



WEBINAR

High-tech energy “ecosystems” for sustainable development

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Rosatom Southeast Asia

28 October 2021

MEETING CLIMATE CHANGE TARGETS: *THE ROLE OF NUCLEAR ENERGY*

Michel BERTHELEMY

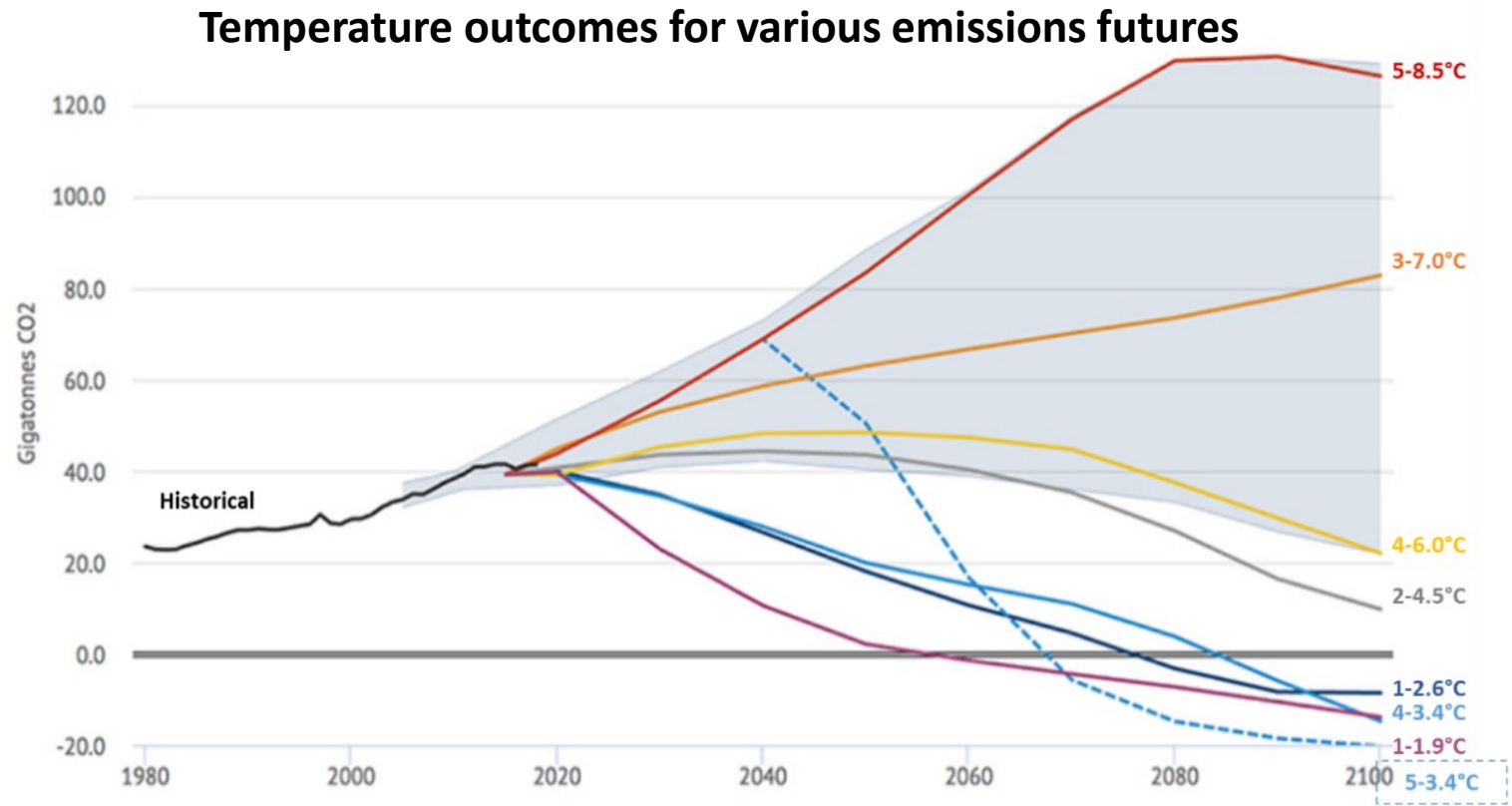
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**New Nuclear Watch Institute
28 Octobre 21, 2021**

1. Context

Global Action Is Urgently Needed

- The magnitude of the challenge should not be underestimated
- The planet has a “carbon budget” of 420 gigatonnes of carbon dioxide emissions for the 1.5°C scenario
- At current levels of emissions, the entire carbon budget would be consumed within 8 years
- Emissions must go to net zero, but the world is not on track



Source: Carbon Brief (2019).

Pathways to Net Zero Emissions

- Pathways based on the world's carbon budget, emissions reductions targets and timelines have been modelled and published by various organisations
- None of the published pathways project aspirational scenarios for nuclear innovation
- All published pathways include levels of nuclear energy deployment based on currently available commercial technologies
- Nuclear innovation does not feature prominently because of a lack of specialised expertise in nuclear technologies among modelling teams

Samples of ambitious and aspirational pathways to net zero

Organisation	Scenario	Parameter	2020	2050	Growth rate (2020-50)
IIASA (2021)	Divergent Net Zero Scenario (1.5°C)	Cost of carbon (USD per tCO ₂)	0	1 647	-
		Wind (in GWe)	600	9 371	1461%
		Solar (in GWe)	620	11 428	1743%
IEA (2021c)	Net Zero Scenario (1.5°C)	Hydrogen (MtH ₂)	90	530	490%
		CCUS (GtCO ₂)	<0.1	7.6	-
		Energy intensity (MJ per USD)	4.6	1.7	-63%
Bloomberg NEF (2021)	New Energy Outlook Green Scenario (1.5°C)	Wind (in GWe)	603	25 000	4045%
		Solar (in GWe)	623	20 000	3110%

Nuclear in Emissions Reduction Pathways

Organisation	Scenario	Climate target	Nuclear innovation	Description	Role of nuclear energy by 2050	
					Capacity (GW)	Nuclear growth (2020-50)
IAEA (2021b)	High Scenario	2°C	Not included	Conservative projections based on current plans and industry announcements.	792	98%
IEA (2021c)	Net Zero Scenario (NZE)	1.5°C	Not included but HTGR and nuclear heat potential are acknowledged.	Conservative nuclear capacity estimates. NZE projects 100 gigawatts more nuclear energy than the IEA sustainable development scenario.	812	103%
Shell (2021)	Sky 1.5 Scenario	1.5°C	Not specified	Ambitious estimates based on massive investments to boost economic recovery and build resilient energy systems.	1 043	160%
IIASA (2021)	Divergent Net Zero Scenario	1.5°C	Not specified	Ambitious projections required to compensate for delayed actions and divergent climate policies.	1 232	208%
Bloomberg NEF (2021)	New Energy Outlook Red Scenario	1.5°C	Explicit focus on SMRs and nuclear hydrogen	Highly ambitious nuclear pathway with large scale deployment of nuclear innovation.	7 080	1670%

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

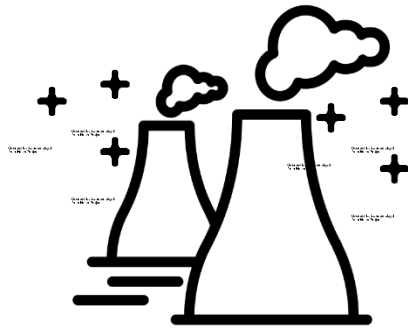
2. The Role of Nuclear Energy

The Full Potential of Nuclear Energy to Contribute to Emissions Reductions



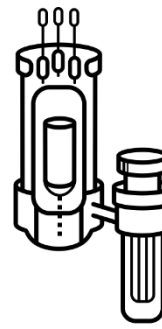
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from Noun Project

**Long Term
Operation**



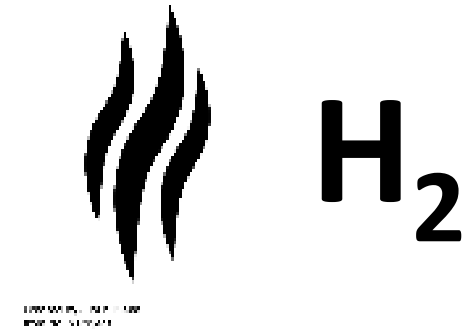
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from Noun Project

**Gen-III
Reactors**



Created by Olena Panasovska
from Noun Project

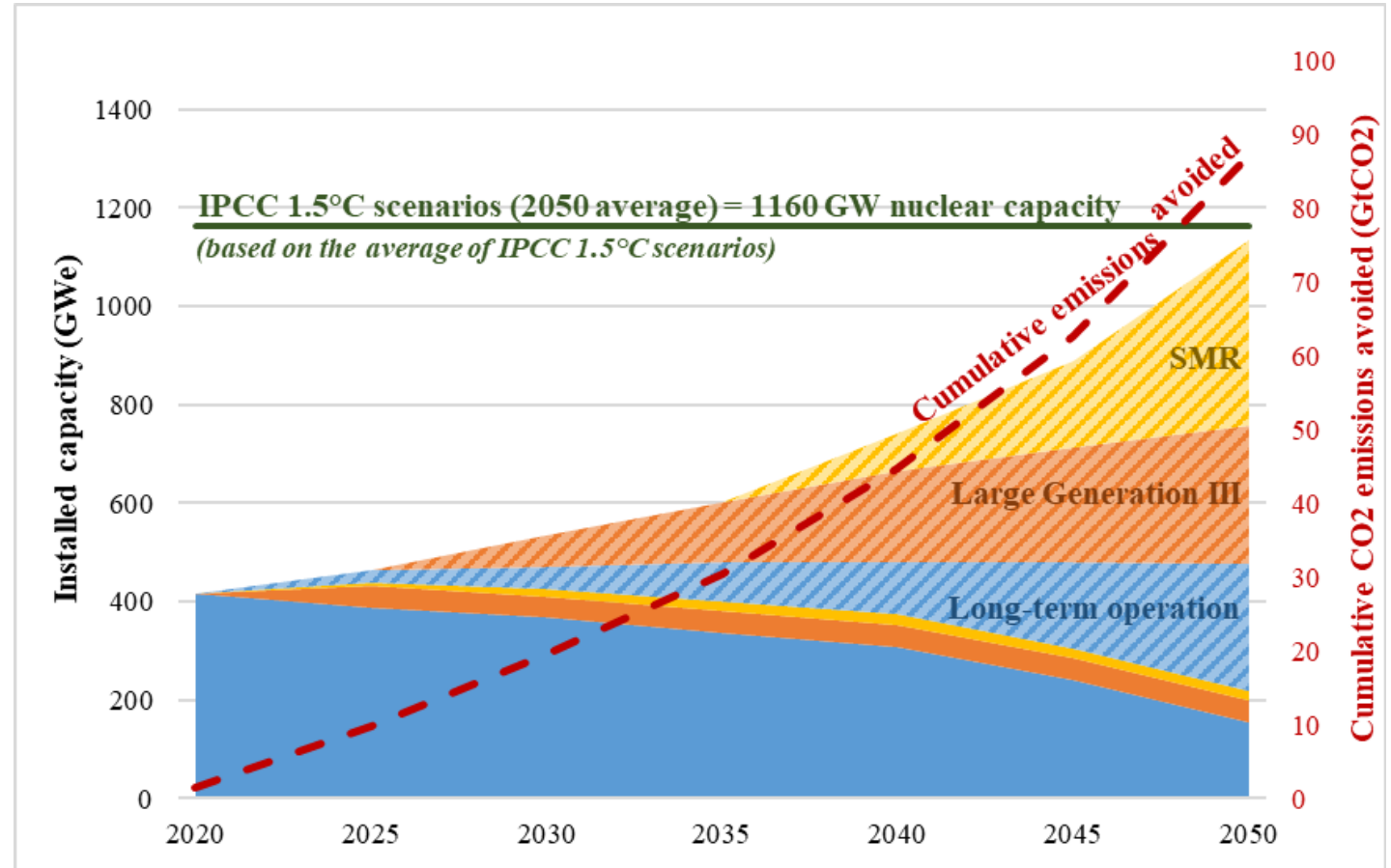
**Small Modular
Reactors**



**Non-Electrical
applications**

Full Potential of Nuclear Contributions to Net Zero

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

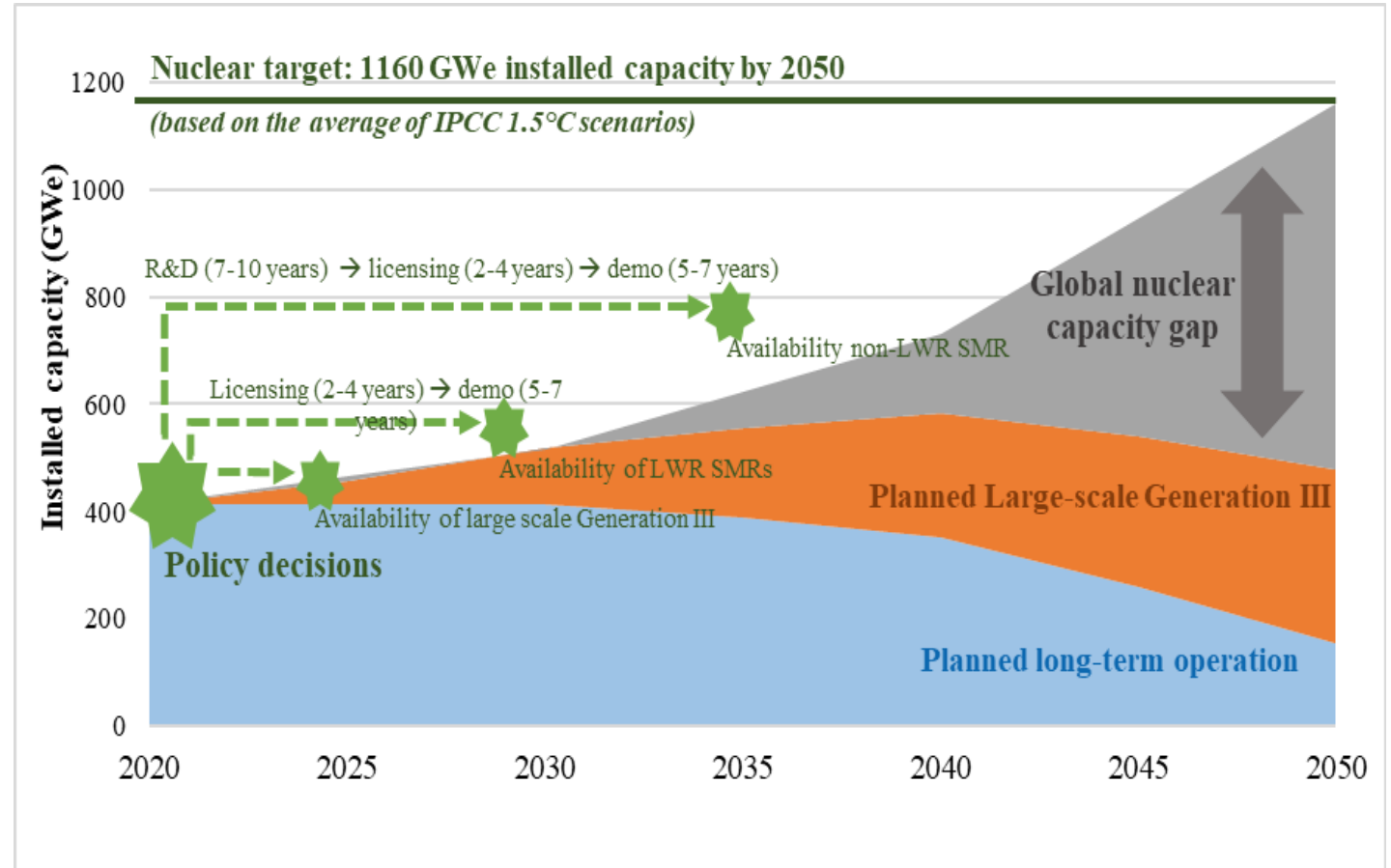


Source: NEA (forthcoming).

