Main outcome of most studies using NPV/LCOE:*
    - *Beneficial to delays in UNF-management irrespective of possible increasing cost-risks*
    - *"Wait-and-see"-policies with high emphasis on short-term economic performance*
- **This NPV/LCOE-framework, despite easy-to-grasp by all stakeholders, leads to a constant bias:**
  - ***Socio-political bias** towards continuously delaying decision-making and thus shaping policy making ➔ **Long term decisions have a lesser weight***
  - ***Technical-economic bias** with utilities applying a diverse set of proprietary decisional models, including financial risk analysis, coping with NPV/LCOE-biased policy environment ➔ **Does not allow for decision flexibility***

ILLUSTRATION OF DECISION-MAKING COMPLEXITY BEING ANALYSED

ILLUSTRATION WITH ONLY TWO DECISIONAL BRANCHES PER DECISIONAL MOMENT FOR ONE DECISIONAL INDICATOR TO BE MINIMISED



IAEA International Conference on SF Management (CN-272 / June 2019, Vienna)

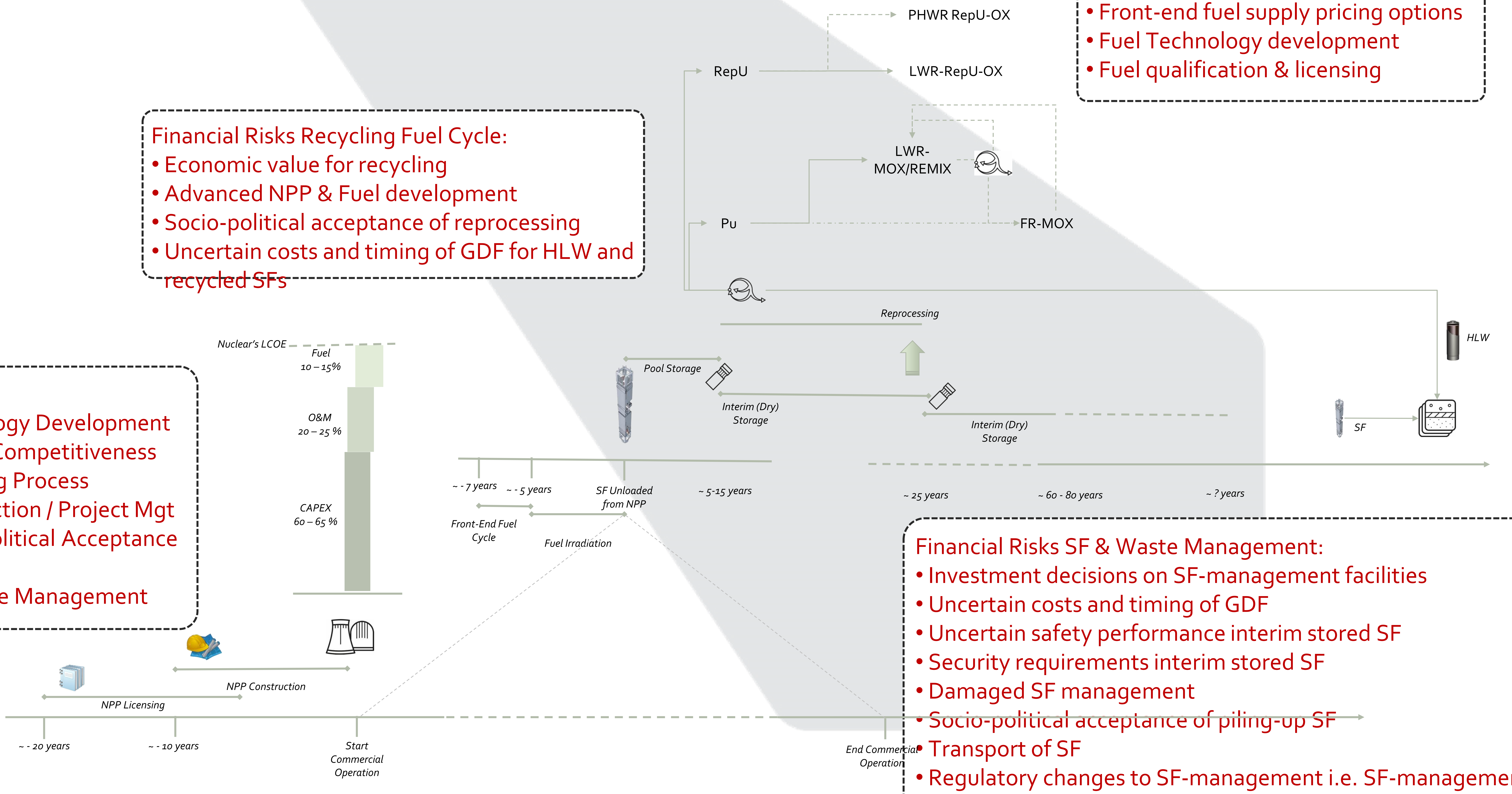
COST/RISK-OPTIMISED NUCLEAR ENERGY FUTURE
CHANGING PRIORITIES THROUGHOUT LIFE-CYCLE

Financial Risks Fuel Cycle:
- Front-end fuel supply pricing options
- Fuel Technology development
- Fuel qualification & licensing

Financial Risks Recycling Fuel Cycle:
- Economic value for recycling
- Advanced NPP & Fuel development
- Socio-political acceptance of reprocessing
- Uncertain costs and timing of GDF for HLW and recycled SFs

Financial Risks:
- NPP Technology Development
- NPP Market Competitiveness
- NPP Licensing Process
- NPP Construction / Project Mgt
- NPP Socio-Political Acceptance

