THE ROLE OF NUCLEAR ENERGY IN A NET-ZERO FUTURE

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16th IEEJ Global Energy Webinar
November 26, 2021

Outline

1. Context – Pathways to net zero emissions
2. The Role of Nuclear Energy
3. Challenges and Recommendations
4. Understanding the cost of electricity

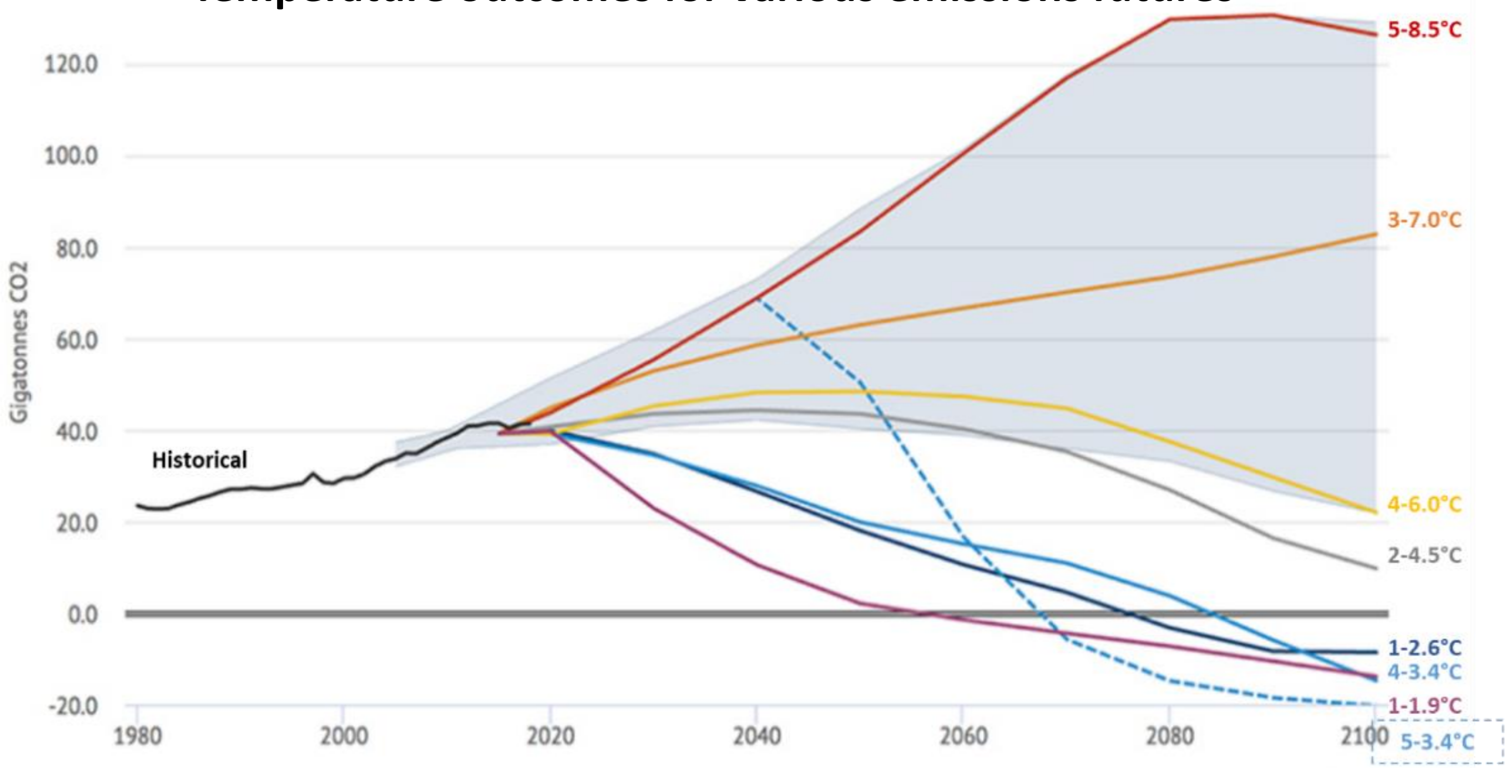
Charting a path towards an achievable and affordable electricity mix for a net-zero future…

1. Context – Pathways to net-zero emissions

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

Temperature outcomes for various emissions futures



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%

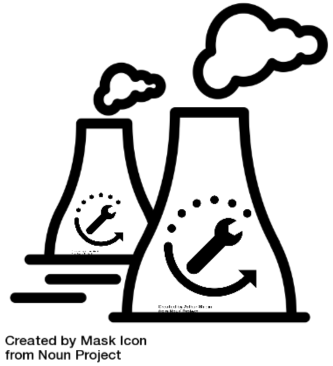
Nuclear in Emissions Reduction Pathways

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%

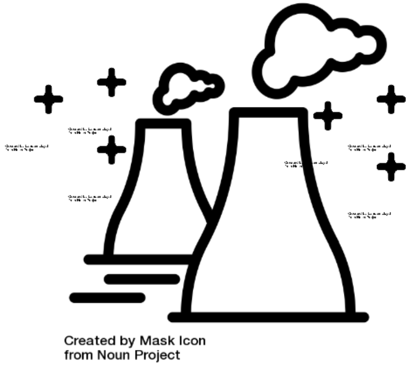
All pathways require global installed nuclear capacity to grow significantly, often more than doubling by 2050.

2. The Role of Nuclear Energy

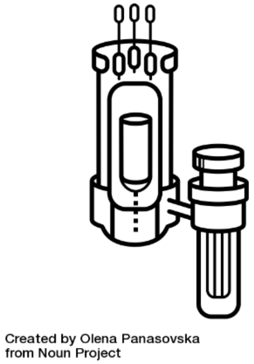
The Full Potential of Nuclear Energy to Contribute to Emissions Reductions