3. Challenges

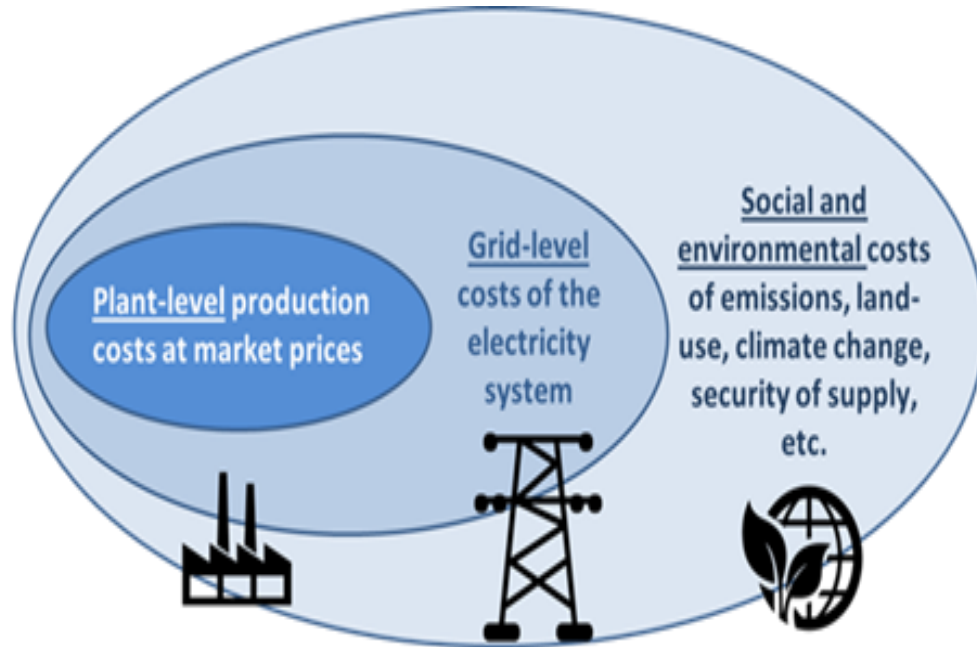
Global Installed Nuclear Capacity Gap

- Under current policy trends, nuclear capacity in 2050 is expected to reach 479 gigawatts – well below the target of 1160 gigawatts of electricity
- There is a projected gap between the *minimum required global installed nuclear capacity* and *planned global nuclear capacity* of nearly 300 gigawatts by 2050
- Owing to the timelines for nuclear projects, there is an urgency to action now to close the gap in 2030-2050



Source: NEA (forthcoming).

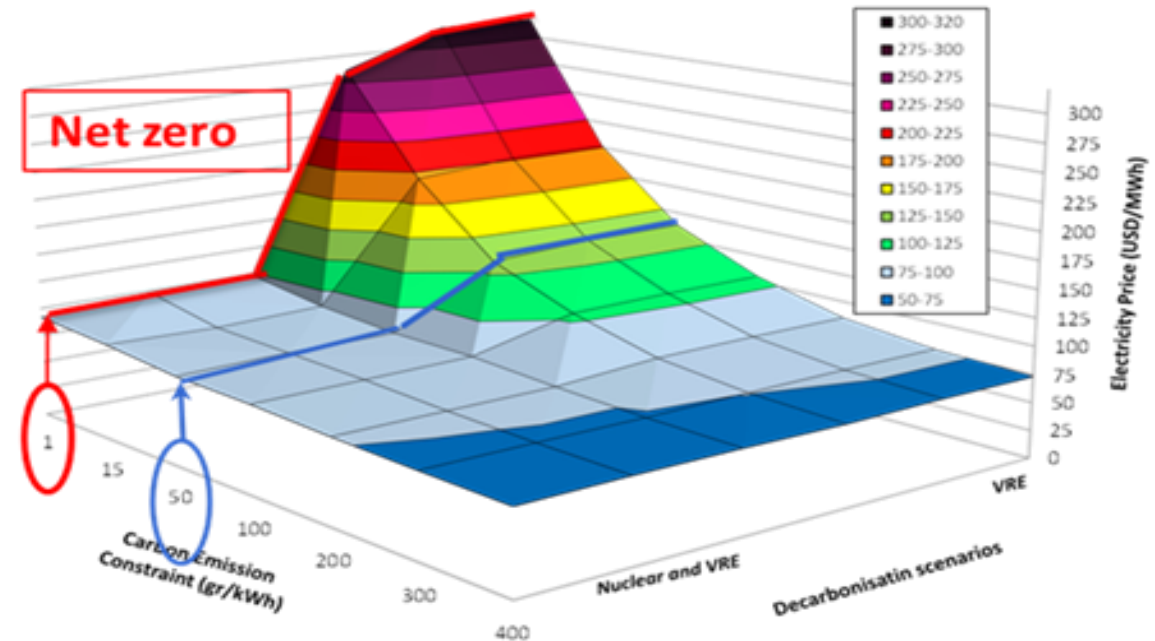
Understanding the costs of electricity provision



Understanding system costs of electricity

Source: [Adapted from NEA \(2012\)](#).

- 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



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

Source: [Based on Sepulveda \(2016\)](#).

- This 3-dimensional graph shows the effects on total costs as carbon emissions are increasingly constrained. The red line shows what happens to total costs when carbon constraints reach net-zero emissions.

5. UN Climate Change Conference (COP-26)

Recommendation for COP-26: Ensuring Full Representation at the Conference

Governments should break the silence on nuclear energy at COP 26, raising the profile of nuclear energy alongside other non-emitting energy technologies. Three key messages are recommended:

- 1. Nuclear energy already makes an important contribution to emissions reductions and it needs to expand to meet Paris Agreement targets.**
 - Nuclear energy is the largest source of low-carbon electricity in OECD countries and the second largest source of low-carbon electricity around the world after hydropower. Nuclear displaces 1.6 gigatonnes of carbon dioxide annually. The average IPCC 1.5°C scenario requires nuclear to reach 1,160 gigawatts of electricity by 2050, up from 394 in 2020
- 2. Near-term nuclear innovations are expected to make significant contributions to emissions reductions targets.**
 - Advanced and small modular reactors (SMRs), as well as nuclear hybrid energy systems, including hydrogen, are advancing quickly, with several SMR designs expected to be commercially deployed within 5 to 10 years
- 3. Policies should be technology-neutral, structured to incentivize desired outcomes such as emissions reductions and security of energy supply.**
 - Taxonomies, as well as criteria for access to climate finance, development finance and Environmental Social and Governance (ESG) finance should be applied consistently with similar levels of scrutiny across technology options, to allow technologies to compete on equal footing

NEA @ COP26: brochures

Small Modular Reactors

- » A wave of near-term innovation in nuclear energy promises to revolutionise nuclear safety and economics and open up new applications in hard-to-abate sectors
- » Small modular reactor (SMR) designs under development offer different value propositions, with a variety of sizes and temperatures intended for different applications
- » SMR reactors are expected to be commercialised within the next decade
- » A rapid SMR uptake could help avoid 15 Gt of carbon emissions by 2050

SMRs are reinventing nuclear energy

Small
SMRs are smaller, both in terms of power output and physical size, than conventional gigawatt-scale nuclear reactors. SMRs are nuclear reactors with power output less than 300 megawatts electric (MWe), with some as small as 1-10 MWe.

Modular
SMRs are designed for modular manufacturing, factory production, portability, and scalable deployment.

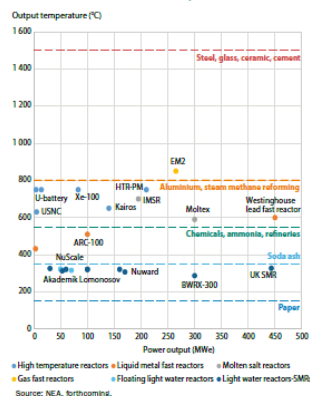
Reactors
SMRs use nuclear fission reactions to create heat that can be used directly, or to generate electricity.

Safety
SMRs build on lessons learnt from over 60 years of experience in the nuclear energy sector to enhance safety and improve flexibility. Many SMR designs incorporate the concept of passive safety, meaning they do not require active interventions or backup power to safely shut down.

Flexibility
SMRs are designed to integrate into energy systems, offering much needed flexibility to enable high shares of variable renewable energy.

Fuel cycle
Some SMR designs seek to recycle waste streams from existing reactors to produce new useful fuel and minimise waste volumes requiring long-term management and disposal.

Figure 1: Near-term SMRs could decarbonise heavy industries with combined heat and power



Climate Change Targets: The role of nuclear energy

- » The climate crisis is one of the defining challenges for this generation and the window for action is rapidly narrowing
- » Nuclear energy is playing an important role and can do more to help meet climate change targets
- » Continued operation of the existing fleet, as well as new builds of large-scale and small modular reactors could avoid 87 gigatonnes of cumulative emissions between 2020 and 2050
- » By 2050, nuclear energy could displace 5 gigatonnes of emissions per year, which is more than what the entire US economy emits annually today
- » Energy policymakers have an important role to play to create the enabling conditions for success

The world is not on track to meet the decarbonisation objectives of the Paris Agreement

As highlighted by the IPCC synthesis report (IPCC, 2018), the world is not on track. Rather than the steep reductions scientists had hoped for, global emissions are expected to rise by 16% by 2030. The window for action is rapidly narrowing. Even if carbon emissions were to remain constant, the entire carbon budget would be consumed within eight years.

Constrained by the world's carbon budget, carbon emissions must peak within the next few years and drop to zero by 2100 (or sooner). This will require policy changes around the world as well as massive investments in innovation, infrastructure, and the deployment of non-emitting energy resources. More specifically, electricity grids must be decarbonised; vehicle fleets must be electrified or transitioned to non-emitting fuels; and a range of industrial sectors (e.g. off-grid mining, buildings, chemicals, iron and steel, cement) must be transformed as well. Current emissions are on a trajectory to far exceed the targets arising from the 1.5° scenario. It is clear that a major shift in direction will be required if countries are to meet their objectives.

The IPCC 1.5°C scenario foresees, on average, 1.160 GW of operational nuclear energy by 2050, a three-fold increase compared to 2020

The 444 nuclear power reactors in operation worldwide today provide 394 gigawatts of electrical capacity that supplies approximately 10% of the world's electricity. Nuclear energy

is the largest source of non-emitting electricity generation in OECD countries and the second largest source worldwide (after hydropower). There are approximately 50 more nuclear reactors under construction to provide an additional 55 gigawatts of capacity and more than 100 additional reactors are planned. Existing nuclear capacity displaces 1.6 gigatonnes of carbon dioxide emissions annually and has displaced 86 gigatonnes of carbon dioxide since 1971 – the equivalent of two years of global emissions (NEA, 2020).

The nuclear sector can support future climate change mitigation efforts in a variety of ways. Existing global installed nuclear capacity is already playing a role and long-term operation of the existing fleet can continue making a contribution for decades to come. There is also significant potential for large scale nuclear new builds to provide non-emitting electricity in existing and embarking nuclear power jurisdictions, and, in particular, replace coal. In addition, a wave of near-term and medium-term nuclear innovations have the potential to open up new opportunities with advanced and small modular reactors (SMRs), as well as nuclear hybrid energy systems, reaching into new markets and applications. These innovations include sector coupling, combined heat and power (cogeneration) for heavy industry and resource extraction, hydrogen and synthetic fuel production, desalination, and off-grid applications.

In a special report published in 2018 (IPCC, 2018), the IPCC considered 90 pathways consistent with a 1.5°C scenario – i.e. pathways with emissions reductions sufficient to limit average global warming to less than 1.5°C. The IPCC found that, on average, the pathways for the 1.5°C scenario require nuclear energy to reach 1.160 gigawatts of electricity by 2050, up from 394 gigawatts in 2020.

System Costs of Electricity

- » Limiting the rise of global temperature to less than 2°C represents an enormous challenge for the whole electricity sector
- » Decarbonising the electricity sector in a cost-effective manner while maintaining security of supply requires the rapid deployment of all available low-carbon technologies
- » System costs are not properly recognised by current market structures and are currently borne by the overall electricity system in a manner that makes it difficult – if not impossible – to make well-informed decisions and investments

Understanding the costs of electricity provision requires systems level thinking

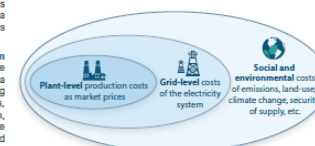
The first level of analysis is plant-level costs of generation, which include, among other costs, the costs of the concrete and steel used to build the plant, as well as the fuel and human resources to operate it. These plant-level costs are typically referred to as the levelised cost of electricity (LCOE), and they may include some costs that were previously considered as externalities – for example, if there is a price on carbon or a legislated requirement to internalise the end of life cycle costs into plant-level costs.

The next level of analysis takes into account grid-level system costs. These are the costs that generating units impose on the broader electricity system – including the costs of maintaining a high level of security of supply at all times as well as delivering electricity from generating plants to customers – in other words, in addition to production, they include connection, distribution, and transmission costs. Most importantly, grid-level costs include the costs associated with compensating for the variability and uncertainty in the supply from generating plants. This includes the costs of additional dispatchable capacity to account for the variability of certain renewables such as wind and solar PV and for maintaining spinning reserves that can be ramped up when the production of variable sources falls short of forecasts.

The final level of analysis addresses the full costs, including the social and environmental costs that different technologies impose on the well-being of people and communities, including negative externalities like atmospheric pollution, impacts on land-use and biodiversity, as well as, in certain cases, positive externalities such as impacts on employment and economic development, or spin-off benefits from technology innovation. These are the externalities that are not accounted for in plant-level costs or grid-level system costs.

The combination of plant-level costs, grid-level systems costs, and full social and environmental costs creates a framework that allows policymakers to compare the costs of different generating options – comparing apples to apples, not apples to oranges. To do so requires a systems level perspective.

Figure 1: Understanding the system costs of electricity



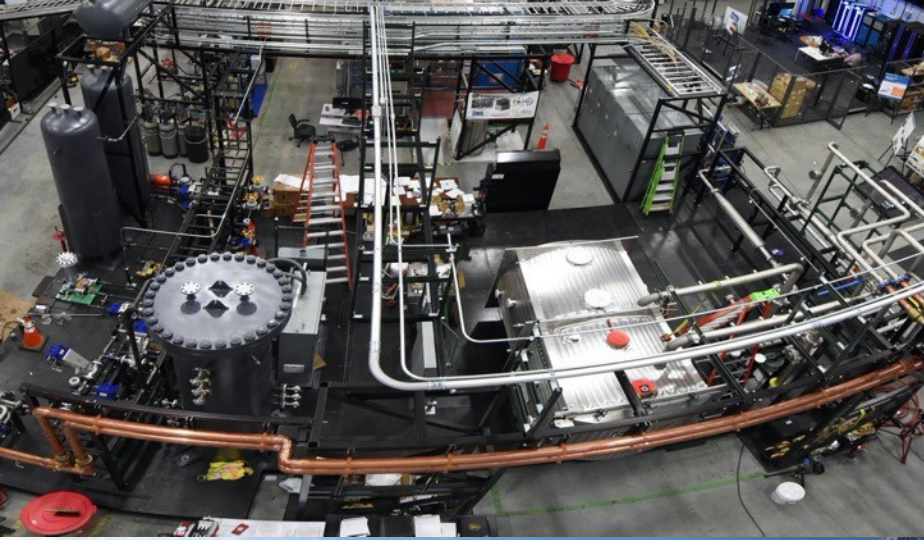
Source: Adapted from NEA (2012).