- Nuclear Waste Management



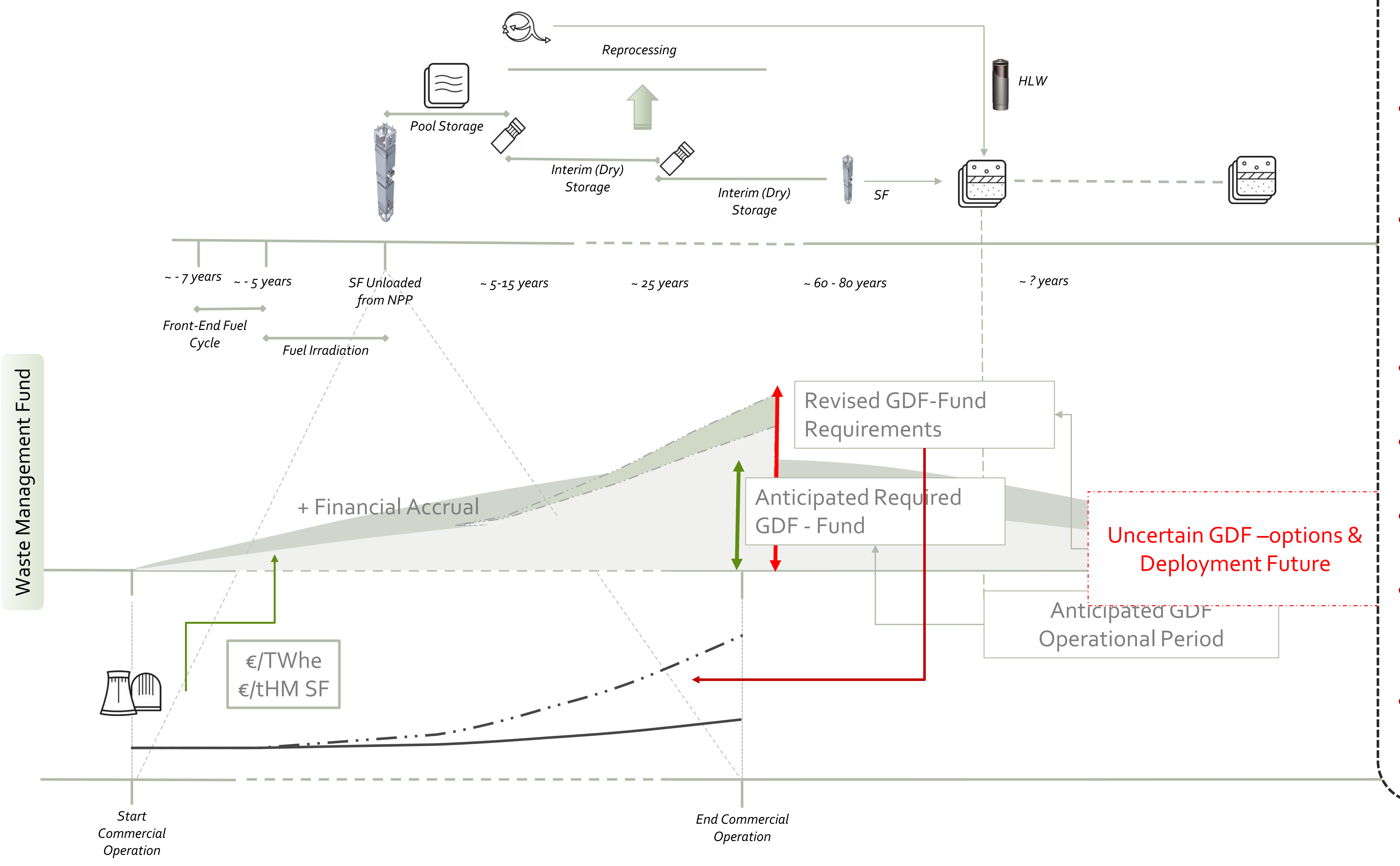
Financial Risks SF & Waste Management:
- Investment decisions on SF-management facilities
- Uncertain costs and timing of GDF
- Uncertain safety performance interim stored SF
- Security requirements interim stored SF
- Damaged SF management
- Socio-political acceptance of piling-up SF
- Transport of SF
- Regulatory changes to SF-management i.e. SF-management provisioning policies

18 October 2022 - London

NNWI Forum

SPECIFIC FOCUS ON BACK-END FUEL CYCLE SNF-MANAGEMENT
AN IMPORTANT UNCERTAIN FINANCIAL RISK TO MANAGE THE COMING FEW DECADES

- *SNF-Management becomes increasingly a financial risk for operating NPPs*
- *Impacting Utilities' financial performance*