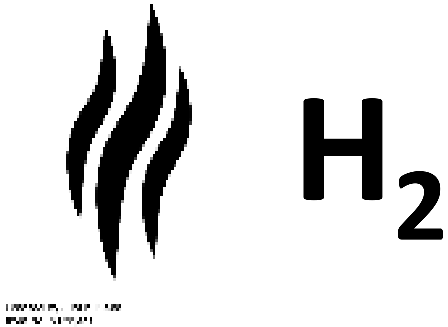
Long Term Operation



Gen-III Reactors



Small Modular Reactors

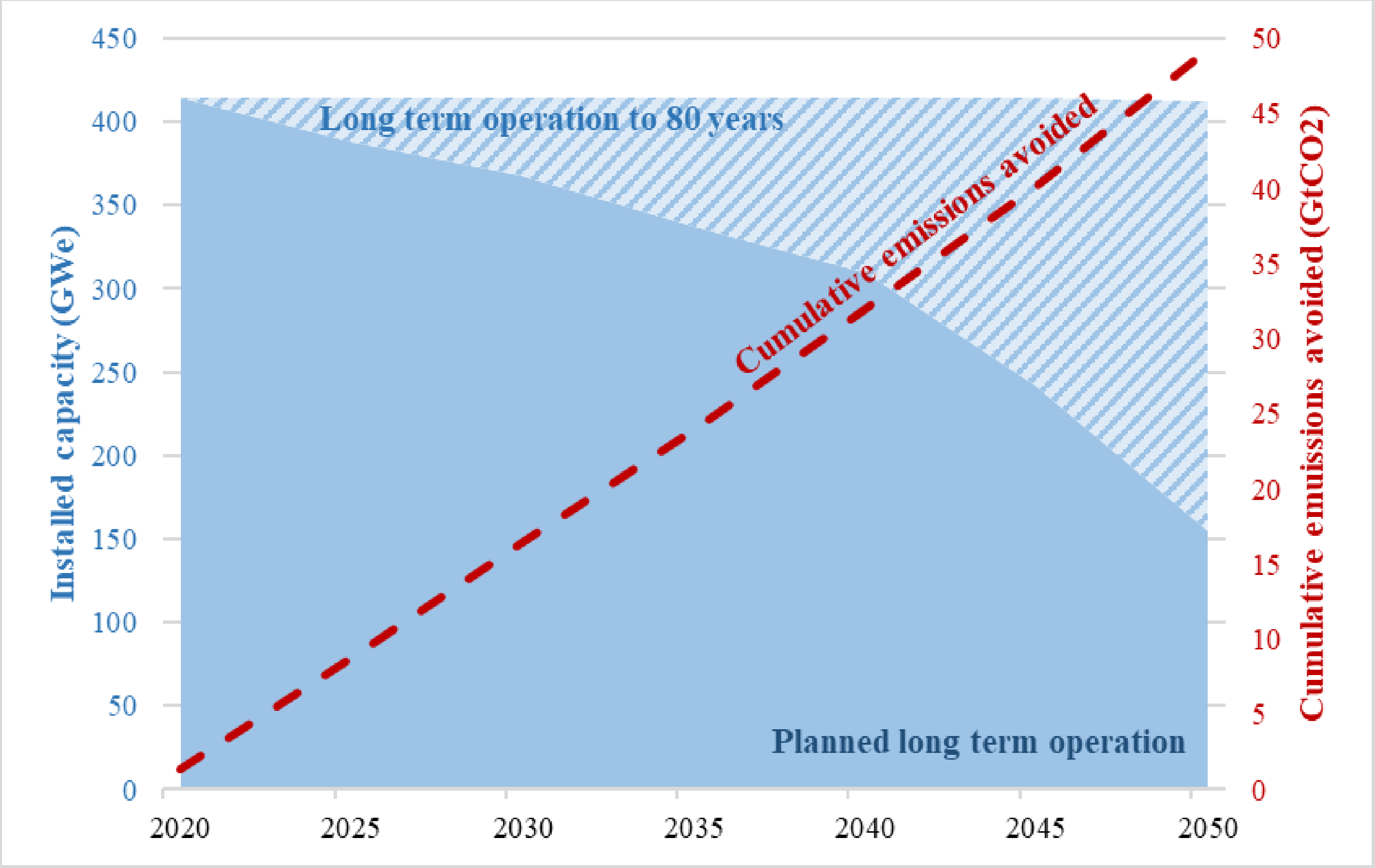


Non-Electrical applications

Long-term Operation

- Presently, the average age of nuclear power plants in OECD countries is 36 years
- The technical potential exists in most cases for long-term operation for several more decades
- Long-term operation is one of the most cost-competitive sources of low-carbon electricity
- Beyond technical feasibility, adequate policy and market are key conditions of success of long-term operation
- Long-term operation could save up to 49 gigatonnes of cumulative emissions between 2020 and 2050

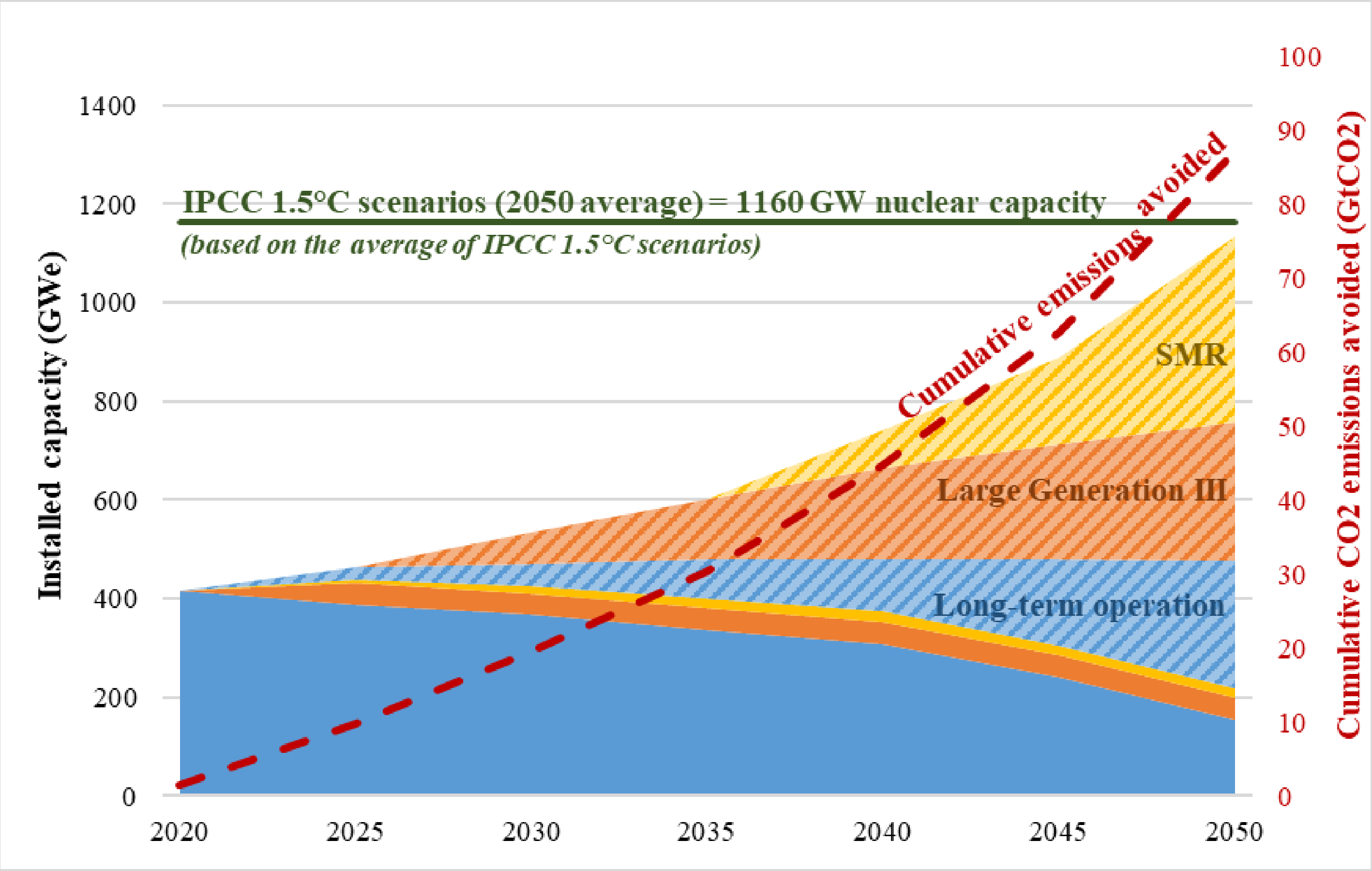
Installed Capacity And Cumulative Emissions Avoided



Source: NEA (forthcoming).

Full Potential of Nuclear Contributions to Net Zero

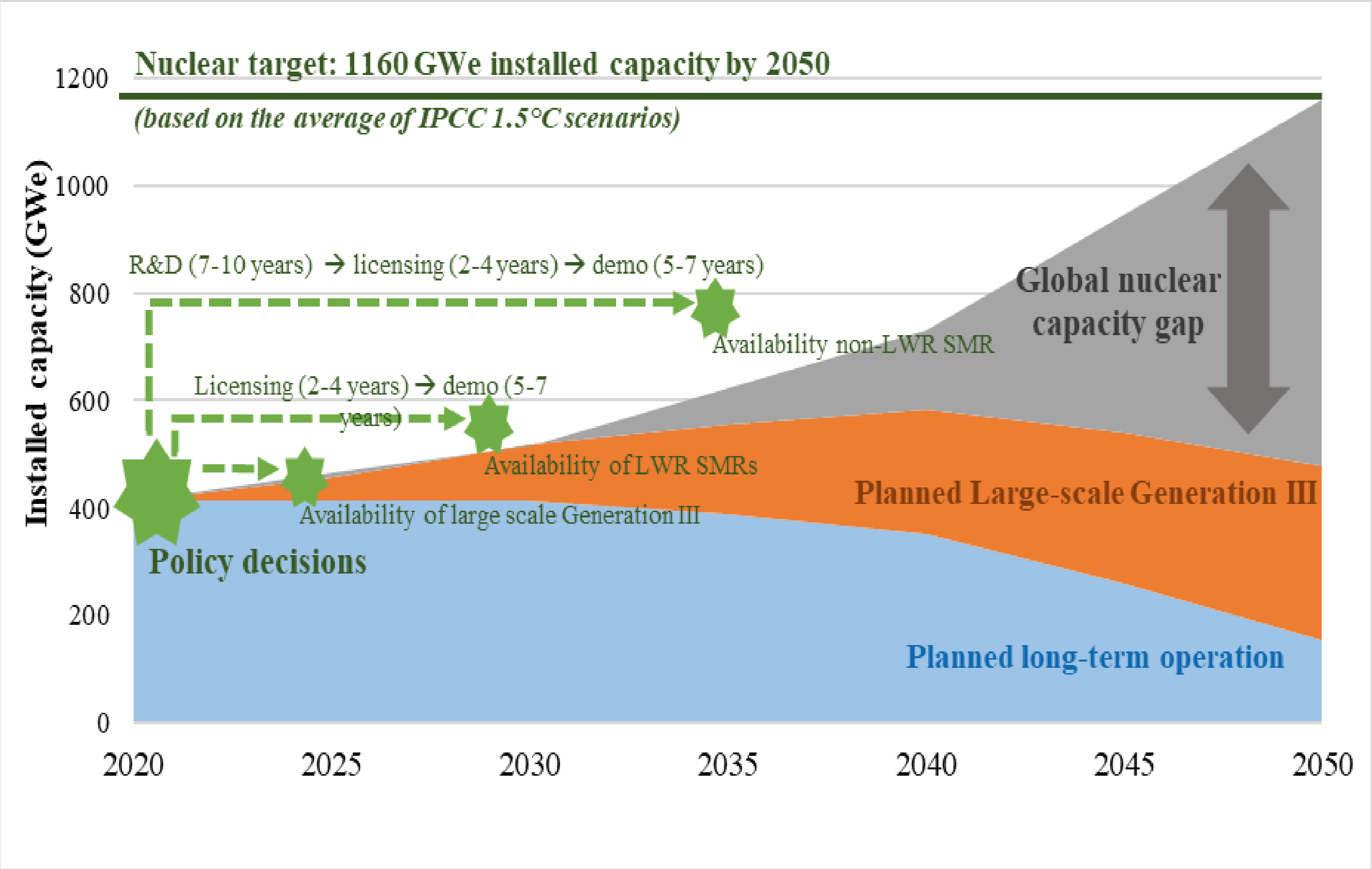
- The contributions from long-term operation, new builds of large-scale Generation III nuclear technologies, small modular reactors, nuclear hybrid energy and hydrogen systems project the full potential of nuclear energy to contribute to net-zero
- Reaching the target of 1160 gigawatts of nuclear by 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).