Total economic system costs, then, are defined as plant-level generating costs plus grid-level system costs. Taking this systems level perspective includes:

- Profile and balancing costs – the grid-level costs imposed by variability and uncertainty.
- Connection, distribution, and transmission costs – the costs of delivering electricity from distributed power generation to customers.



Thank you for your attention



Webinar:
**High Tech Energy Ecosystems
for Sustainable Development**
**New Nuclear Watch Institute
(NNWI)**



Flexible, Clean Nuclear— Renewable Energy Deployment for a Net-Zero Future

28 October 2021

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 Idaho National Laboratory

We need nuclear to reach net-zero



28% by 2040

Projected increase in world energy use by U.S. Energy Information Administration.*



2.7 degrees by 2040

Projected increase in atmospheric temperatures if global greenhouse gas emission continue at current rate by Intergovernmental Panel on Climate Change

We cannot reach our climate goals without contribution from nuclear energy!

MIT Future of Nuclear Energy Study (2018)

Key finding: Without contribution from nuclear, the cost of achieving deep decarbonization targets increases significantly.

International Energy Agency, Nuclear Power in a Clean Energy System (May 2019)

Despite significant renewable energy growth over the last 20 years, the overall contribution of clean energy supply to electric generation has not changed... In many parts of the world, low-cost natural gas is displacing nuclear generation as a complement to variable wind, solar.

Clean Energy Targets are Trending

updated Dec 2020

Clean energy commitments are rapidly gaining popularity.

ThirdWay research for the U.S. identified a total of 153 portfolio standards and other commitments to clean energy since 1983; 67% were adopted since 2016.

Climate leaders want more technology options to choose from.

Prior to 2016, 90% of commitments in the U.S. were exclusive to renewable energy. That trend has almost completely reversed, with 73% of states, utilities, and major cities now embracing “technology-inclusive” commitments like **clean energy standards** that take advantage of nuclear power, carbon capture, and other carbon-free options.

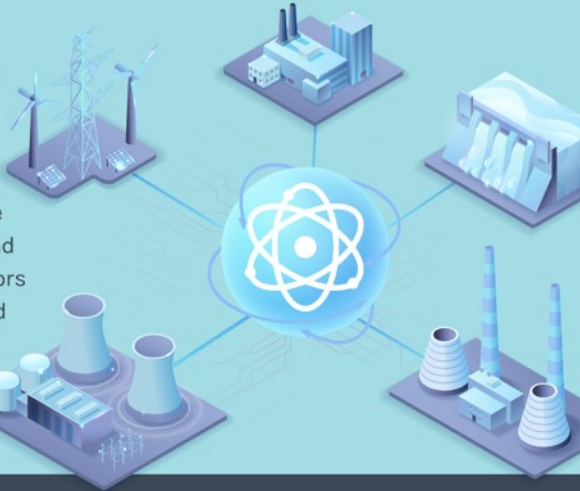


IES

Integrated Energy Systems

Embracing new operational paradigms—nuclear energy flexibility

Nuclear is evolving into a **more flexible energy source** that can work alongside chemical plants and renewable generators to create integrated energy systems.



THE FLEXIBILITY OF NUCLEAR

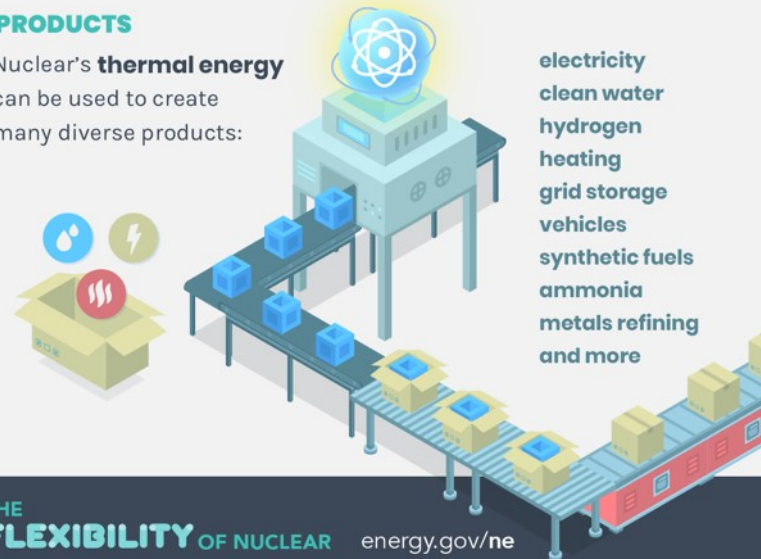
energy.gov/ne

- **Operational flexibility**
- **Product flexibility**
- **Deployment flexibility**

Nuclear flexibility can be key to enabling deployment of other clean energy generators.

PRODUCTS

Nuclear's **thermal energy** can be used to create many diverse products:



electricity
clean water
hydrogen
heating
grid storage
vehicles
synthetic fuels
ammonia
metals refining
and more

THE FLEXIBILITY OF NUCLEAR

energy.gov/ne

MICROREACTOR
1 MW – 20 MW



SMALL MODULAR REACTOR
20 MW – 300 MW



LARGE SCALE REACTOR
300 MW – 1,000+ MW



SIZE

Nuclear has the **right-sized reactors** to meet the energy needs of any community.

THE FLEXIBILITY OF NUCLEAR

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U.S. DEPARTMENT OF
ENERGY

Office of
NUCLEAR ENERGY



NICE Future

Nuclear Innovation: Clean Energy Future

IDAHO NATIONAL LABORATORY



IES

Integrated Energy Systems

Flexible Nuclear Energy for Clean Energy Systems, September 2020
<https://www.nice-future.org/flexible-nuclear-energy-clean-energy-systems>

Advanced reactor design concepts

Benefits:

- High-degree of passive safety
- Higher temperature operation for versatile applications
- Reduced waste
- Long operational lifetimes (~5-20 yr)
- Advanced manufacturing of components to reduce costs
- Modularity supports additional build-out on an as-needed basis
- Enhanced siting options, reduced site preparation

60+ private sector projects under development

SIZES

SMALL

1 MW to 20 MW
Micro-reactors

*Can fit on a flatbed truck.
Mobile. Deployable.*

MEDIUM

20 MW to 300 MW
Small Modular Reactors

Factory-built. Can be scaled up by adding more units.

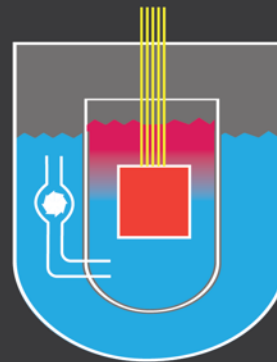
LARGE

300 MW to 1,000 + MW
Full-size Reactors

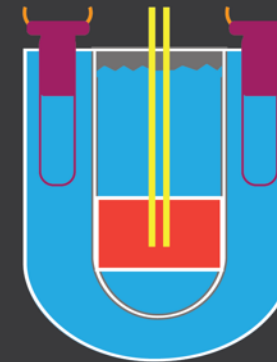
Can provide reliable, emissions-free baseload power

Advanced Reactors Supported by the U.S. Department of Energy

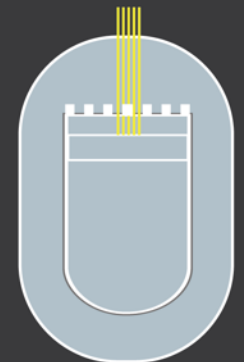
TYPES



MOLTEN SALT REACTORS –
Use molten fluoride or chloride salts as a coolant. Online fuel processing. Can re-use and consume spent fuel from other reactors.



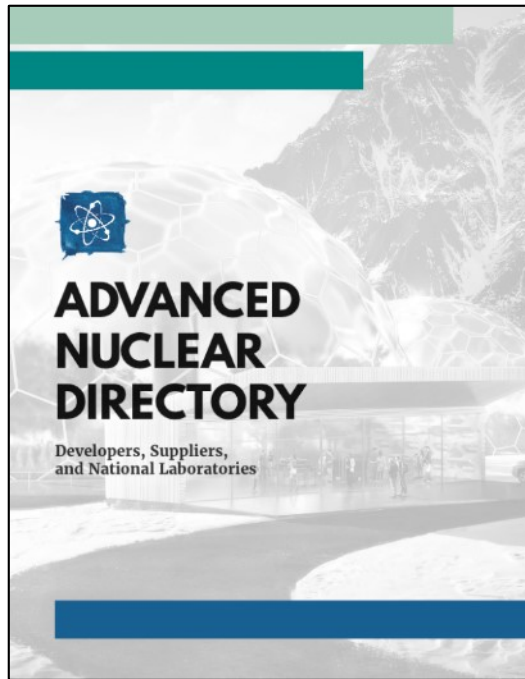
LIQUID METAL FAST REACTORS –
Use liquid metal (sodium or lead) as a coolant. Operate at higher temperatures and lower pressures. Can re-use and consume spent fuel from other reactors.



GAS-COOLED REACTORS –
Use flowing gas as a coolant. Operate at high temperatures to efficiently produce heat for electric and non-electric applications.

Enhanced private-sector interest in advanced nuclear is motivating a new “National Reactor Testing Station”

- New opportunities have resulted in significant private sector interest in advanced nuclear
- Facilities and capabilities needed to develop, test, and demonstrate promising advanced reactor concepts to *enable commercialization and deployment*, domestically and beyond



National Reactor Innovation Center (NRIC)



- Launched by DOE in FY2020, authorized by the Nuclear Energy Innovation Capabilities Act (NEICA)
- Mission: Accelerate the demonstration and commercialization of advanced reactors by inspiring stakeholders, empowering innovators, and delivering successful demonstration reactors.
 - Partner with industry to bridge the gap between research and commercial deployment
 - Leverage national lab expertise and infrastructure
- Manage demonstrations to success

For more information on NRIC and to download resources, see <https://nric.inl.gov/>.



NRIC Enables Nuclear Reactor Demonstrations

NRIC advanced reactor testing infrastructure

- Goal: Demonstrate two advanced reactors by 2025
- Strategy:
 - Repurpose two facilities at INL and establish two test beds to provide confinement for reactors to go critical for the first time
 - Build/establish testing infrastructure for fuels and components
- Capabilities:
 - NRIC DOME (Demonstration of Microreactor Experiments)
 - Advanced Microreactors up to 20 MWth
 - High-Assay Low-Enriched Uranium (HALEU) fuels < 20%
 - NRIC LOTUS (Laboratory for Operations and Testing in the US)
 - Up to 500 kWth experimental reactors
 - Safeguards category one fuels
 - Experimental Infrastructure
 - Molten Salt Thermophysical Examination Capability
 - Helium Component Test Facility

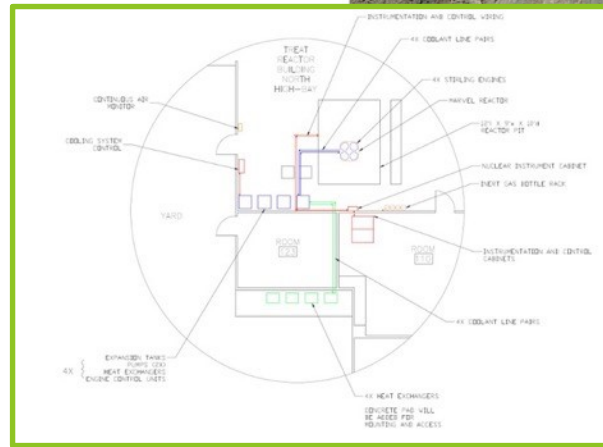
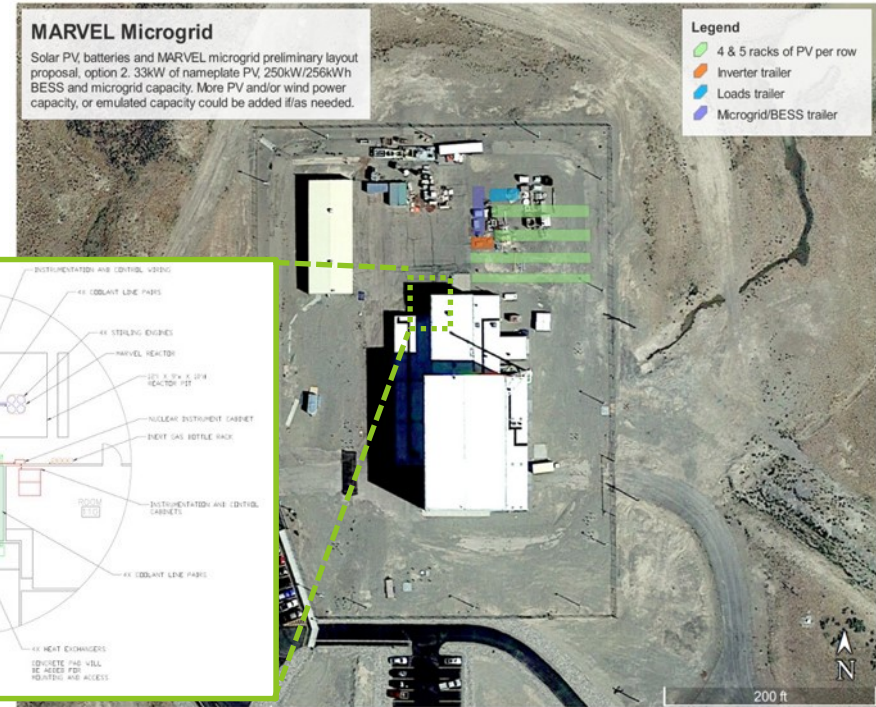


*Anticipate initial reactor testing in ~2024.
Flexible testbed to support testing of
multiple reactor concepts using the same
infrastructure ~annually.*

Microreactor Demonstration Test Facility

MARVEL

- The U.S. has not built a new nuclear reactor in decades—but we are ready
- Microreactor Applications Research Validation and Evaluation (MARVEL) will pave the way to future commercial endeavors
- Full-scale, electrically heated prototype designed, fabricated, and assembly in less than nine months
- Sited at the INL Transient Reactor Test Facility (TREAT), operated as a part of a microgrid providing combined heat and power (CHP) alongside solar PV, batteries
- Demonstrate nuclear microgrid operations and provide opportunity to demonstrate operation with coupled energy users
- MARVEL Construction Complete: ~December 2022
- MARVEL Criticality: December 2023