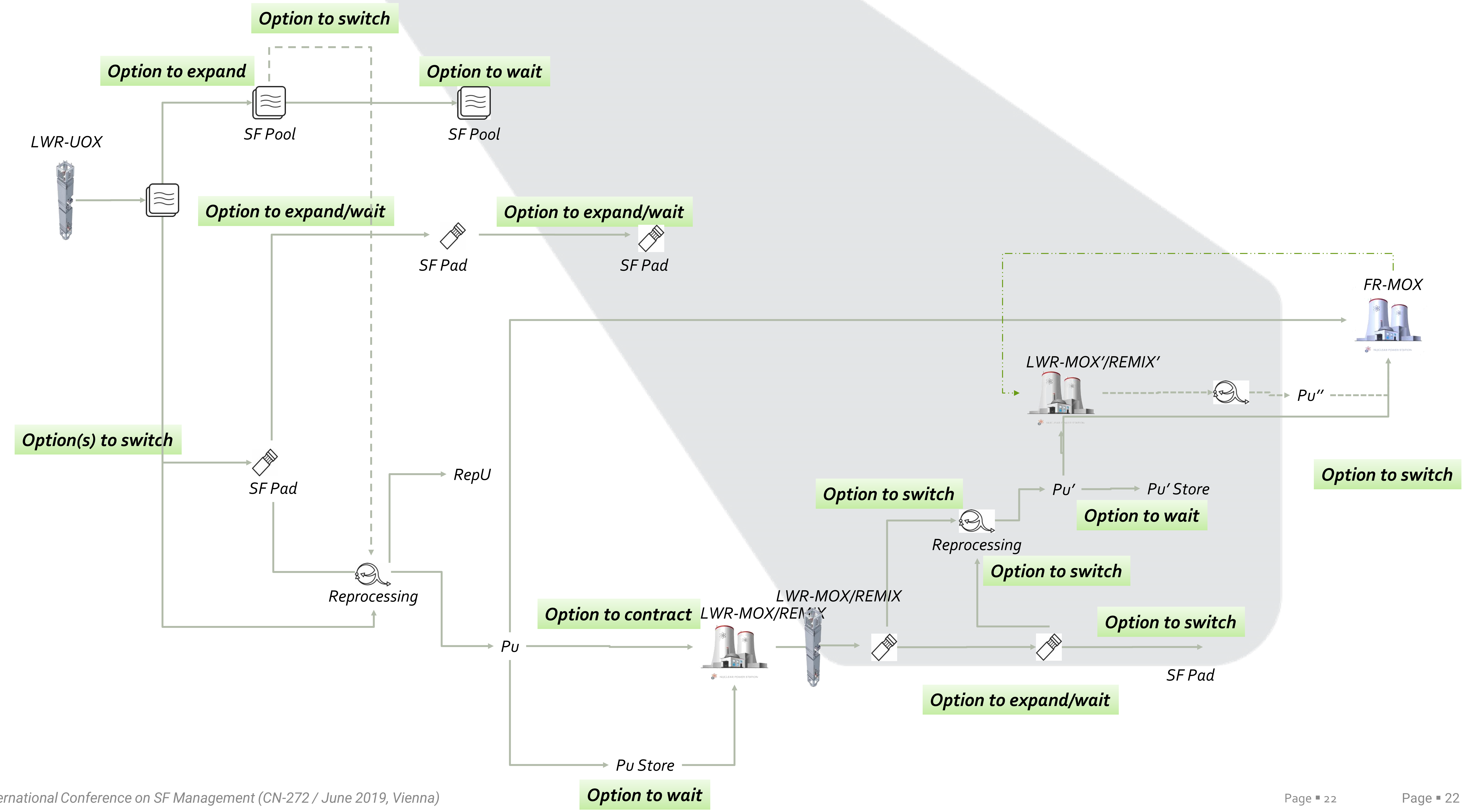
Financial Risks from:

- **Technical behaviour and safety of UNF during (long-term) SF interim storage**
- **Damaged SF limited interim storage duration**
- **Security of interim stored SF (especially at away-from-reactor ISFSI or at stranded ISFSI sites)**
- **GDF Costs and timing**
- **Regulatory changes**
- **Socio-political context**
- **Transport & repackaging/reconditioning of SF**
- **Financial market performance (e.g. lower interest rates)**

IAEA International Conference on SF Management (CN-272 / June 2019, Vienna)

THE BACK-END PRESENTING A VARIETY OF VALUE-ADDING OPTIONALITIES

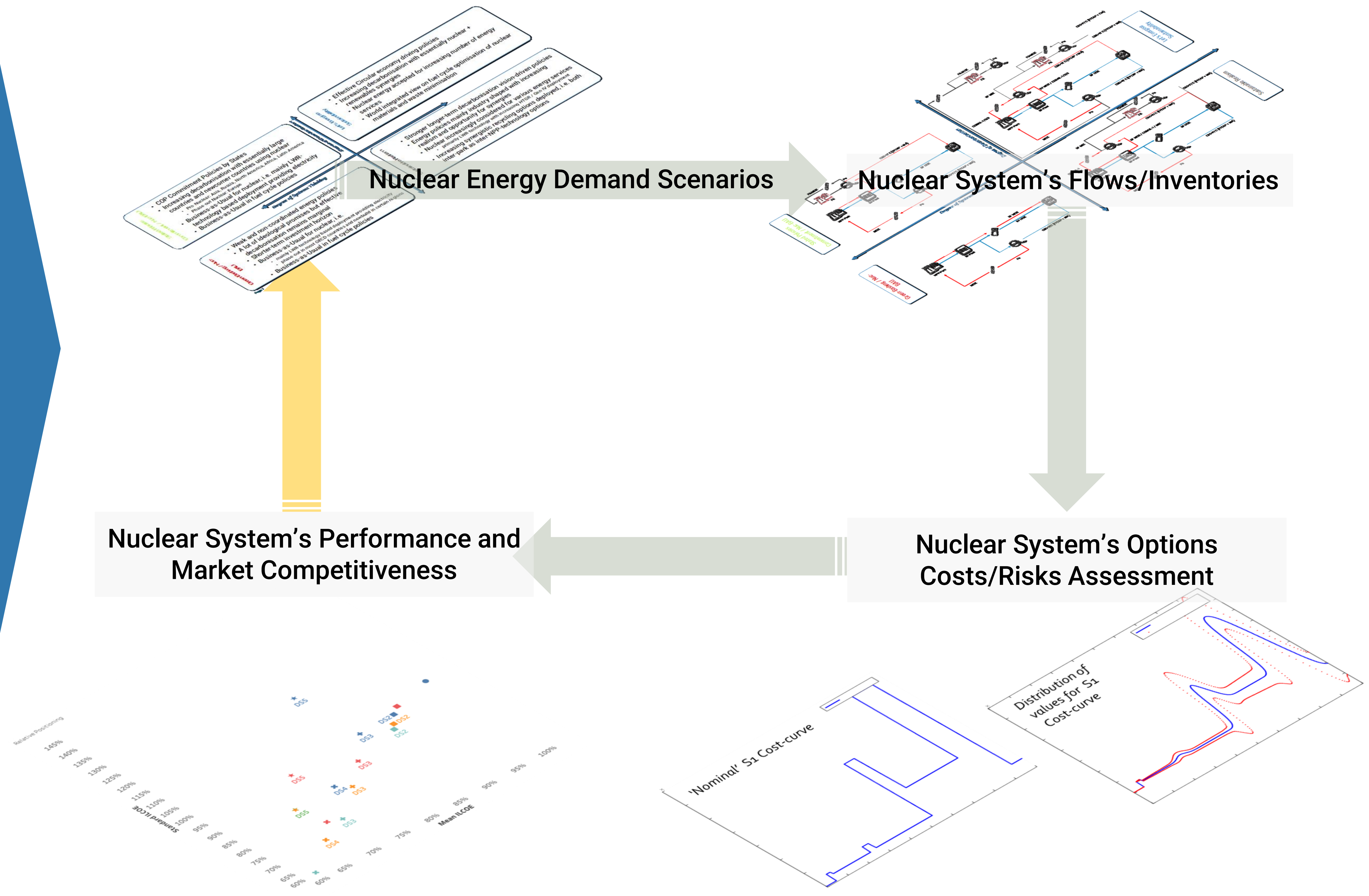
HAVING FLEXIBILITY IN OPTIONS PRESENTING MITIGATION VALUE TO UNCERTAIN ENVIRONMENT AND RISKS