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).

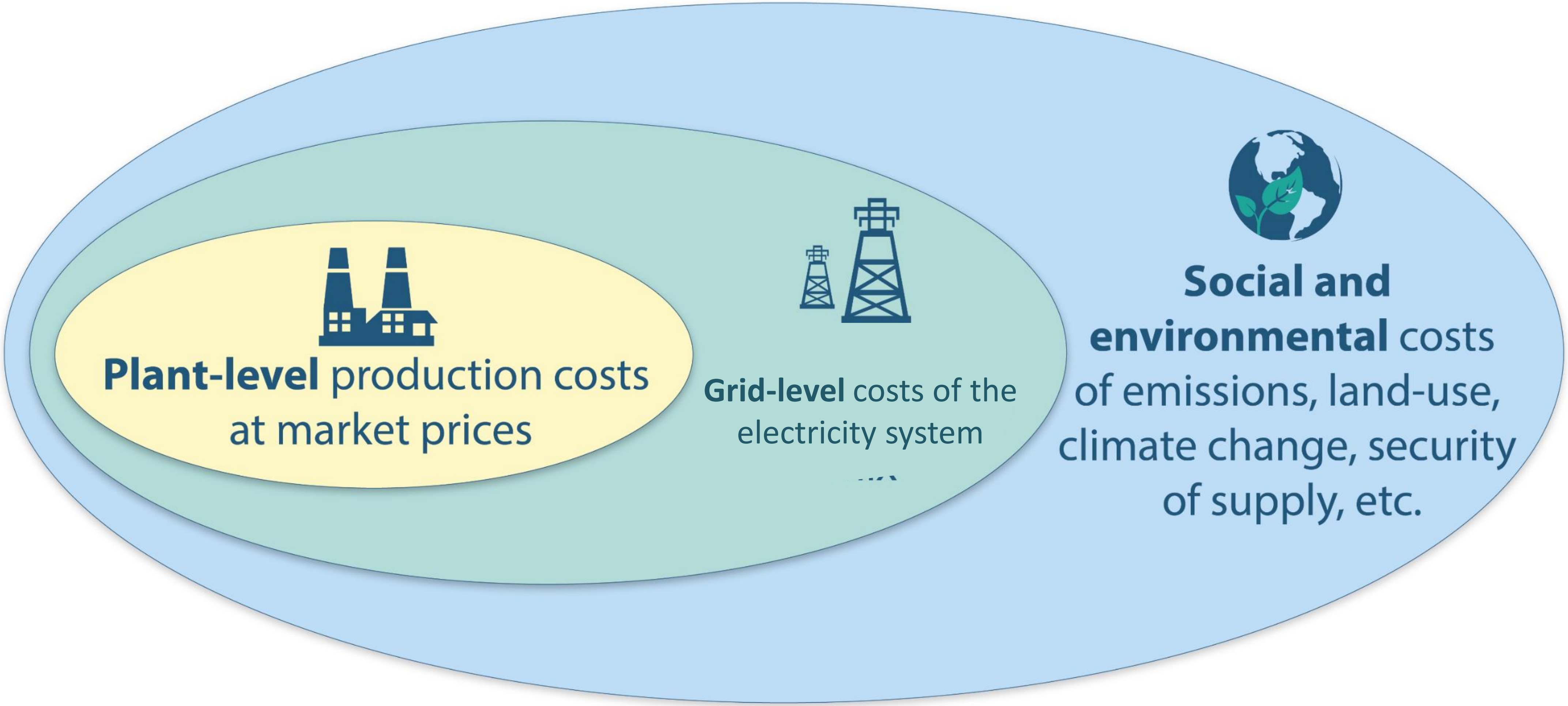
3. Challenges and Recommendations

Nuclear Energy Faces Many Challenges

- **The nuclear sector must move quickly to demonstrate 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

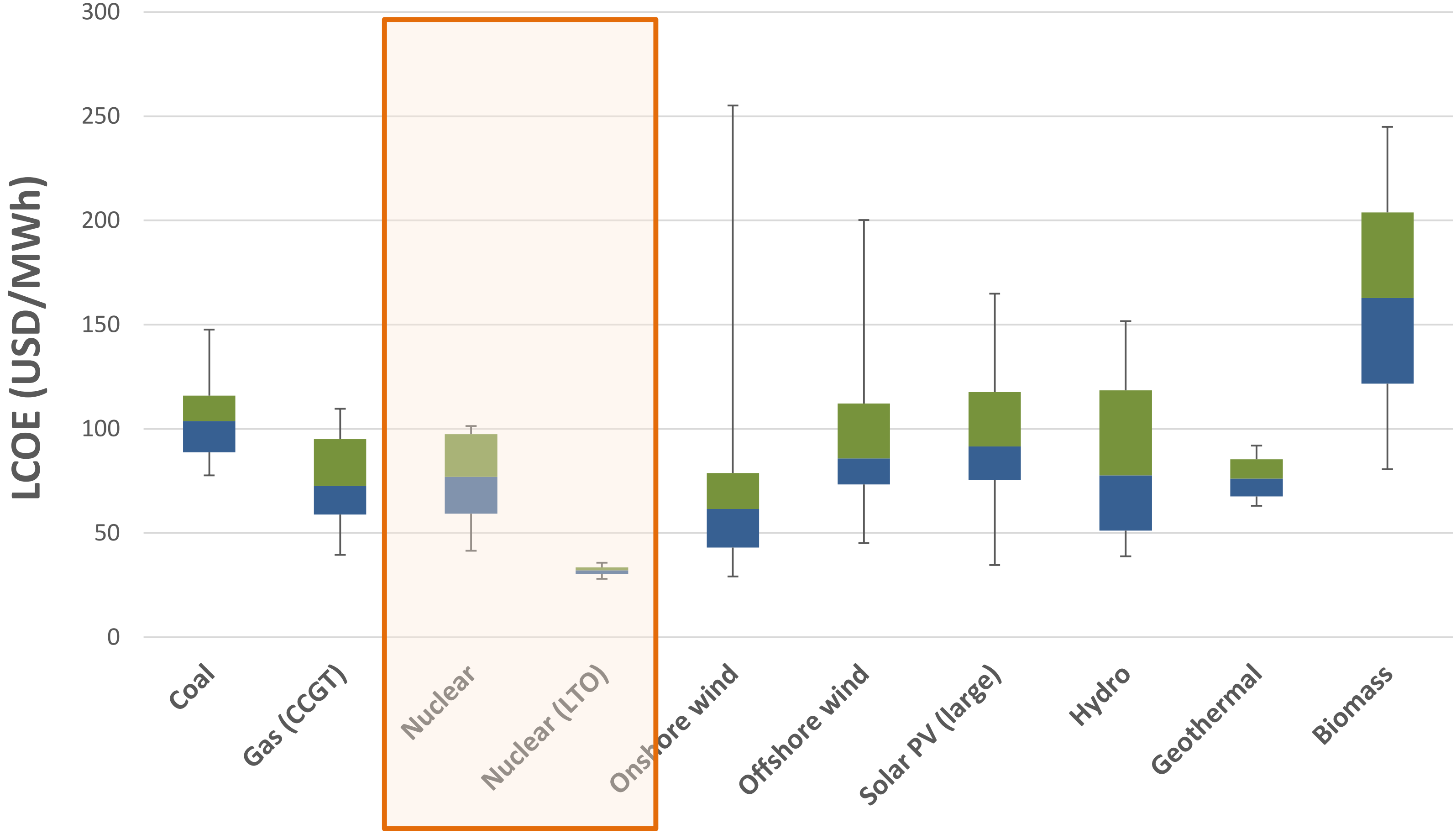
4. Understanding the Costs of Electricity