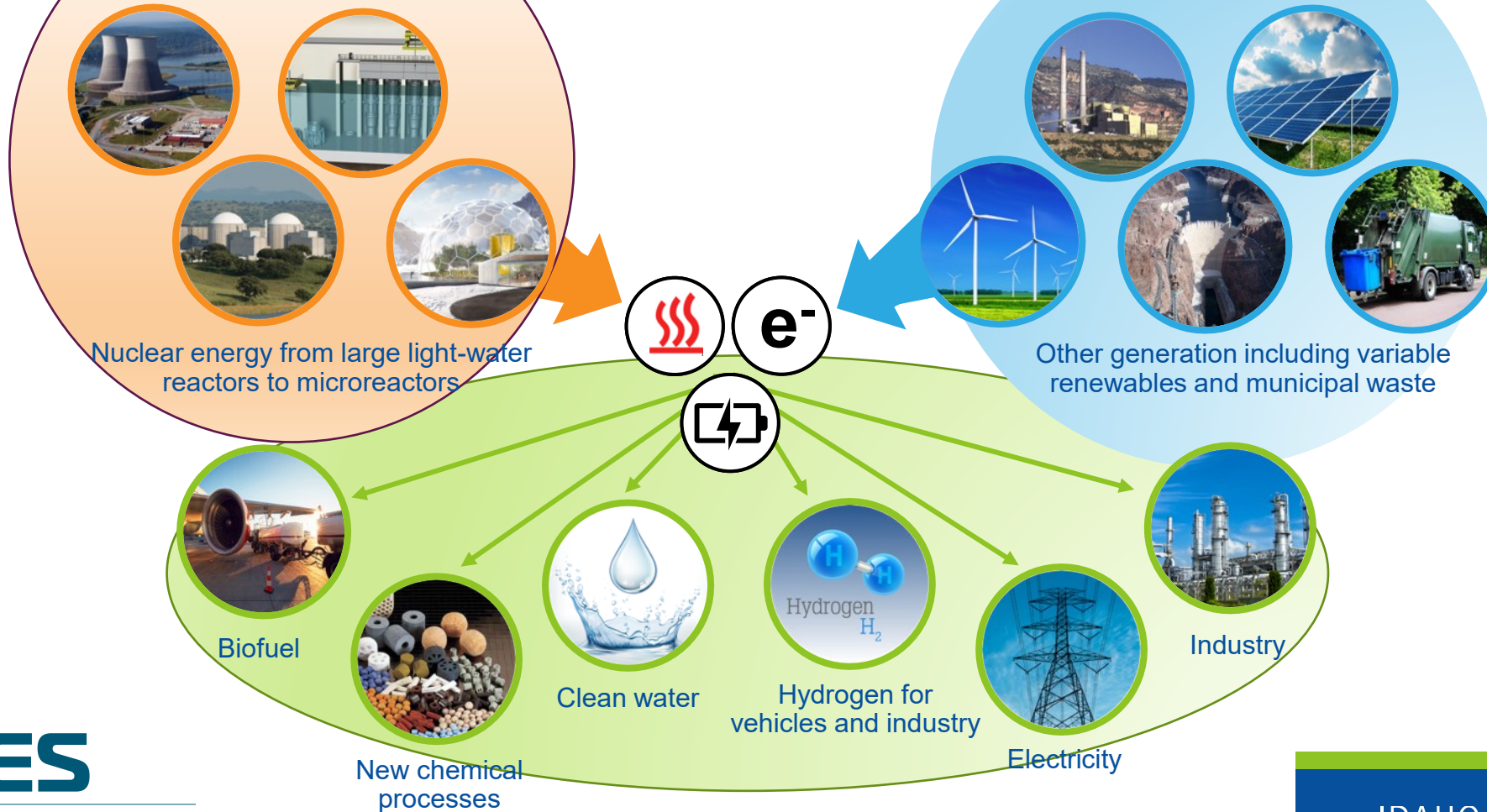
Hydrogen production
Desalination
Heat for industry



Product flexibility: Cross-sectoral energy solutions for a resilient net-zero future

Future Energy System: Transforming the Paradigm

Integrated systems leverage contributions from all low emission energy generation options to support decarbonization of electricity, industry, and transportation

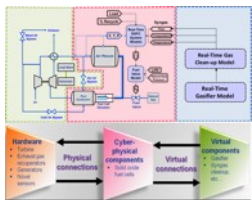


Goals

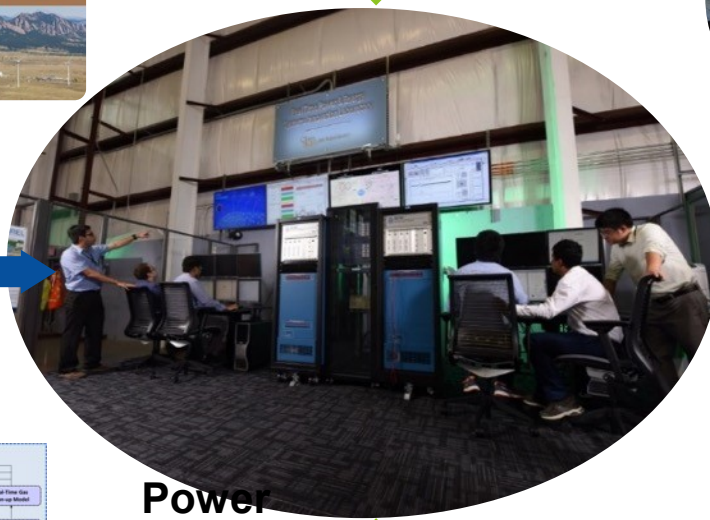
- Maximize energy utilization and generator profitability
- Minimize environmental impacts—
decarbonization across all energy use sectors
- Maintain affordability, grid reliability and resilience



Demonstration of integrated energy systems (IES) (electrically heated)



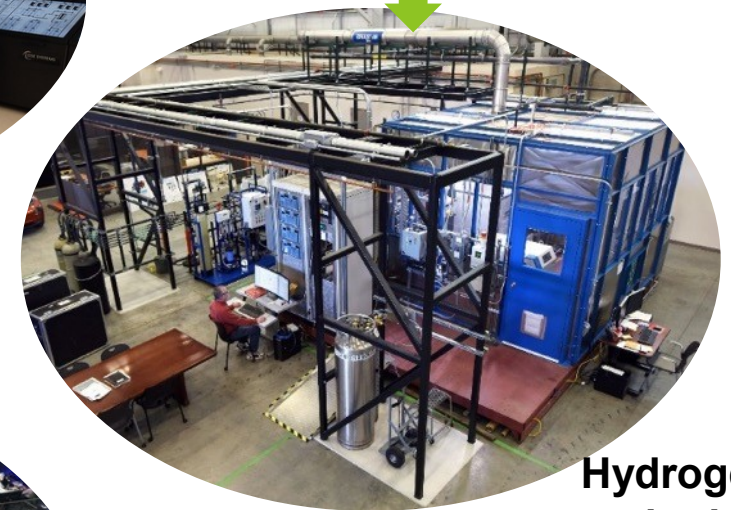
Realtime connections to remote facilities enhance IES demonstration capabilities



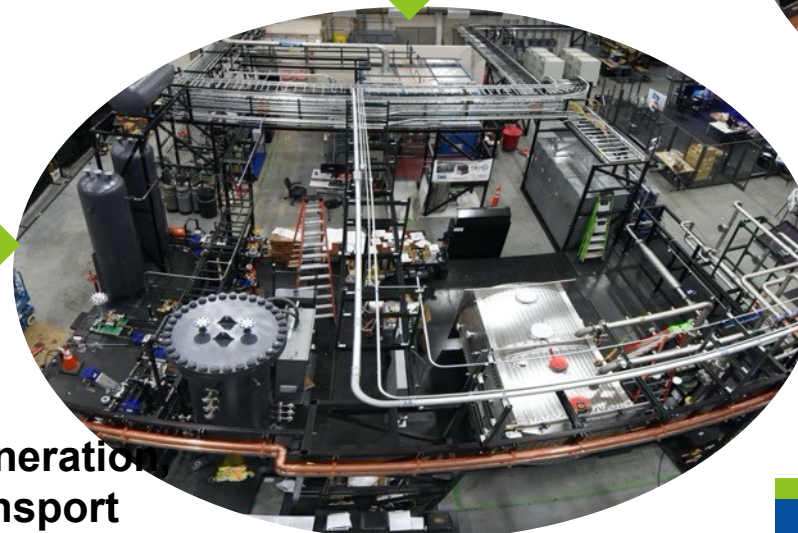
Power Hardware and Grid-in-the-Loop, Microgrid



Human-in-the-Loop Operations



Hydrogen and other Flexible Industrial Processes



Thermal Energy Generation, Storage, and Transport (Microreactor Emulation)

Partnerships enable nuclear—H₂ production demonstrations

Three projects have been announced for demonstration of hydrogen production at nuclear power plants

- Demonstrate hydrogen production using direct electrical power offtake from a nuclear power plant
- Develop monitoring and controls procedures for scaleup to large commercial-scale hydrogen plants
- Evaluate power offtake dynamics on NPP power transmission stations to avoid NPP flexible operations
- Produce hydrogen for captive use by NPPs and first movers of clean hydrogen

Schedule:

- Exelon: Nine-Mile Point NPP; LTE/PEM Vendor 1; using “house load” power; PEM skid testing is underway at NREL; H₂ production beginning ~January 2022
- Energy Harbor: Davis-Besse NPP; LTE/PEM Vendor 2; power provided by completing plant upgrade with new switch gear at the plant transmission station; installation to be made at next plant outage; contract start anticipate by October 2022
- Xcel Energy: HTE/SOEC Vendor 1; Project negotiations are being finalized. Tie into plant thermal line engineering has been completed; official project start anticipated by January 2022

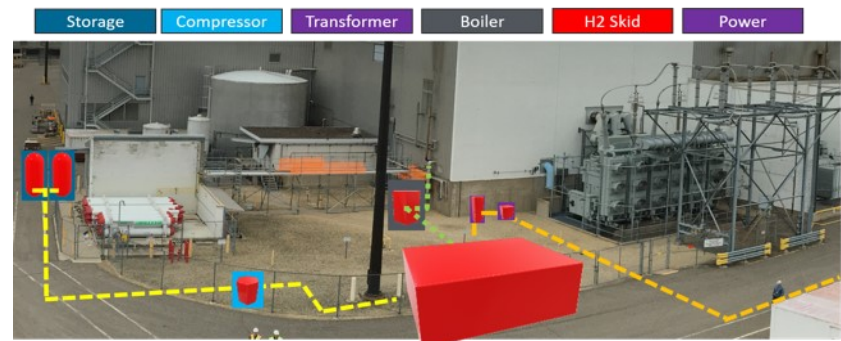
Davis-Besse Nuclear Power Plant LTE-PEM Vendor 1