HOW WE ASSESS THE OPTIONAL VALUE OF FR'S IN SUCH ANALYSIS ?

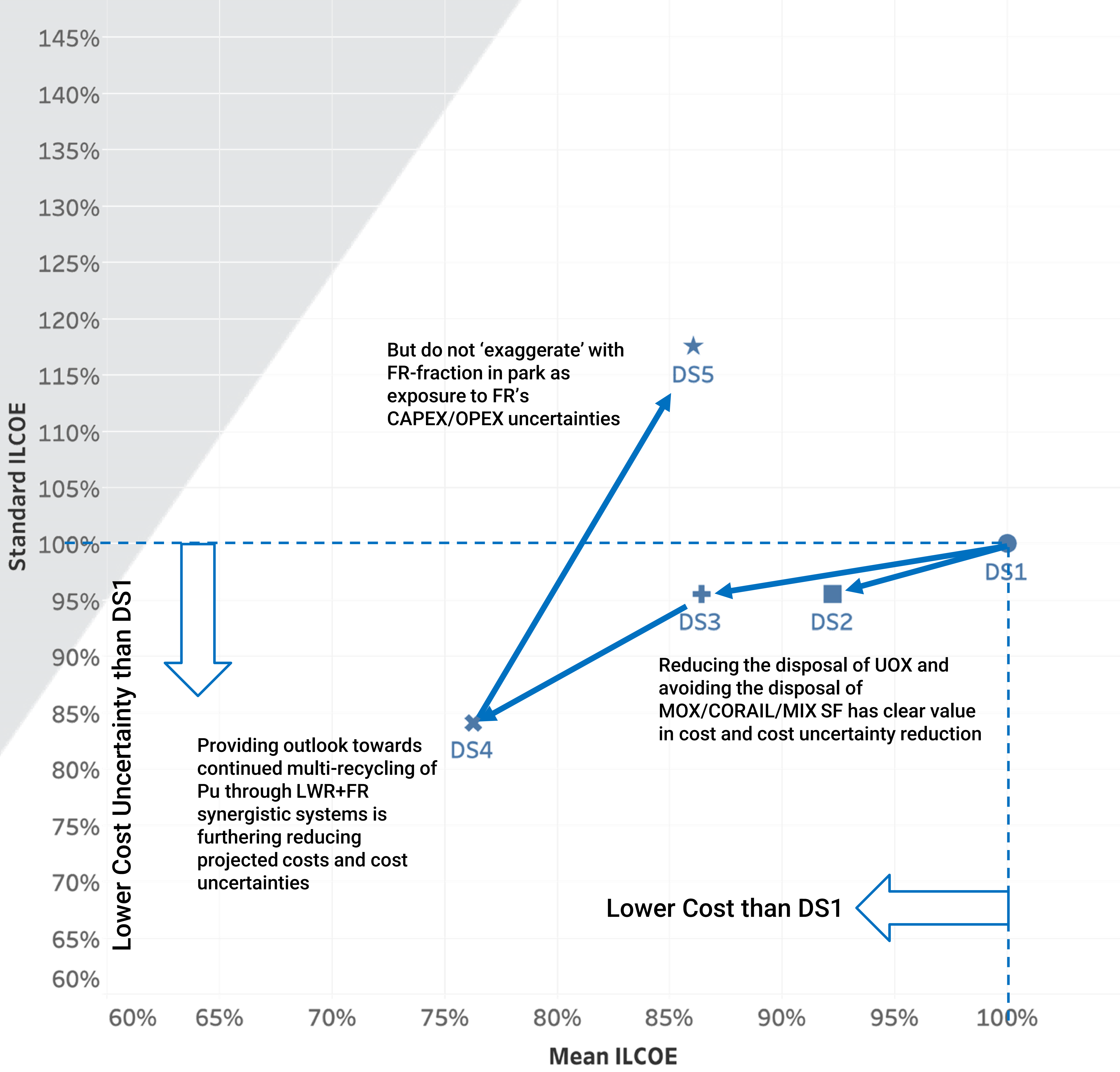
- ***There are uncertainties in achieving the sustainability objectives for nuclear energy:***
  - Timely U_{nat} availability and price
  - Safe, secure and economic performance of long-term interim stored SF
  - Deployment calendar for GDF's
  - Pu (multi-)recycling capacity in non-FR NPP-Park
  - Economics of FR versus non-FR NPP's
  - Technological readiness of FR and associated fuel cycle services
  - Socio-political influence on SF-management options
  - Energy market developments