Understanding the System Costs of Electricity



Comparing Electricity Generation Options

Plant-level costs of electricity generation options

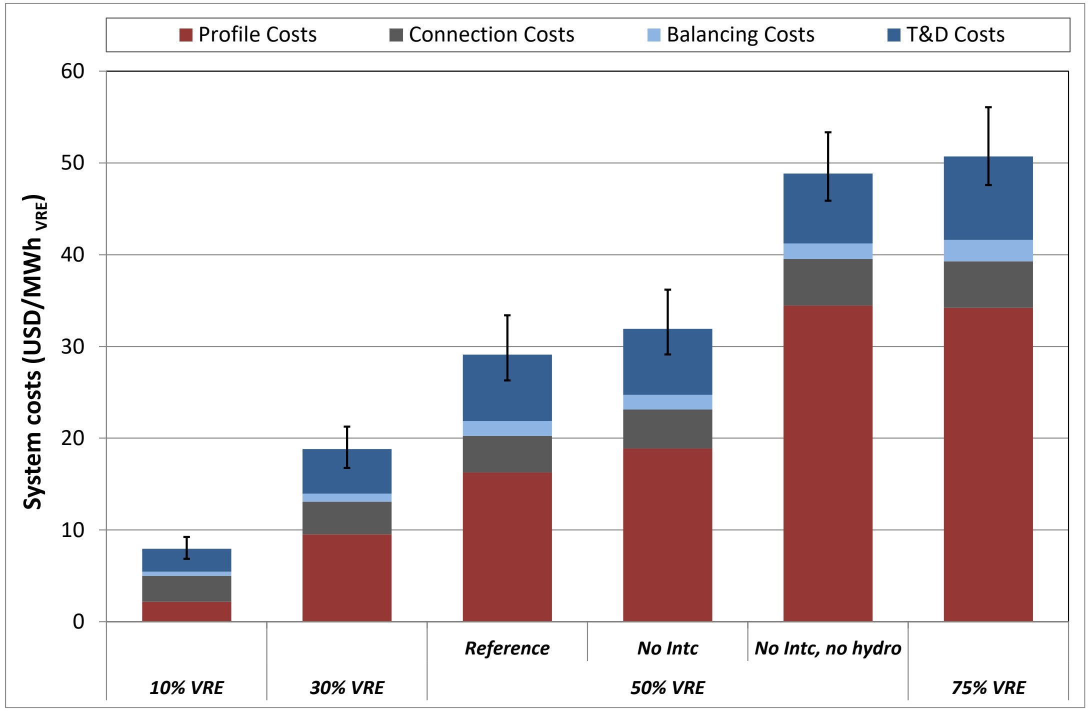


Long term operation of nuclear power is <u>*the lowest cost option*</u> for non-emitting electricity generation.

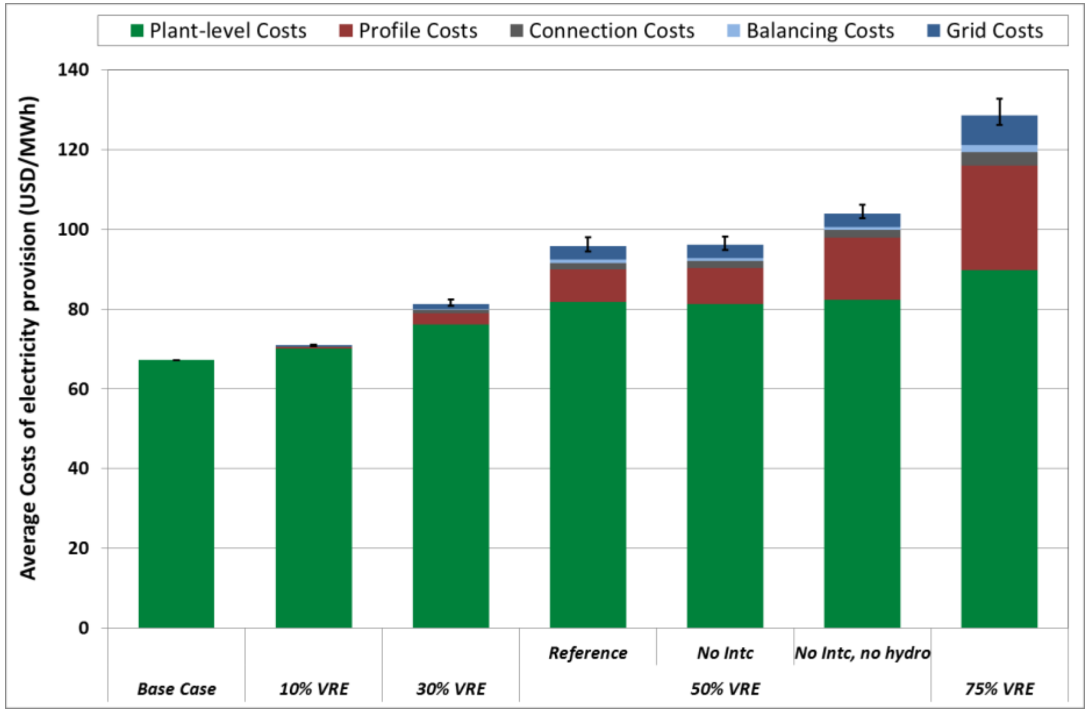
Source: IEA/NEA (2020) with cost of capital of 7% and CO2 price @ 30 USD/tCO2

Comparing Electricity Mix Options

Grid-level costs of electricity mix options



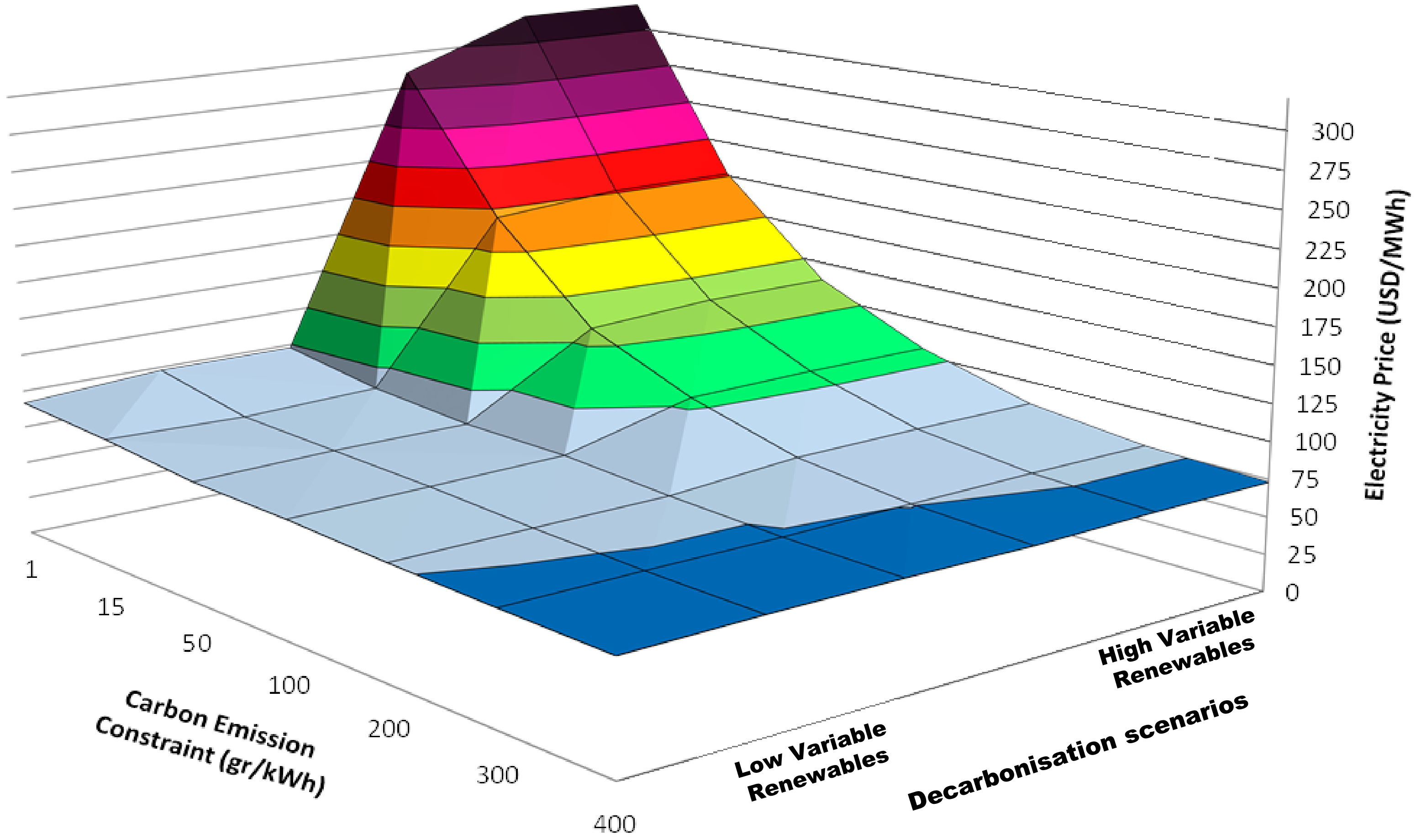
System costs of electricity mix options



As the share of variable renewables grows, electricity system costs increases significantly