Nine Mile Point Nuclear Power Plant LTE/PEM Vendor 2

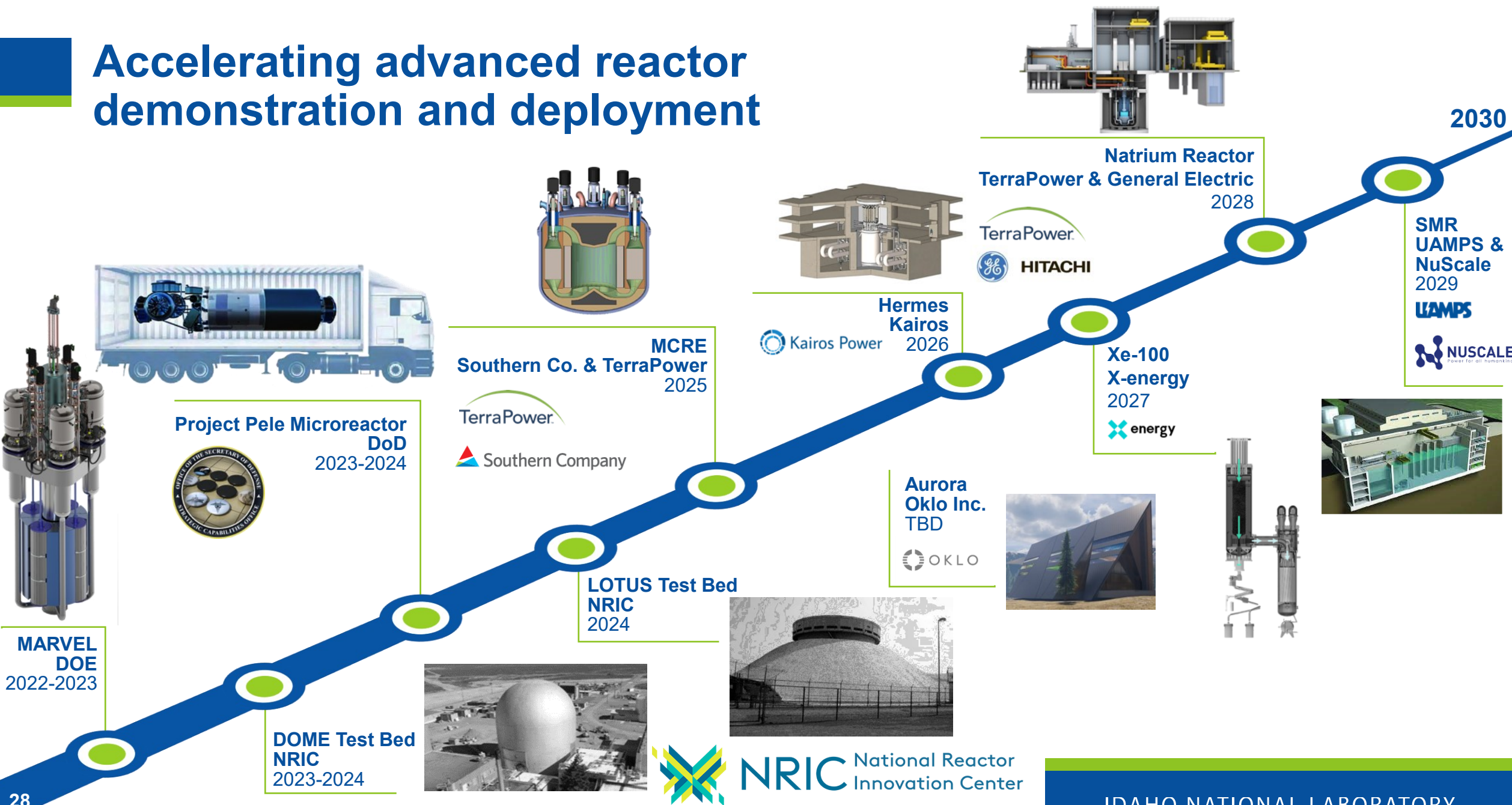


Thermal & Electrical Integration at Xcel Energy Nuclear Plant HTE/Vendor 1

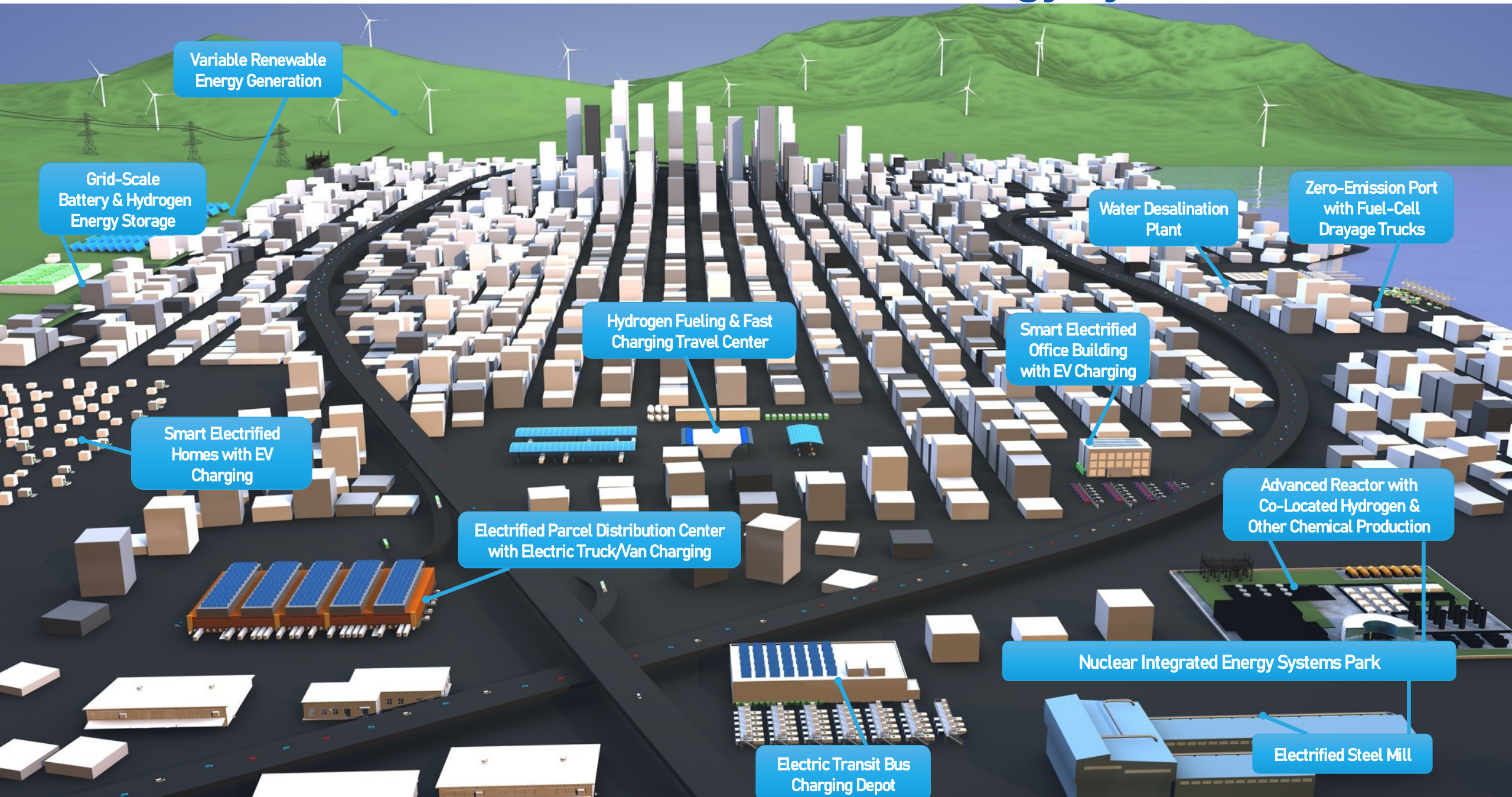


HTE/SOEC efficiency is 20-30% higher than LTE/PEM

Accelerating advanced reactor demonstration and deployment



A vision for net-zero distributed energy systems



Variable Renewable Energy Generation

Grid-Scale Battery & Hydrogen Energy Storage

Smart Electrified Homes with EV Charging

Hydrogen Fueling & Fast Charging Travel Center

Electrified Parcel Distribution Center with Electric Truck/Van Charging

Electric Transit Bus Charging Depot

Water Desalination Plant

Zero-Emission Port with Fuel-Cell Drayage Trucks

Smart Electrified Office Building with EV Charging

Advanced Reactor with Co-Located Hydrogen & Other Chemical Production

Nuclear Integrated Energy Systems Park

Electrified Steel Mill

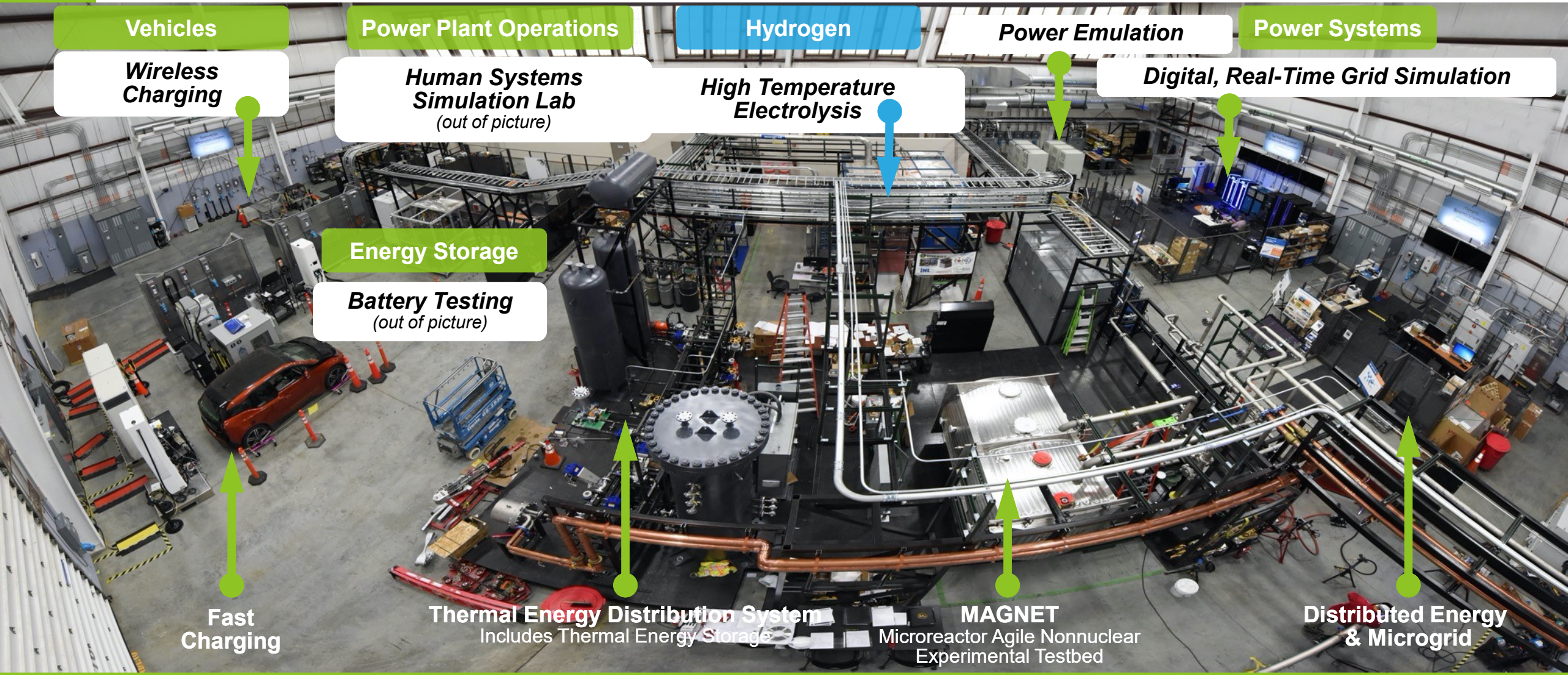


Idaho National Laboratory



WWW.INL.GOV

Integrating systems for the nation's net-zero future



Vehicles

Wireless Charging

Power Plant Operations

Human Systems Simulation Lab
(out of picture)

Hydrogen

High Temperature Electrolysis

Power Emulation

Digital, Real-Time Grid Simulation

Power Systems

Energy Storage

Battery Testing
(out of picture)

Fast Charging

Thermal Energy Distribution System
Includes Thermal Energy Storage

MAGNET
Microreactor Agile Nonnuclear
Experimental Testbed

Distributed Energy & Microgrid



Rolls-Royce SMR

NNWI

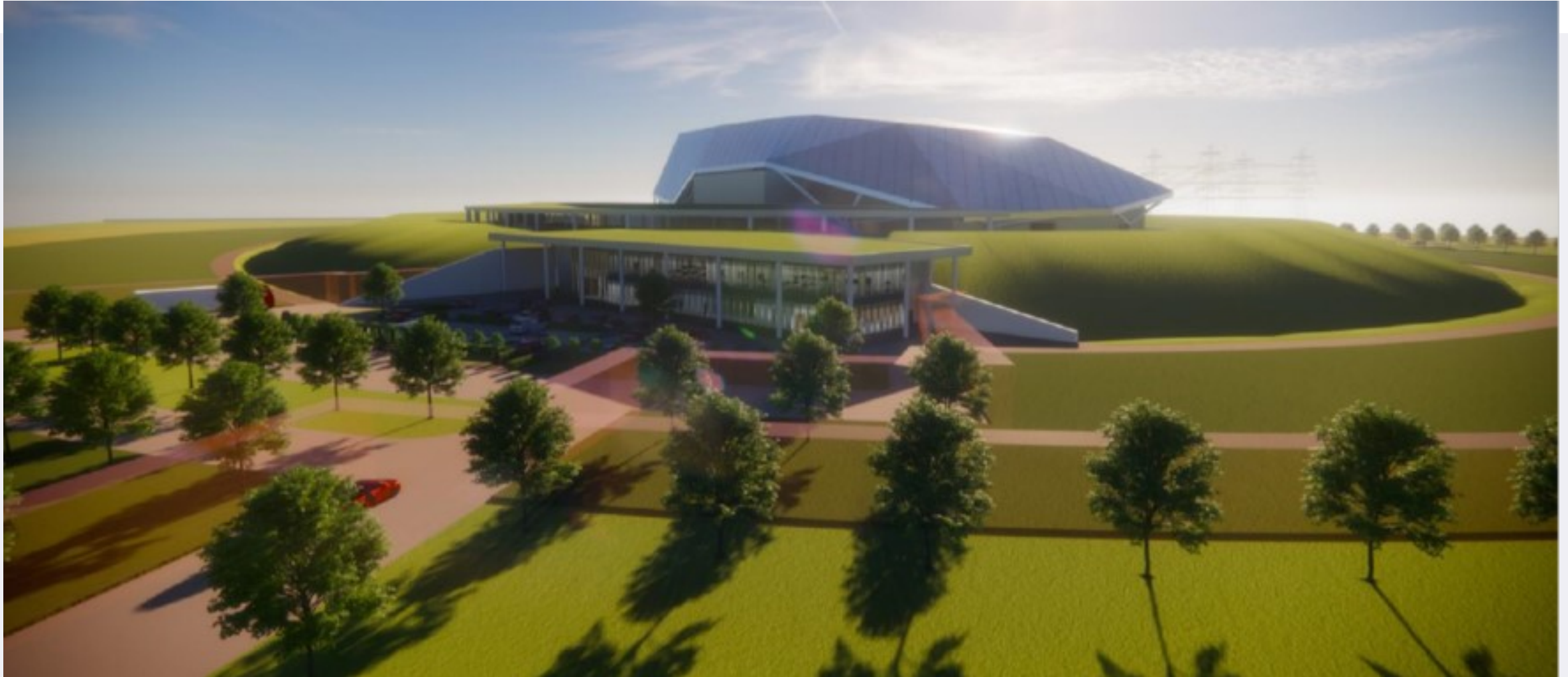
28 October 2021

This information is provided by Rolls-Royce in good faith based upon the latest information available to it; no warranty or representation is given; no contractual or other binding commitment is implied



SMR Video

<https://vimeo.com/551457837/0735106fb6>





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

- Rolls-Royce has a strong nuclear heritage with roots in defence and civil development
- Rolls-Royce has been designing, manufacturing and supporting Royal Navy submarines' small reactors for over 50 years
- Thanks to their 100+ years of experience and operations in 50+ countries, Rolls-Royce are a globally recognised and trusted partner

Civil Aerospace



Power Systems



Defence



Strong nuclear heritage with roots in defence and civil development

Nuclear Business Experience

Defence Nuclear

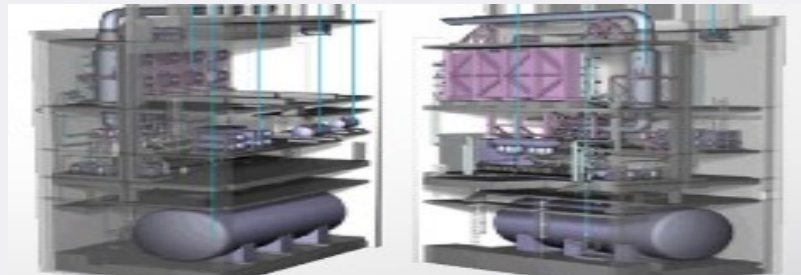
Submarines



- Sole technical authority for over 50 years
- Reactor plant design and supply
- Operation of licensed sites
- Fuel fabrication
- Through life services
- Through-life 24 hour global operational support
- 6 generations of reactors

Civil Nuclear

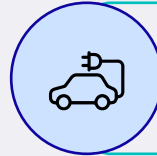
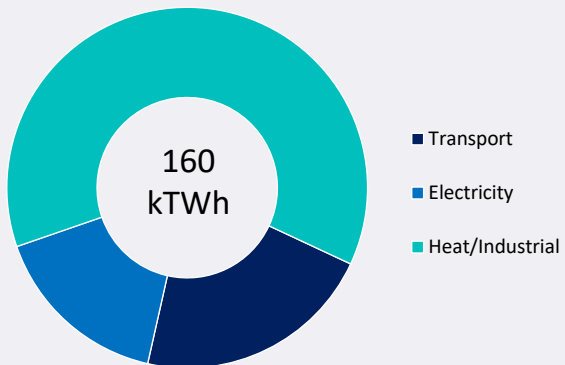
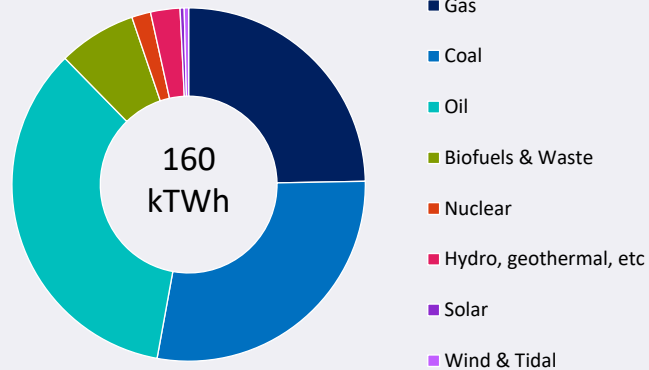
Nuclear Services and Projects



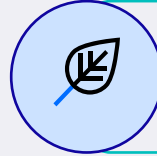
- Emergency diesel generator system
- Waste treatment systems
- Services: Inspection, predictive maintenance, inventory management
- Complex components supply

Tomorrow's energy market will look fundamentally different as the world transitions to a low carbon environment

Only 13% global energy is low carbon



- The challenge is huge, covering transport and heat as well as grid electricity



- Decarbonisation obligations are having a material impact on energy policies



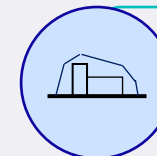
- There are a limited number of solutions to decarbonising many sectors. Most need more clean electricity



- The demand for clean electricity is set to grow considerably in any scenario



- Industrial companies are seeking to decarbonise production quickly and economically