Analysis Scheme



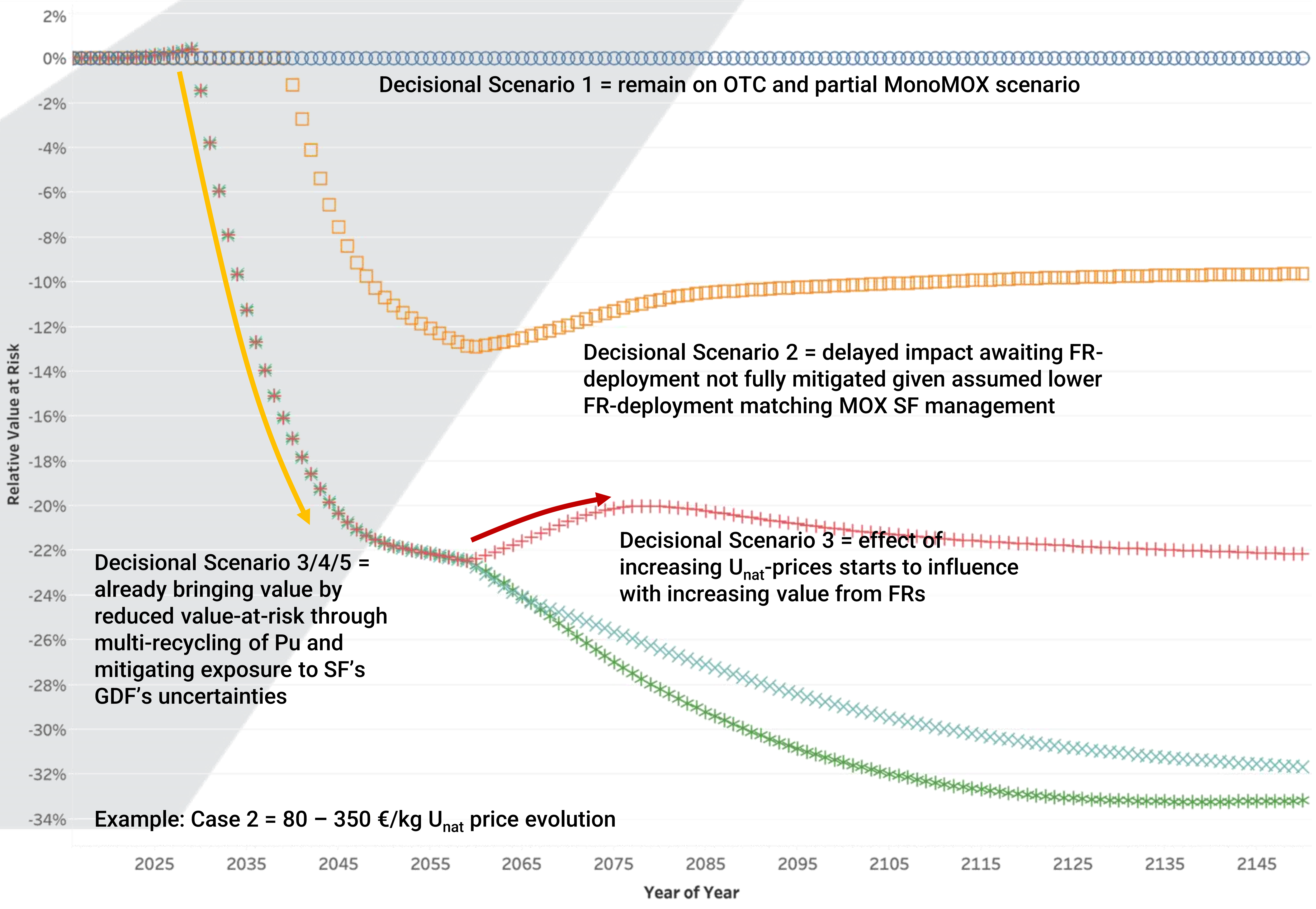
COST/RISK MITIGATION ROLE FOR MULTI-RECYCLING OF PU AND FOR SPECIFICALLY FOR FR'S

- The projected costs (as shown before) integrates the 'nominal' cost and the uncertainties associated with the different nuclear energy system' components performances
  - Visualisation of
    - Relative Expected Cost to Reference Scenario
    - Relative Expected Cost Uncertainty to Reference Scenario



WHAT IS VALUE-AT-RISK OF NOT PURSUING FR-DEPLOYMENT ?