Charting a Path to Net-Zero Electricity

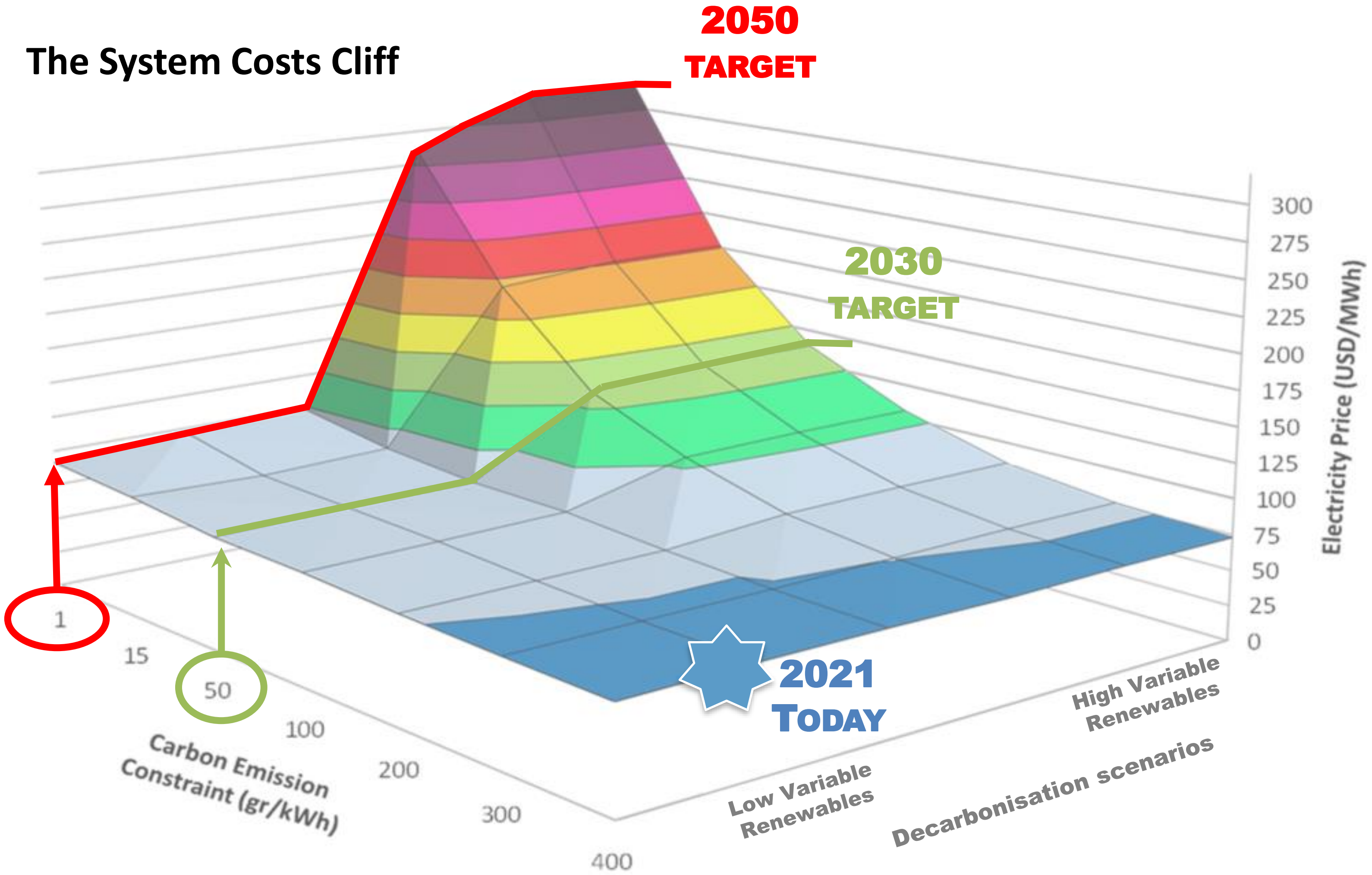
The System Costs Cliff



The system costs of electricity depend on the composition of the electricity mix (ie. Low vs. high shares of variable renewables) and carbon emission constraints.

Source: N. Sepulveda, MIT

Charting a Path to Net-Zero Electricity

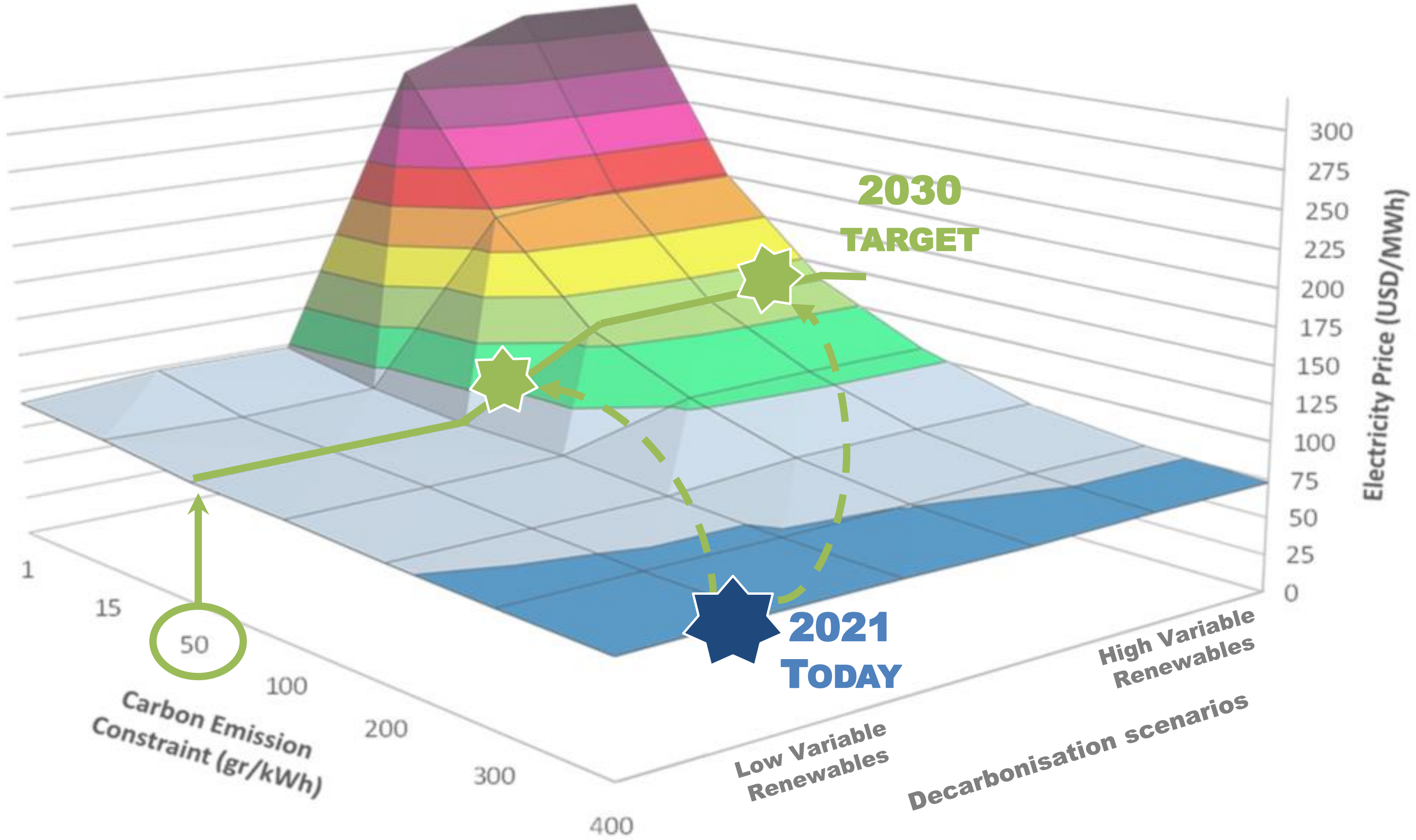


- The blue star indicates where we are today
- The green line corresponds to 2030 targets
- The red line corresponds to net-zero 2050 targets