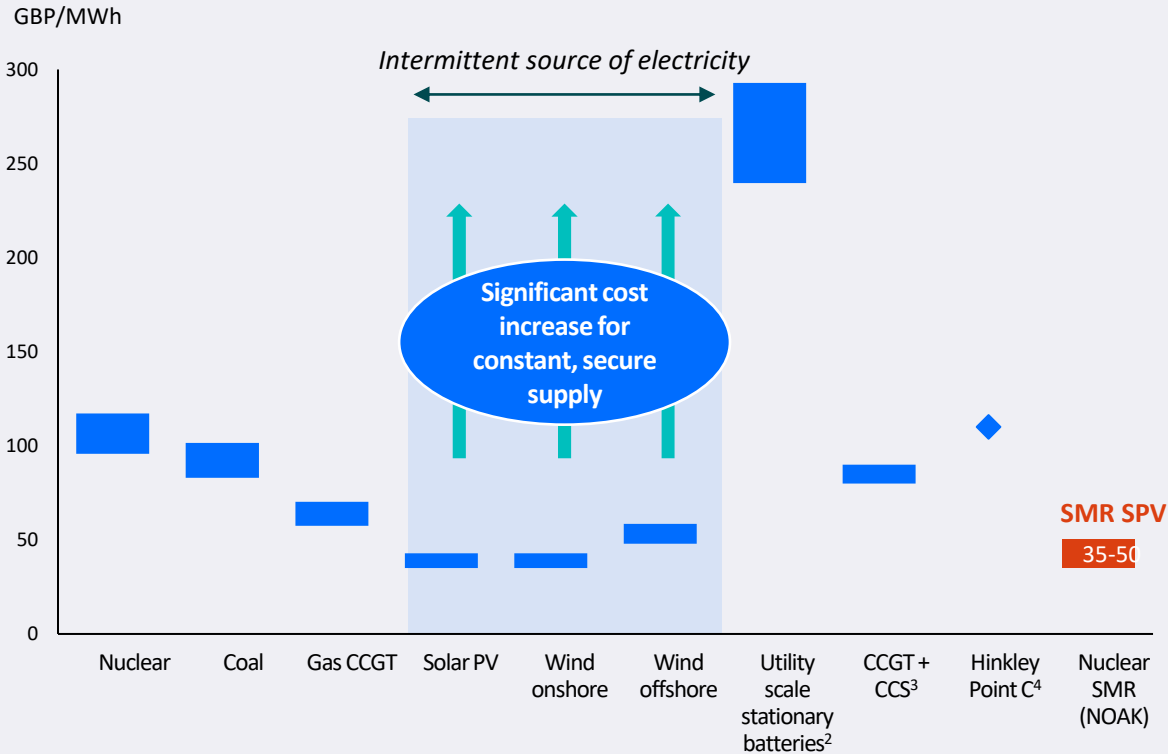


- Our SMR provides a low cost, investible, and deliverable solution to predictable clean electricity at a scale unmatched by other clean sources

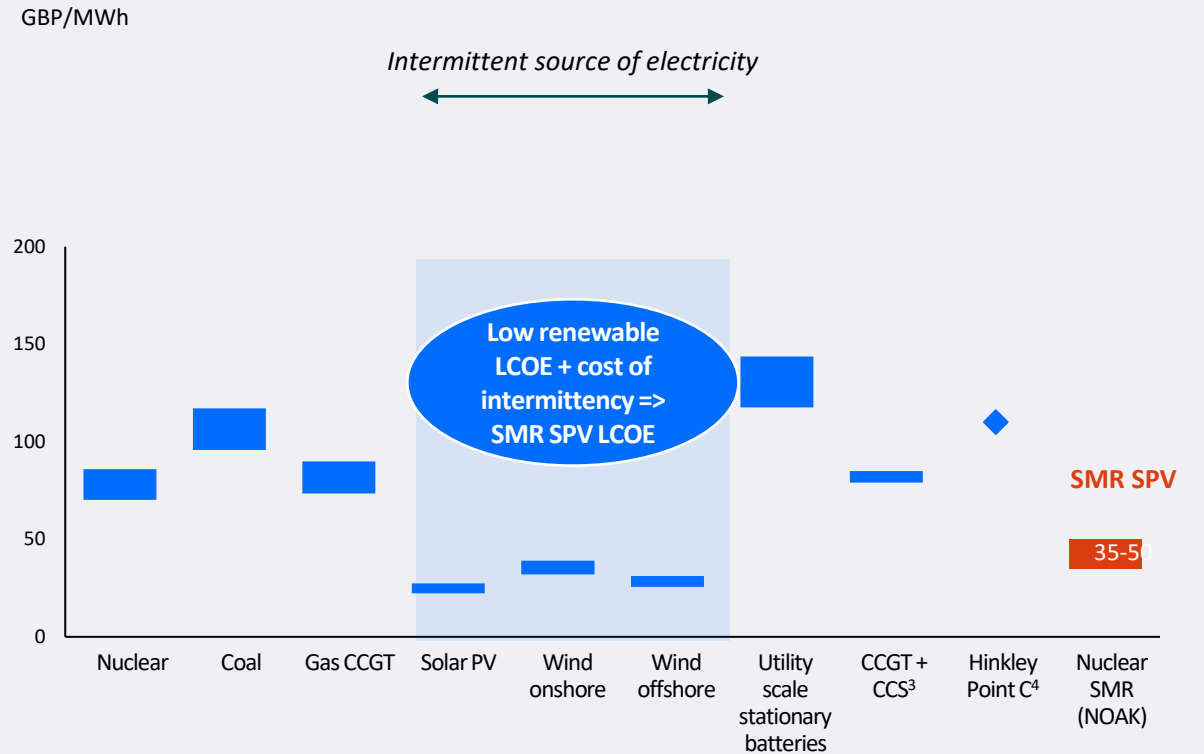


The LCOE for SMRs is similar to renewable LCOEs and is significantly cheaper once storage costs for renewables are included

European LCOE / Levelised Cost of Storage (“LCOS”), by technology for indicative assets¹ commissioning in 2019



European LCOE / LCOS, by technology for indicative assets¹ commissioning in 2040



Sources: IEA WEO 2020, BEIS Electricity Generation Cost Report 2020

Notes: CCGT = Combined Cycle Gas Turbine; CCS = Carbon Capture and Storage; USD = United States Dollar

1. Data from IEA WEO 2020, converted from USD to GBP (0.7) with +/-10% range applied
2. IEA Data – 2020 base year
3. Data from BEIS Electricity Generation Cost Report 2020 – Refers to 2025 LCOE as this is the first estimated deployment date of this technology
4. GBP92.5 CFD agreed price, scaled by CPI to 2019, as per CFD agreement

SMR Range determined by financing mechanism



Rolls-Royce SMR is a revolutionary nuclear product; factory fabricated, road transported and site assembled.

The RR SMR approach is a holistic, integrated power station and not just a nuclear reactor design.

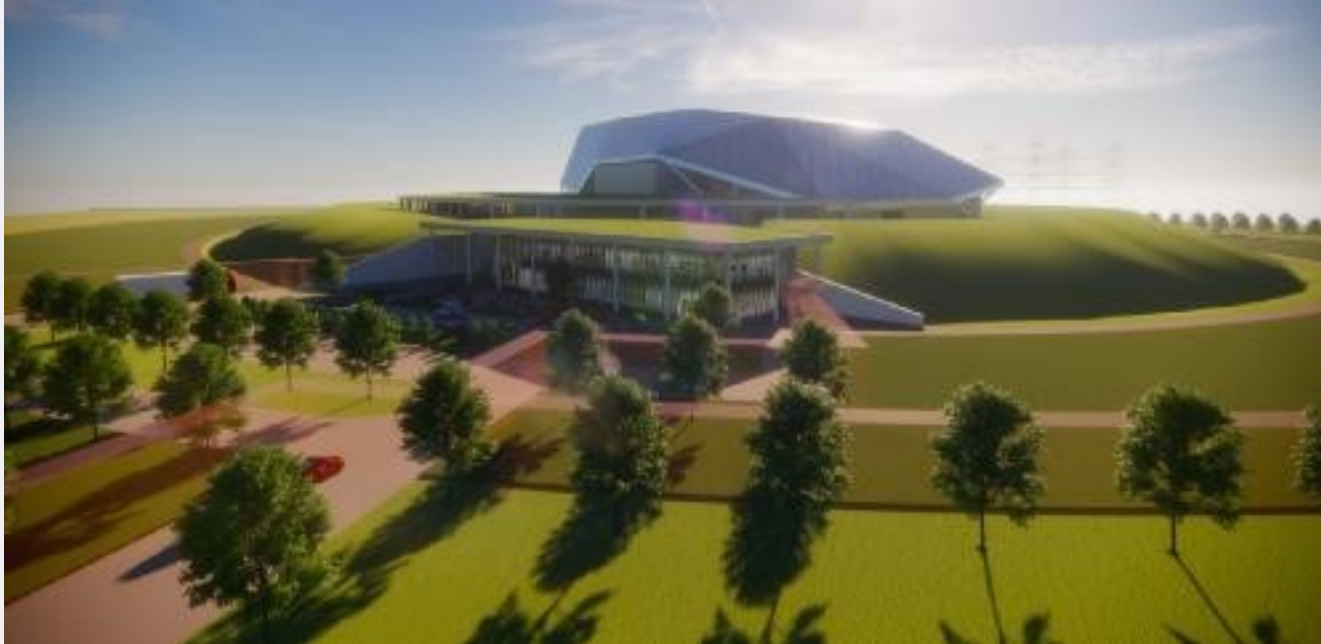
~470 MWe output

50 Hz design

Proven PWR Technology & Standard Fuel

Power station delivery as a turnkey project

4 yr Construction (Nth unit)



Enhanced Gen III+ levels of safety and security

1st unit on grid early 2030s

Capital cost under £1.8 Bn*

Adaptable, multi-use power & heat output

LCOE £35-£50 per MWh*

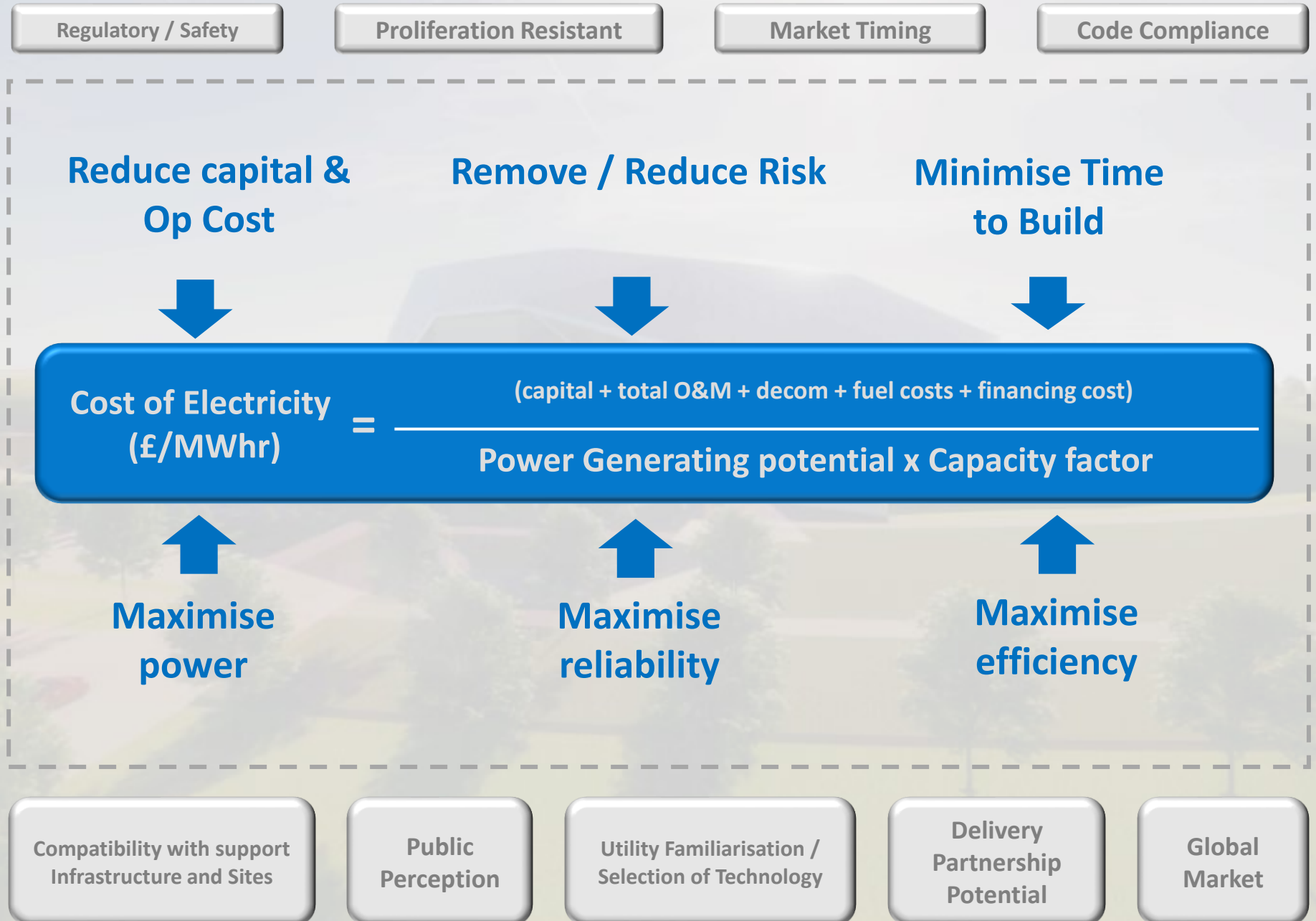
Rolls Royce SMRs – Low cost, Deliverable, Investable Low Carbon Power



Our whole design has been driven by market requirements from conception

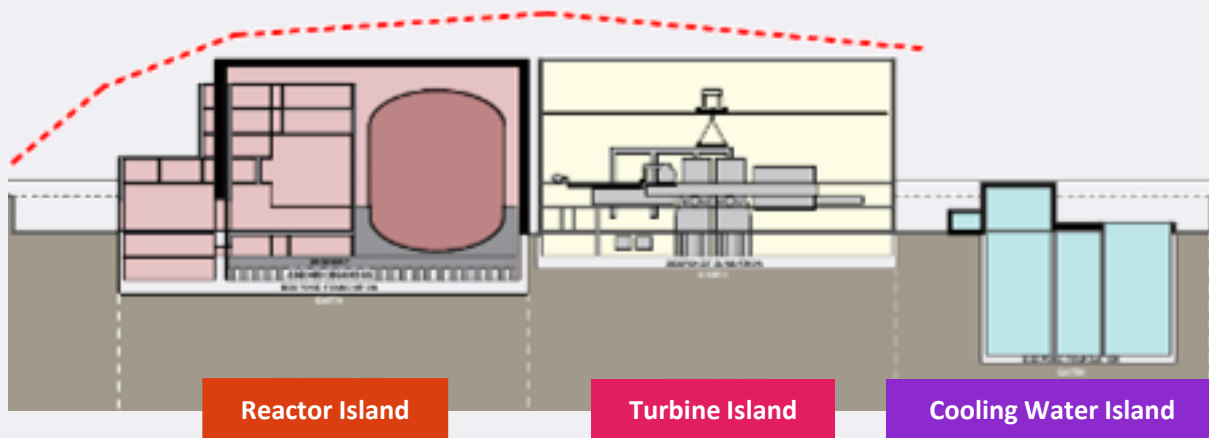
Those that we can control within the design