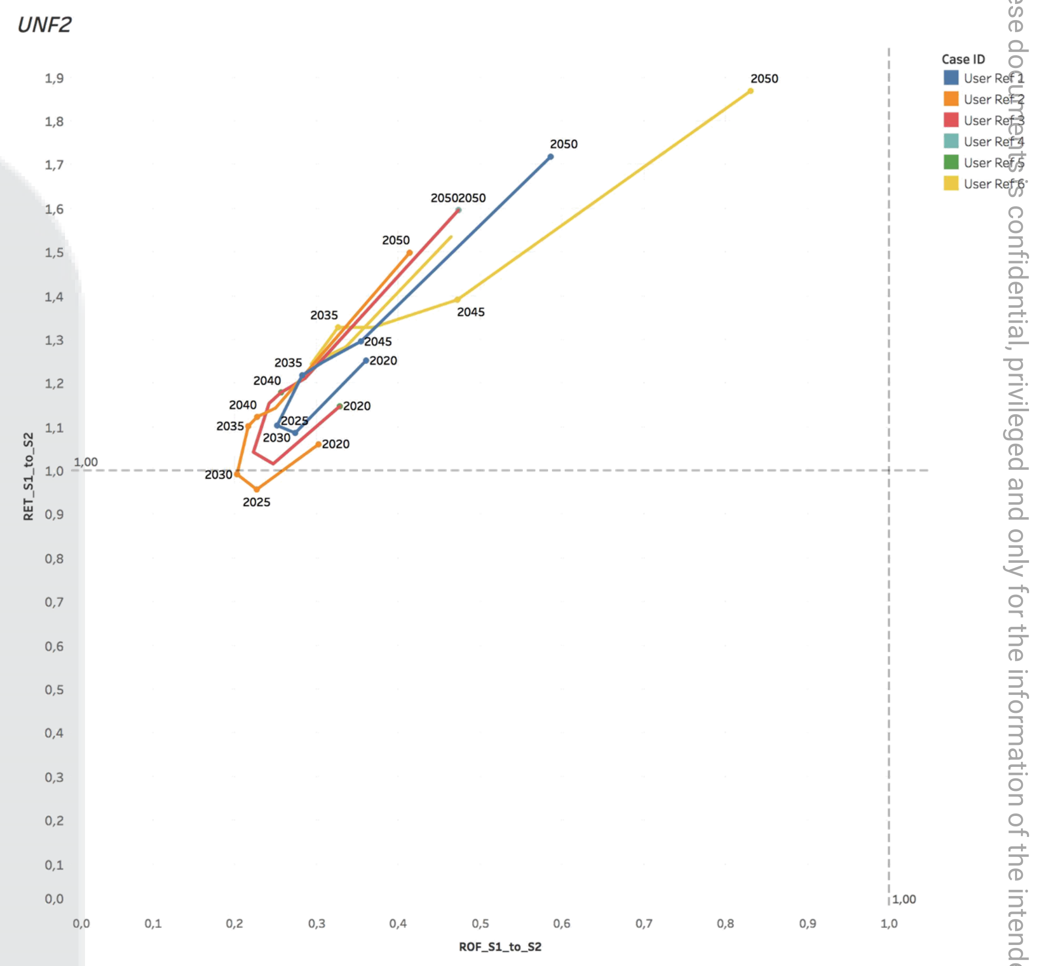
- Value-at-Risk is a measure for the financial risk one is taking by not executing a decisional option
- With the generalised though representative scenario assumptions
  - The FR may represent some 10% of the total system's cost over one century
  - But intermediate options allow to mitigate FR-specific risks till early part of second half of this century