Source: N. Sepulveda, MIT

Charting a Path to Net-Zero Electricity

The System Costs Cliff

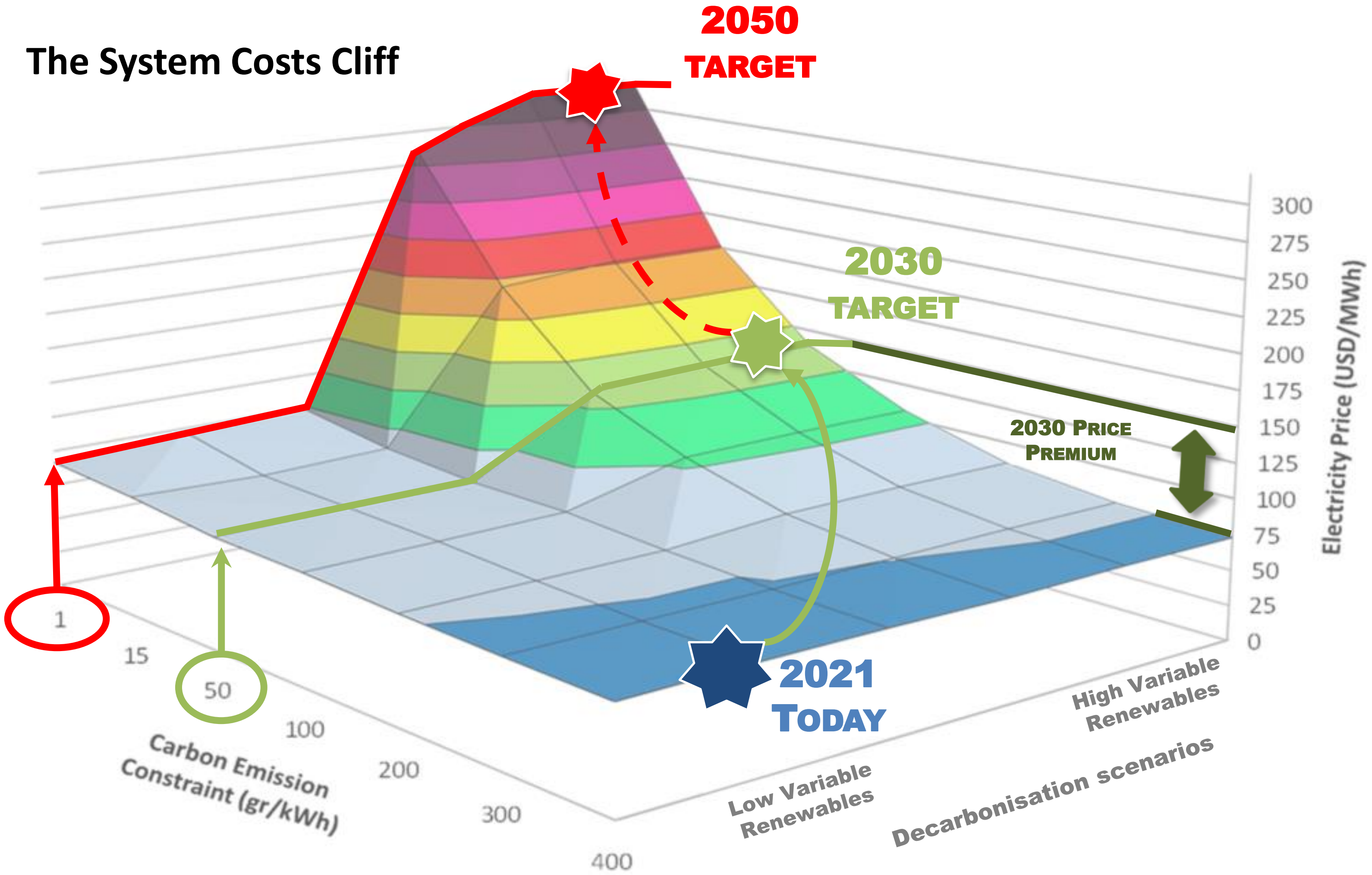


- Many different pathways are possible to reach 2030 targets
- System costs increase on pathways to 2030 targets with higher shares of variable renewables

Source: N. Sepulveda, MIT

Charting a Path to Net-Zero Electricity

The System Costs Cliff

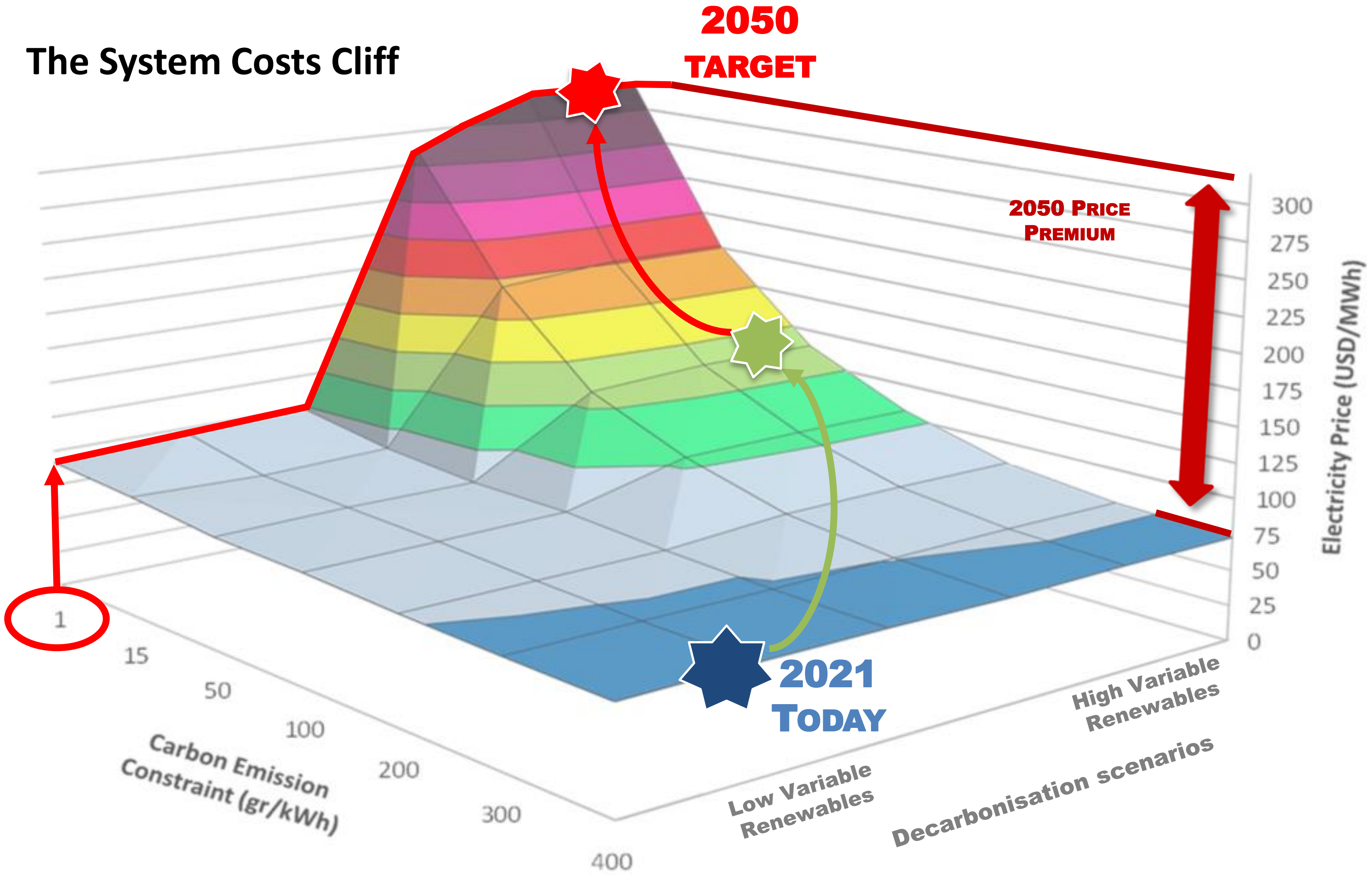


- We may be able to reduce emissions to meet 2030 targets by growing the share of variable renewables to very high levels in the mix