Those that we must recognise as key influencing factors on design and technology choices



Power Station Basic Design

A compact, cohesive layout that encompasses all the needed facilities for a nuclear power station



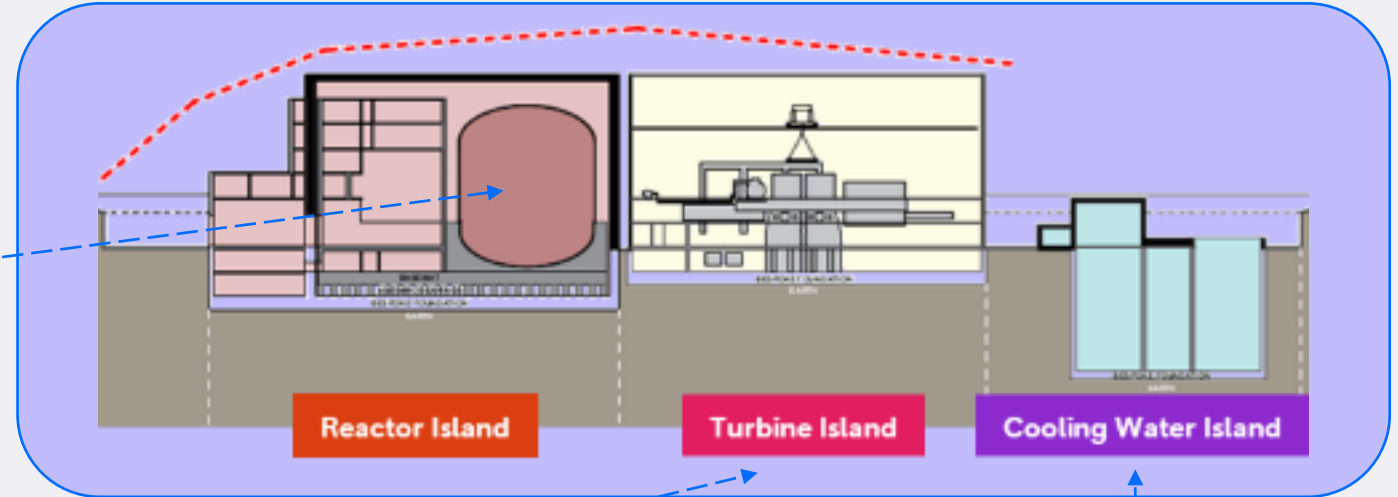
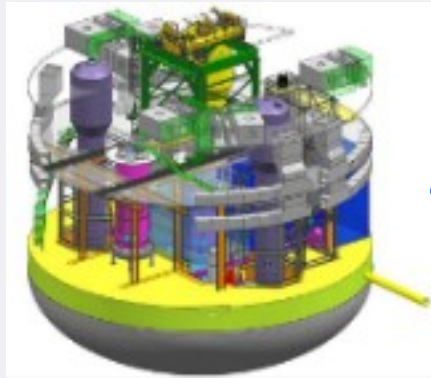
- Designed for installation on an **extensive range of in-land and coastal sites**, including **international context**
- **Aseismic bearing** insulates all modules from site conditions enabling **repeatable** product manufacture and deployment
- Enabled through design features such as **seismic isolation** for safety related areas
- **470MWe** and is capable of load following and operation on house load where required
- **Passive safety systems**, remove reliance on grid power for safety related functions
- **Design can be configured to support other heat-requiring or cogeneration applications**



Rolls-Royce SMR plant: Key Features

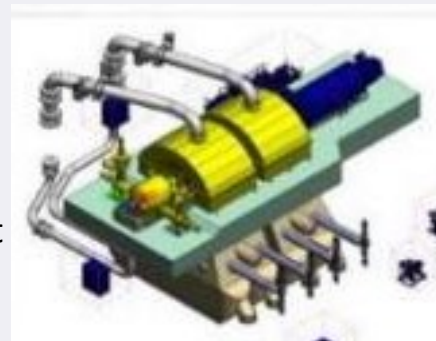
Reactor Systems

- A robust and licensable design incorporating:
 - A 3-loop PWR
 - 3 reactor coolant pumps (one in each loop)
 - 3 vertical **u-tube** steam generators
 - Steam pressurised using a **pressuriser**
- Nuclear fuel is industry standard 17x17 assembly **UO₂** enriched up to **4.95%**,
- **Boron free design** to enable a **low environmental impact and eliminate handling hazards.**



Turbine Island

- Comprises a commercially available turbine and generator set



Cooling Water Island

- Indirect cooling system utilises modular cooling towers to remove heat from the turbine island

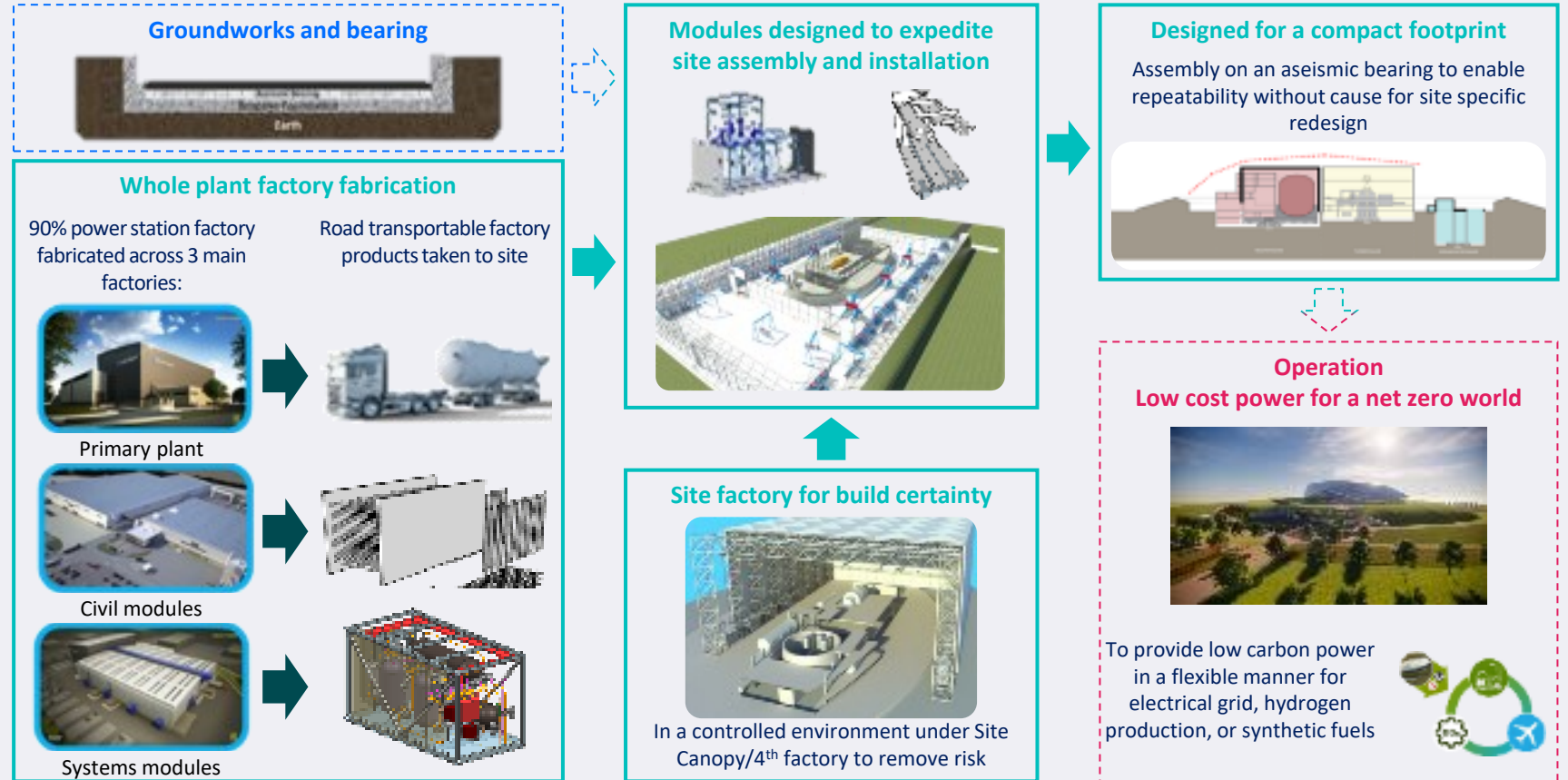




Our product approach represents a completely different way of building new nuclear power plants

Key differentiators from conventional nuclear and SMR competitors:

- ✓ SPV will provide a full turnkey solution to the market
- ✓ 90% of the plant is factory fabricated
- ✓ Many risks traditionally associated with new nuclear have been removed
- ✓ No longer consider a “mega EPC project”





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



EPC (mega project)

vs.

✓ EMA (factory product)



SMR – Risk impact reduction

SMR – Risk probability reduction

Conventional EPC (e.g. Large nuclear)

- Mega project GBP10bn+
- High probability of interface failure
- High impact across multiple parties with cross-dependency
- Long build duration

Plant design

- Lower Capex
- Factory fabricated
- Repeatable product
- Logistics

Site activity

- Much smaller footprint
- Site factory
- Quicker to build
- Options to decouple civil ground works from factory scope

Interfaces

- Simpler contracting structure
- Factory build is normal procurement activity
- Greatly reduced site complexity, #parties

Commercial simplification

- Single contract to SMR SPV
- Fewer parties
- Simplified structure


Capability


- SMR SPV turnkey supply




The heat and power from SMRs supports a range of industrial uses. Shared usage minimises the cost of plant ownership and maximises the economic efficiency of the low carbon energy.

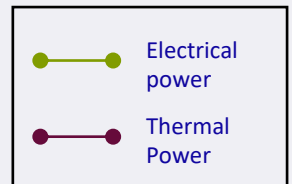
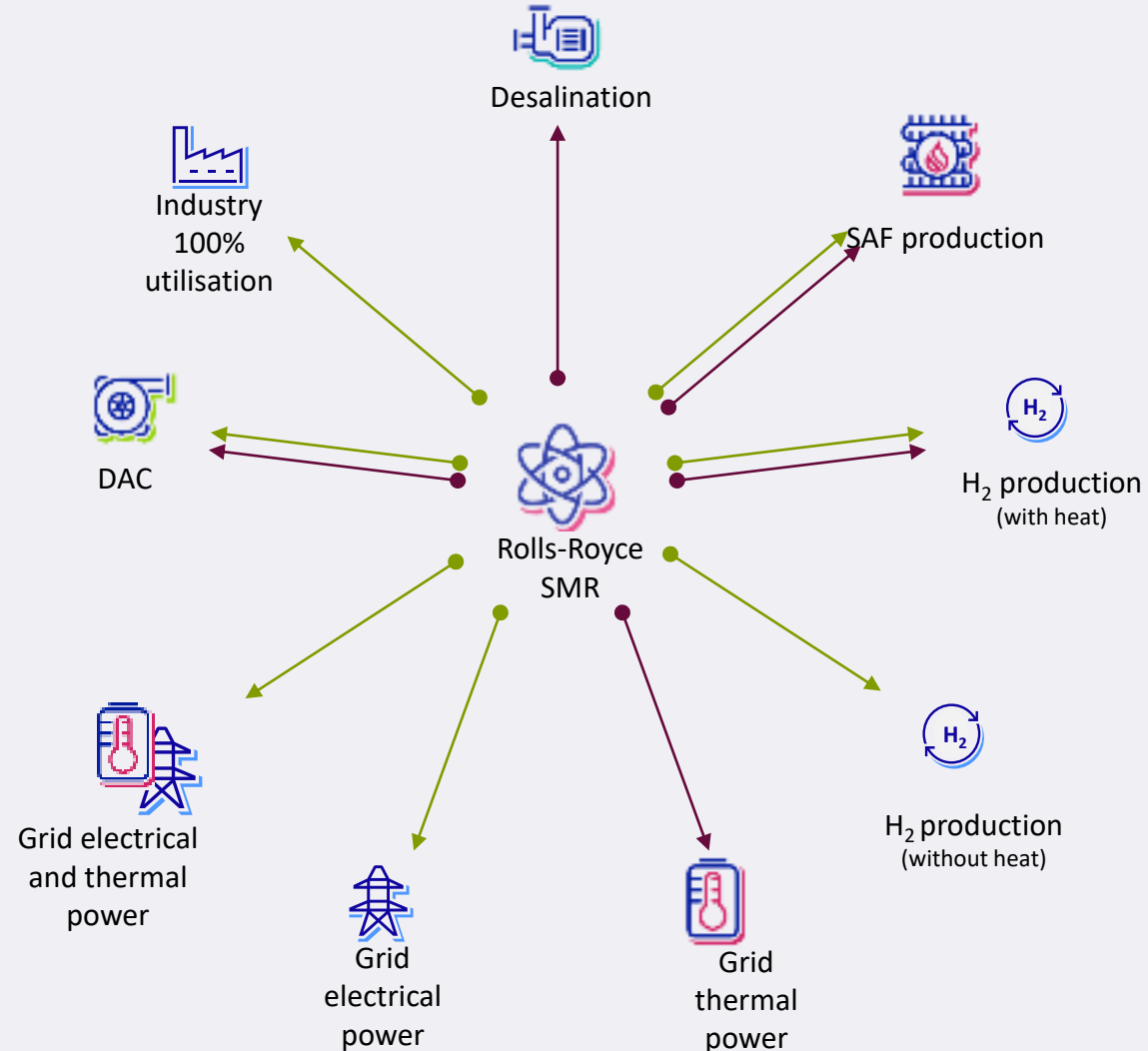
One Rolls-Royce SMR and associated plant can. . . .