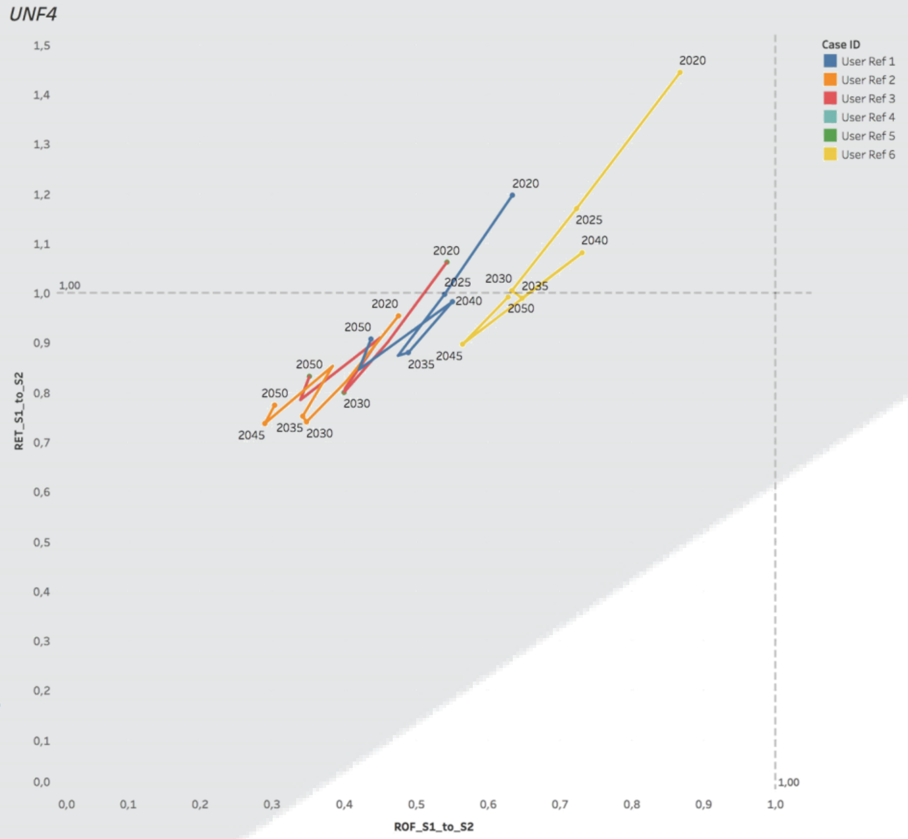


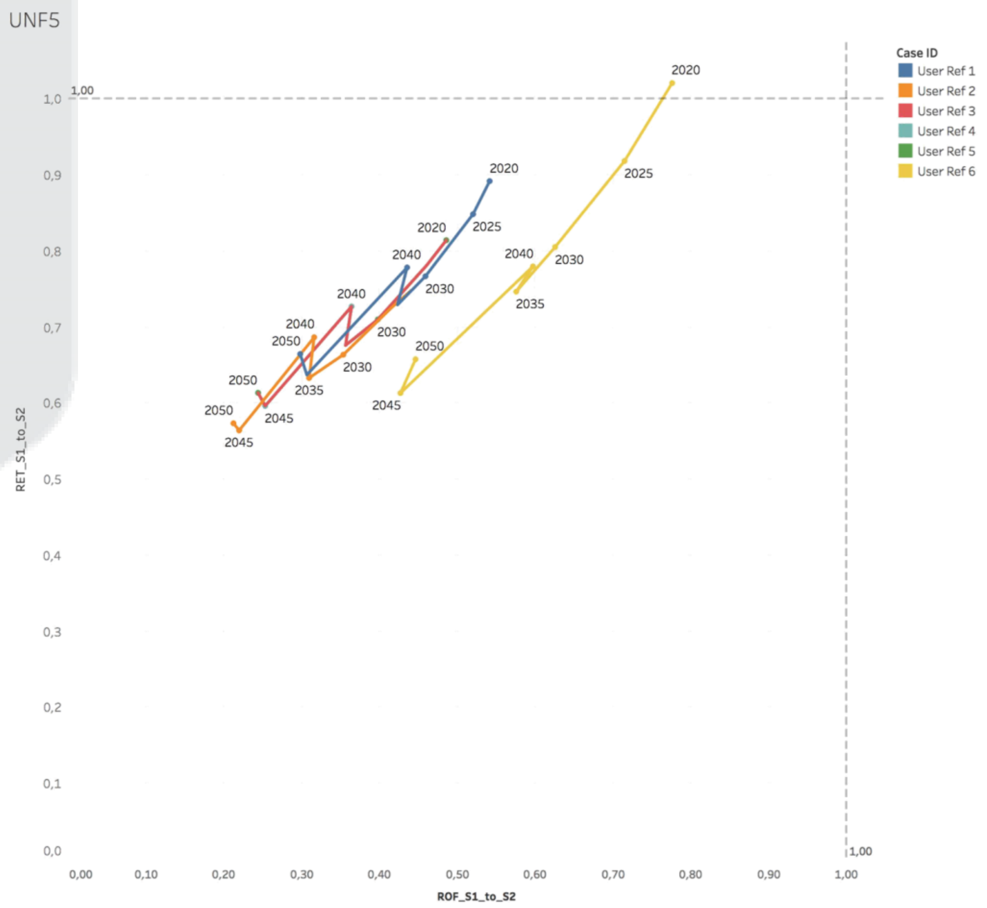
IN CONCLUSION

IT IS EXTREMELY IMPORTANT TO USE APPROPRIATE ASSESSMENT METHODOLOGIES TO VALUE THE ROLE OF NUCLEAR ENERGY

- ***Nuclear Energy is unbeatable in a long-term perspective***
    - **But needs to compete in a shorter-term decisional context**
- ***Market value for nuclear energy increasingly influenced by risk-mitigation***
    - **Today, even more so by the energy market context**
    - **Structurally, energy-security and systems resilience are key objectives**
- ***Energy and Financial Markets value risk-mitigating options***
    - **Need to use appropriate 'tools' to value nuclear energy**
- ***Nuclear-21's "Let's Energise Sustainability" be published in Q1/'23***







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World Nuclear Transport Institute

"If you want to write a new story read an old book!"

Martin Porter – WNTI Secretary General
New Nuclear Watch Institute Forum 2022, London
Tuesday 18 October 2022

Overview

- Transporting RAM – How Difficult Is It?
- Perceptions of nuclear transport
- Challenges
- Opportunities

Safety Regulatory Framework

- Current regulatory framework established in the 1960's to enforce standards for (predominantly) transport of fuel, waste and sources. Little changed since.
- International hierarchy
  - UN 'Orange Book' sets the model for all dangerous goods
  - Modal regulations for road (ADR), rail (RID), sea (IMDG) and air (IATA)
  - IAEA SSR-6 specifies application to radioactive materials
- Prescriptive rather than enabling
- Binding on contracting parties rather than companies
- Enacted by regulations made by contracting parties

Learning From Experience

Planned:

- Drop testing
- Fire testing
- Immersion testing
- Impact testing
- Exercising & rehearsing
- Decades of defence propulsion

Unplanned:

- Mont Louis
- Halifax, Nova Scotia

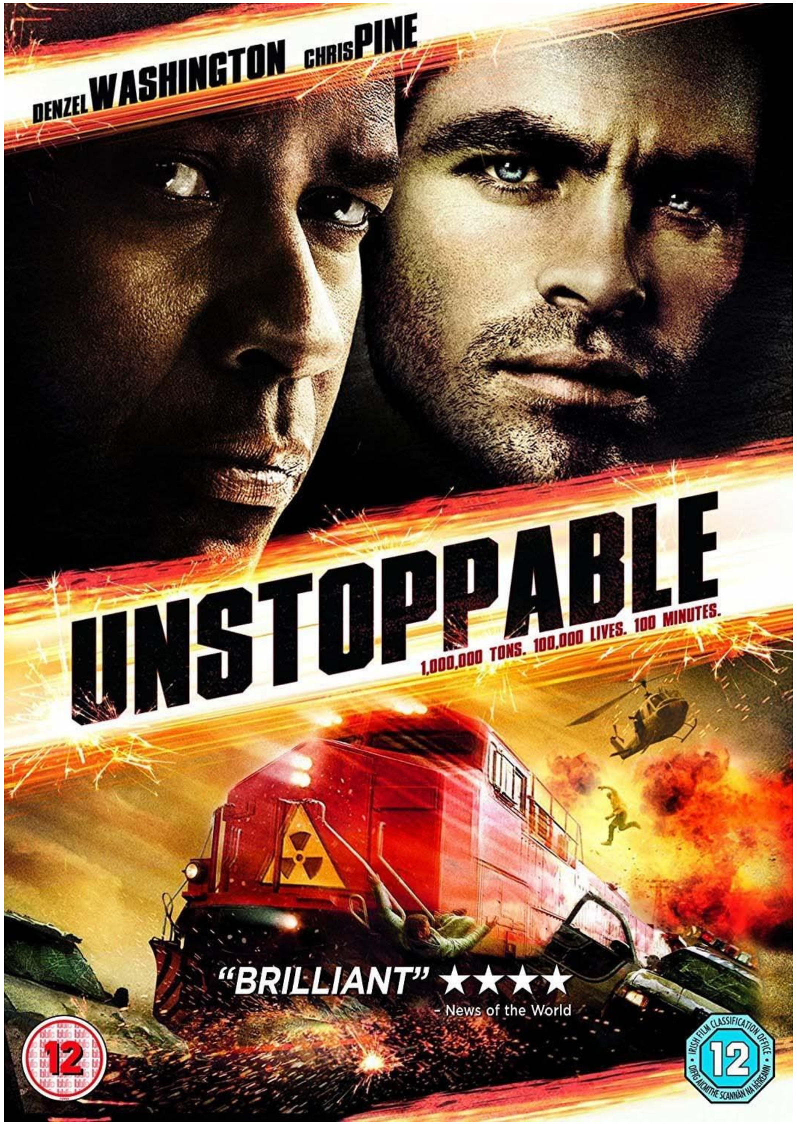
Learning From Experience

Aqaba, Jordan - 28 June 2022
12 dead immediately, >250 injured

Hollywood Blockbuster Recipe For Success

- Begin with powerful story line loosely based on a real event
  - A train carrying phenol suffers a series of mishaps and runs away without a driver
- Embellish the facts with some high drama
  - The train careers towards a sleepy town with lots of well-meaning people
- Secure the services of some A-list actors
  - Denzil Wasington, Chris Pine et al.
- Draw in the audience with a powerful advertising campaign
  - Unstoppable: 1,000,000 tons, 100,000 lives, 100 minutes
- Enjoy the success
  - $167,000,000 grossed and an Oscar nomination

Unstoppable



Unstoppable

It was Phenol!!!

Nuclear Positive Messaging

'Nuclear' and 'Radiation' are two of the most misunderstood and misrepresented words in the dictionary!

- Education
- Public engagement
- Openness and consistency
- Fact, science, objectivety
- We should all be 'waving the flag'!

Challenges

- New nuclear (SMR, AMR, micro-reactors, molten salt reactors etc.), waste and decommissioning are presenting new challenges to the industry.
- Emergent nations have new nuclear ambitions. New actors are looking to enter the nuclear world.
- The regulatory framework is not yet fully aligned to exploit some technological and operational advancements. Regulatory revision is a protracted process.
- Perceptions of radioactive material operations are not always objective or scientific. Delays and denials of shipment remain as tangible risks to sea and air transport.
- Security threats to nuclear transport are an evolving and ever-changing environment

Delays & Denials of Shipment

Class 7 transport burden. Is it a bureaucratic 'nuisance' for the supply chain?

Not just a commercial issue, can increase security risk

- adopting longer routes
- prolonging time at risk
- enhancing predictability
- ……

Can have significant personal outcomes in some medical applications.

Opportunities

- New technologies are emerging to redress the climate challenge. EU taxonomy success endorses the industry view that nuclear can provide a valuable contribution to a sustainable future.
- Low carbon transport is available. New rail technology offers 76% less carbon emissions than road for equivalent payloads. Electricity offers zero emission rail transport. Nuclear propulsion is on the horizon (“30 knots for 30 years”)
- New approaches to managing spent fuel being worked up. Flask repurposing to dual-use (transport and medium-term storage) an option. GDF planning is progressing.
- Engagement with regulators is enabling new ways of working.
- Agile, harmonised regulation is key to enabling our future nuclear aspirations.

Summary

- Global nuclear programme is moving from ‘old’ generation and reprocessing to new generation and nuclear propulsion.
- Nuclear materials have been transported for many decades without serious incident of release.
- The use, storage, transport and disposal of radioactive materials stimulates emotive debate.
- Many environmentally-positive innovations are helping nuclear to drive and realise carbon reduction.
- Enablement and encouragement from policy-makers and regulators is opening up opportunities. Key to progress.
- Public perception needs to be informed by science not supposition.

WNTI are the voice of the global nuclear industry and hold observer status at IAEA and consultative status at IMO.

WNTI lobby and educate

WNTI operate Working Groups, delivering outcomes:

- New package type for waste
- Regulatory consultation
- Raw material (UOC/HEX) cylinder engineering and identification
- Nuclear propulsion policy

WNTI Contacts

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