Source: N. Sepulveda, MIT

Charting a Path to Net-Zero Electricity

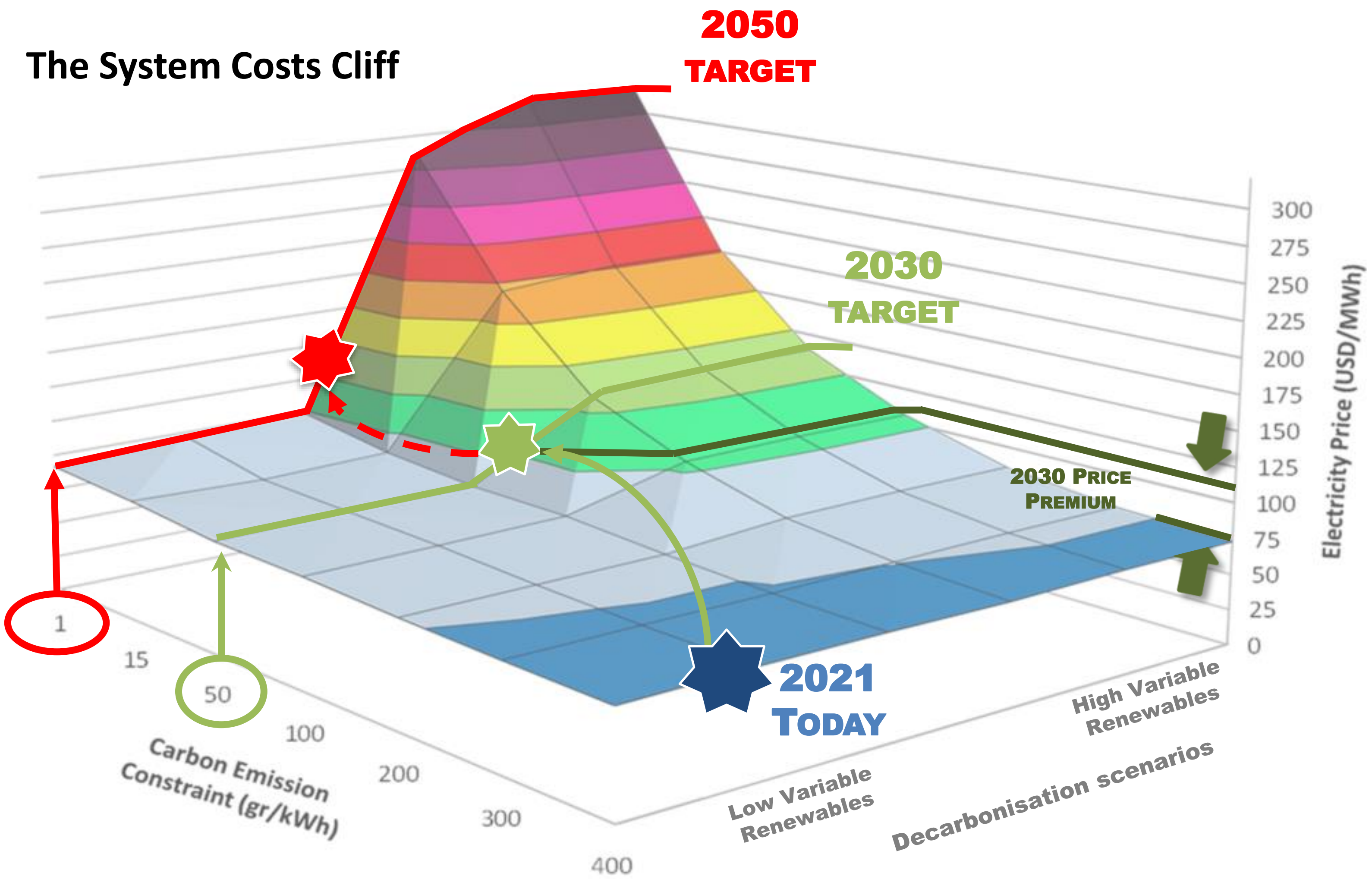
The System Costs Cliff



- But the costs of reaching 2050 targets of net-zero with very high shares of variable renewables are likely prohibitive