 Power a million homes

 Produce 170 tonnes of H₂ per day

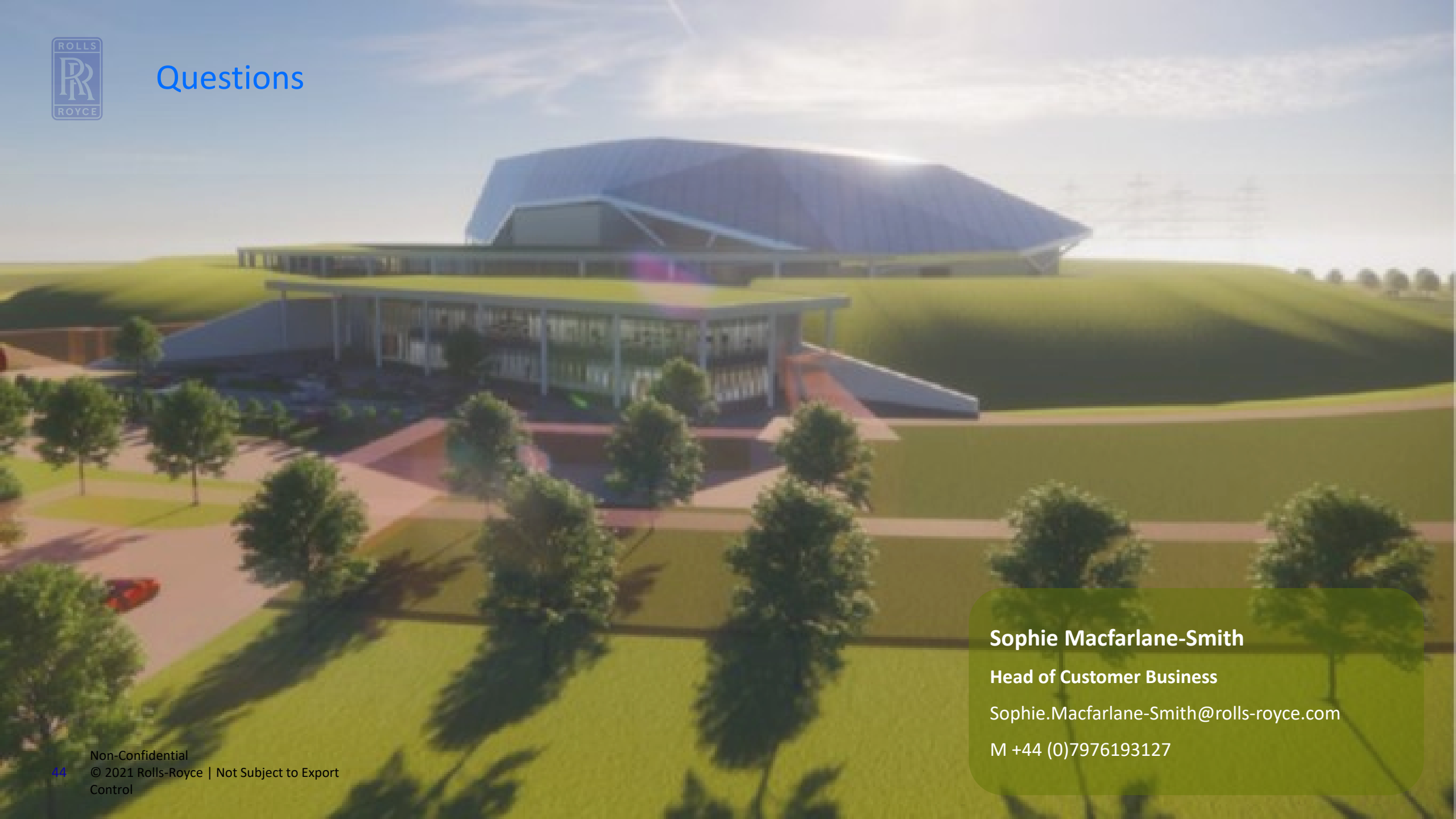
 Produce 280 tonnes of net zero synthetic fuel per day

 Heat or cool a city the size of Sheffield (pop c580,000)





Questions



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ROSATOM

Rosatom vision on energy solutions for net-zero clusters of the future

Egor Simonov

Director, Rosatom Southeast Asia

High-tech energy “ecosystems” for sustainable development

28.10.2021

ROSATOM AT A GLANCE



138.3 Bn USD
10-YEAR PORTFOLIO OF OVERSEAS ORDERS

16.7 Bn USD
REVENUE*

RUSSIAN DESIGNED NPPs AVOIDED
213 M tonnes of CO₂eq

35 UNITS
OVERSEAS NPP PORTFOLIO

R&D INVESTMENT
4.5% of revenue

0 INES
LEVEL-2 INCIDENTS

>250 000
EMPLOYEES

GLOBAL FOOTPRINT -
> 50 countries



* Source: Rosatom IFRS, annual report

NUCLEAR TECHNOLOGIES CONTRIBUTE TO UN SUSTAINABLE DEVELOPMENT GOALS



Contribution to the UN Sustainable development goals is a key principle for Rosatom activities.
In 2020 Rosatom became a member of the UN Global Compact network



Nuclear power plants – **clean** and **affordable energy**, combat **climate change**, **industry** and **economic growth**



Nuclear Medicine & Isotope products – **good health and well-being**



Desalination and water treatment – **clean water & sanitation**



Multipurpose irradiation centers – **zero hunger** and **good health and well being**



Centers for Nuclear Science & Technologies – **innovation, infrastructure and industry development, good health and well-being** and **education**



Source: *Climate change and nuclear power 2018 IAEA*

NET-ZERO CLUSTERS





- ✔ Clean energy sources as a tool in achieving net-zero production
- ✔ Decrease of CO2 emissions
- ✔ Eco-friendly industries
- ✔ Lower costs
- ✔ High production efficiency and economic viability

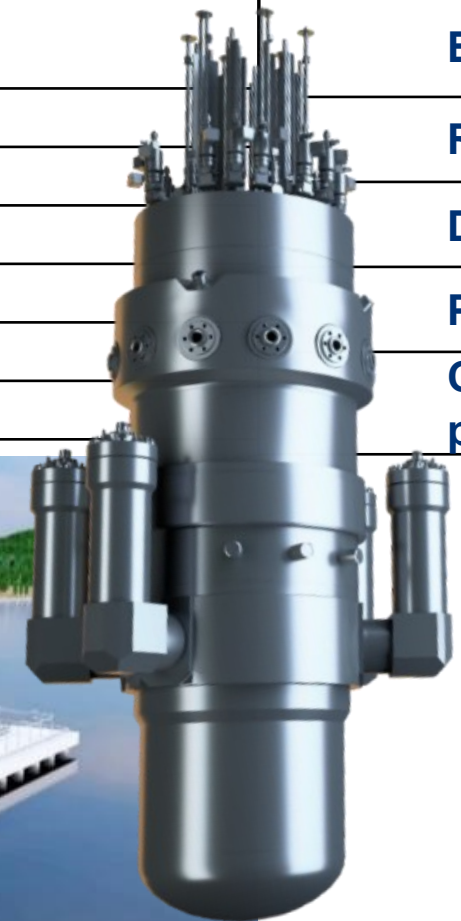
NET-ZERO CLUSTERS



- ✓ New clean standards
- ✓ Integration of different industries around a single clean energy source
- ✓ SMRs, wind power plants as potential energy sources, depending on size and geography of clusters

MODERN SMR SOLUTIONS

 Floating NPP		Land-based solution 	
Electrical capacity	100 MW	Electric capacity	>110 MW
Refueling cycle	up to 10 years	Refueling cycle	up to 6 years
Design life	60 years	Design life	60 years
Displacement	16 680 tons	Plant area	0,06 km ²
Length	112 m	Construction period	3-4 years
Beam	30 m		
Draught	5 m		



WORLD'S ONLY FLOATING NUCLEAR POWER PLANT



2 x KLT-40S

Electrical capacity	70 MW
Thermal capacity	300 MW
Fuel cycle	3 years
Design life	40 years



APRIL 2019

Comprehensive dockside tests of the floating power unit “Akademik Lomonosov” were completed

JUNE 2019

Operation license was issued

DECEMBER 2019

FNPP was connected to the grid

MAY 2020

FNPP was put into commercial operation

WIND ENERGY SOLUTIONS



- ✔ Zero pollution to the environment
- ✔ Minimal power transmission loss
- ✔ Fast installation, low maintenance and operating costs
- ✔ Five Rosatom wind farms operating in Southern Russia, with an installed capacity totaling 660 MW
- ✔ The portfolio of wind power plants to be built by ROSATOM by 2027 in Russia totals 1.7 GW

ENERGY STORAGE SYSTEMS

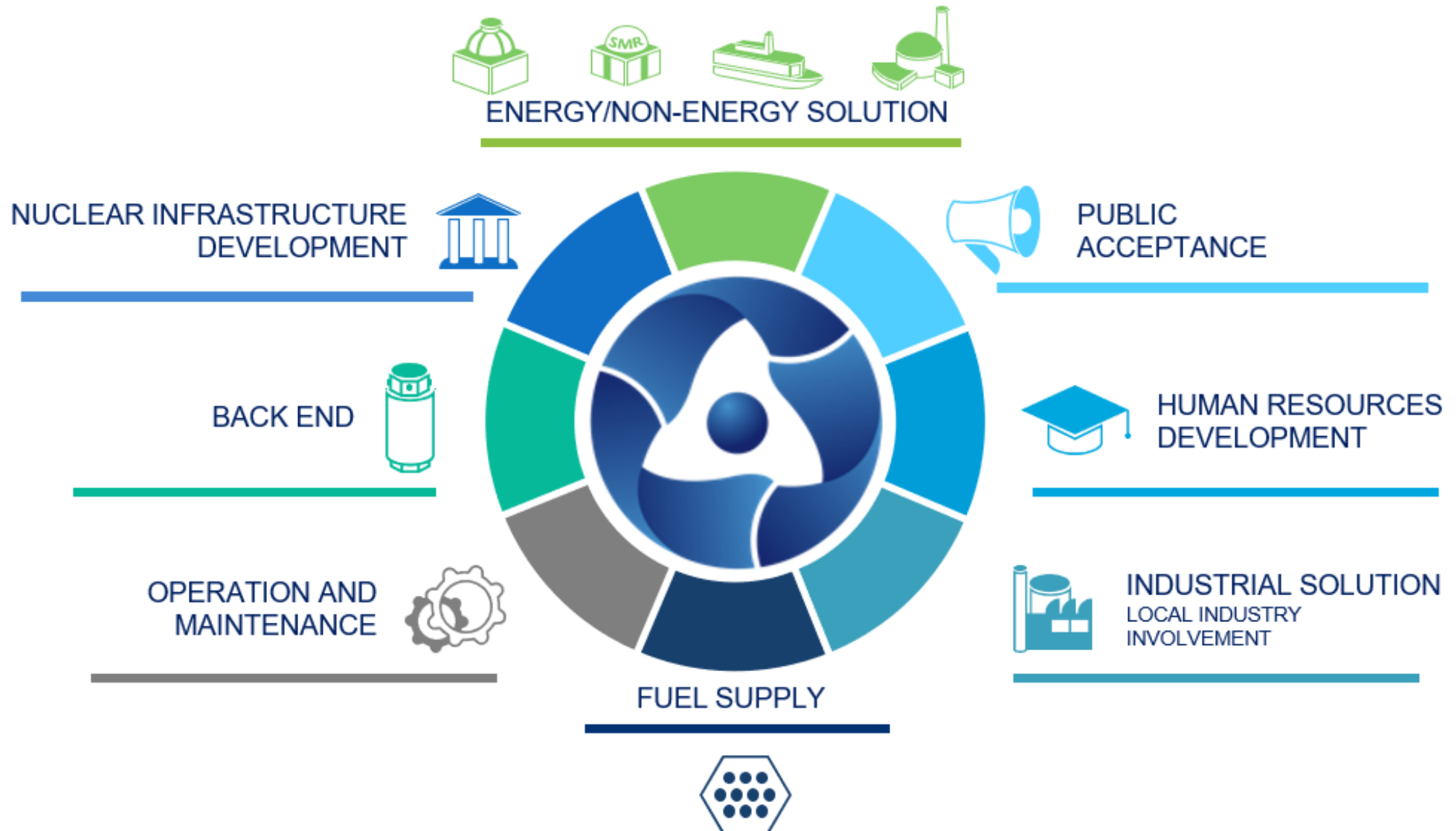


- ✔ Lithium-ion batteries are energy storage systems for renewable energy, power systems and electric transport
- ✔ Energy storage systems on lithium-ion batteries significantly reduce equipment costs and increase its efficiency
- ✔ Not explosive
- ✔ Environmentally friendly

HYDROGEN SOLUTIONS



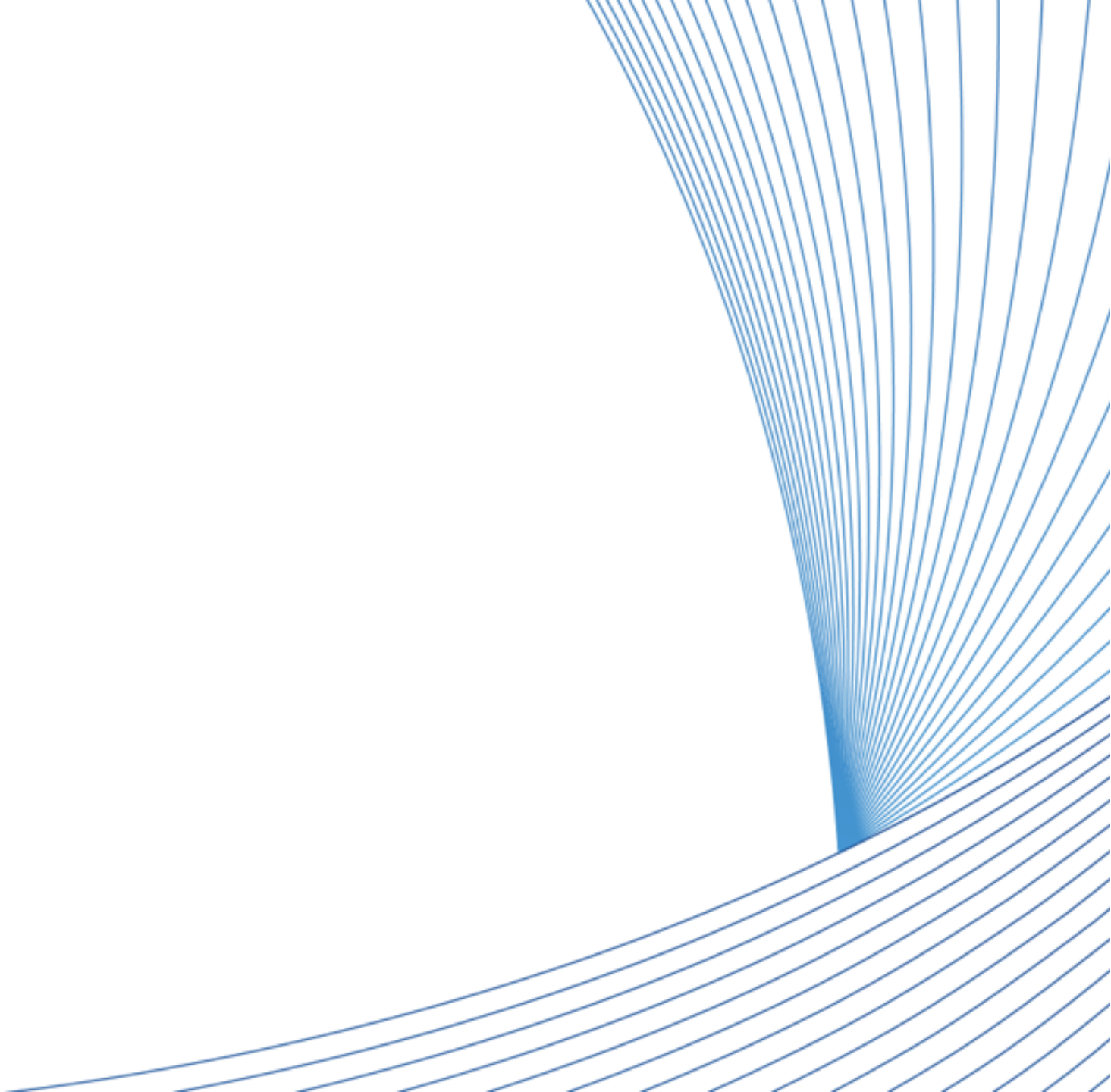
INTEGRATED OFFER





ROSATOM

Thank you!





WEBINAR

High-tech energy “ecosystems” for sustainable development

Chair:

Tim Yeo

Chairman

New Nuclear Watch Institute

Speakers:

Michel Bérthelemy

Nuclear Energy Analyst

OECD Nuclear Energy Agency

Shannon Bragg-Sitton

Integrated Energy Systems Lead,
Nuclear Sciences and Technology

Idaho National Laboratory

Sophie Macfarlane-Smith

Head of Customer Business

Rolls-Royce SMR

Egor Simonov

Regional Vice President, Director of

Rosatom Southeast Asia