Source: N. Sepulveda, MIT

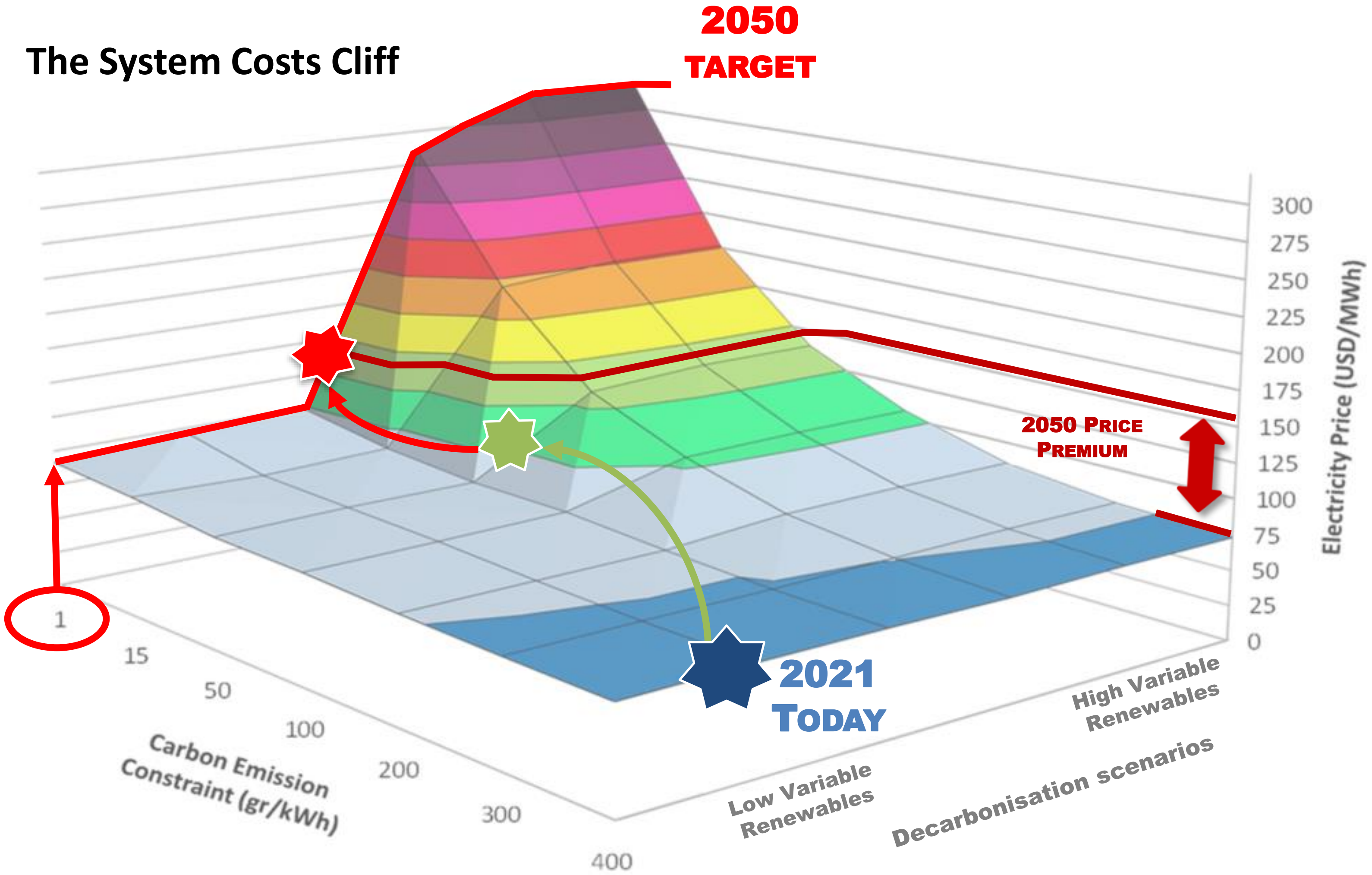
Charting a Path to Net-Zero Electricity



- By thinking one step ahead and planning TODAY for NET ZERO

Source: N. Sepulveda, MIT

Charting a Path to Net-Zero Electricity

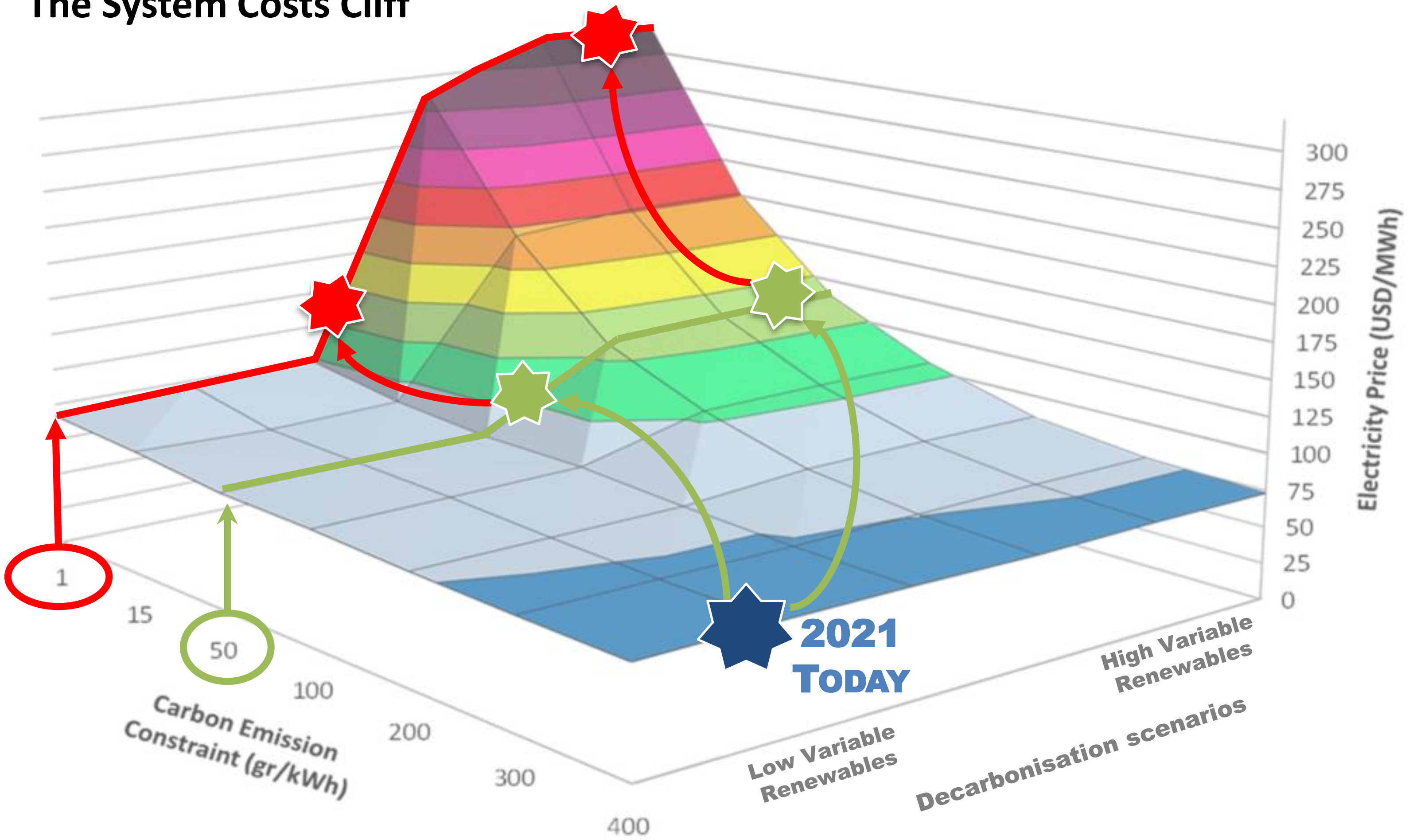


- We can chart an affordable path to net-zero electricity generation, with a balanced mix of variable renewables and nuclear energy

Source: N. Sepulveda, MIT

Charting a Path to Net-Zero Electricity

The System Costs Cliff



Source: N. Sepulveda, MIT

Which path do you chose?

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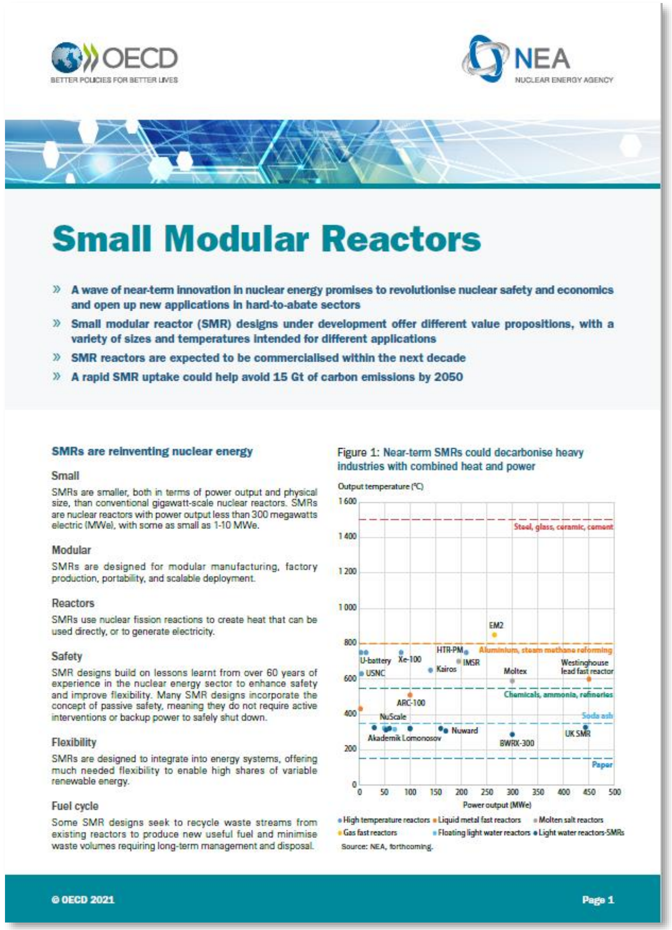
New NEA brochures on nuclear innovation, climate change and economics



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

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

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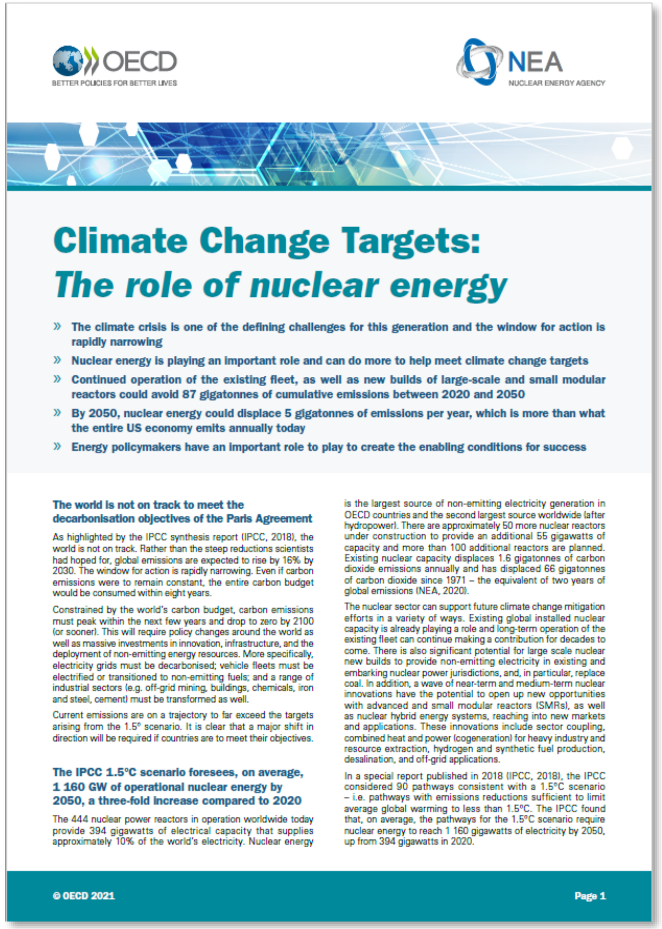

Climate Change Targets: *The role of nuclear energy*

- 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

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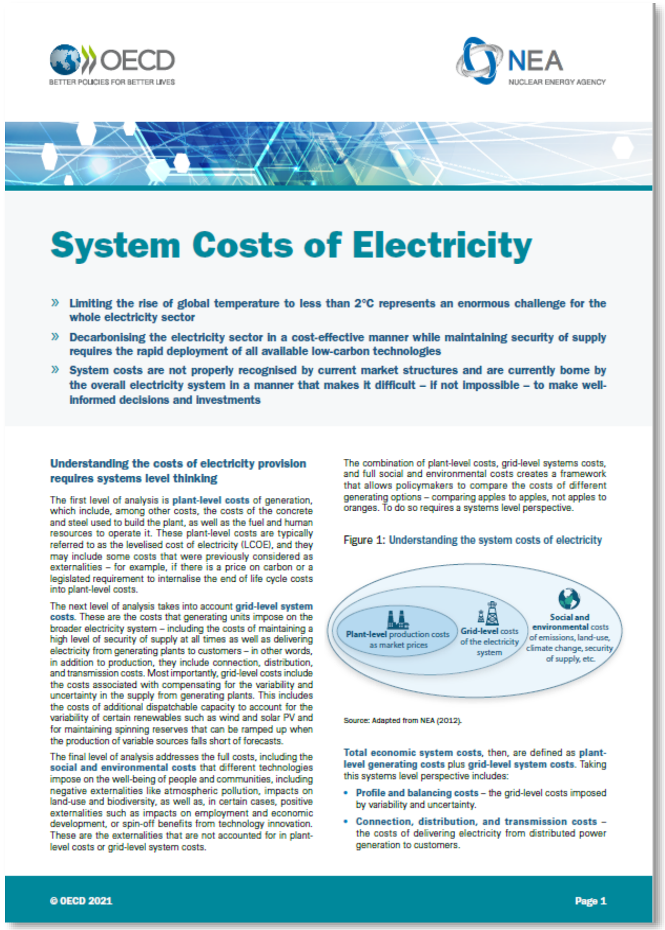

System Costs of Electricity

- 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

Figure 1: Understanding the system costs of electricity

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