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Nuclear Power and Other Energy Sources in the Energy Mix

Introductory remarks

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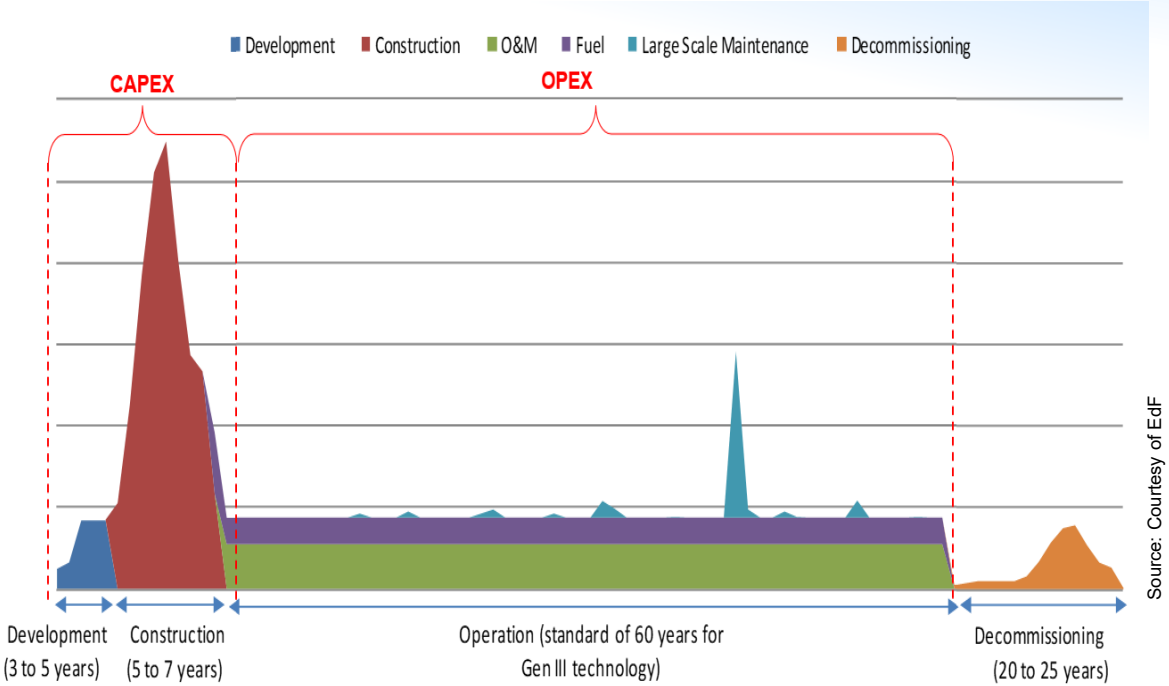
Planning and Economic Studies Section, IAEA

The Role of Nuclear Power in the Energy Transition – Warsaw, 12 June 2024

Timeline of a NPP project

Lifetime of a Nuclear Power Plant



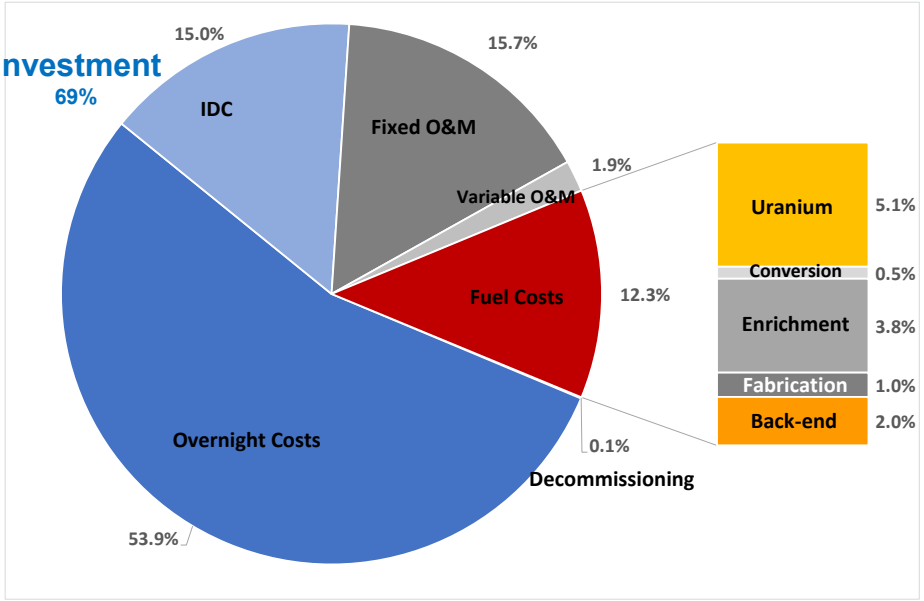
Source: Courtesy of EdF

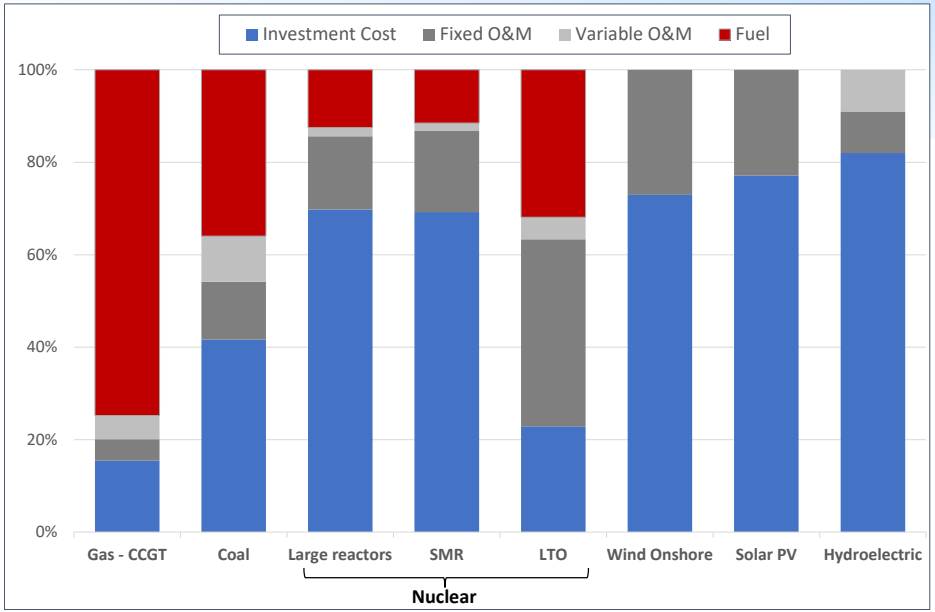
- Very long-life cycle (+100 years), which requires a strong involvement of the government over the whole period.
- Startup phase is significant in length and effort, some 10-15 years before construction begins.
- Long construction periods (5-7 years) with interlinked sequences of work and testing.
- Very large upfront capital costs: most of total (discounted) electricity generation costs are in the construction phase, before generating a single kWh.
- **These characteristics have a major impact on financing and investing.**

Very High **High** | **Low** | **Moderate** | **Risk profile of a nuclear project**

Generation Cost Structure

Generation Cost Structure of different technologies (7% discount rate)

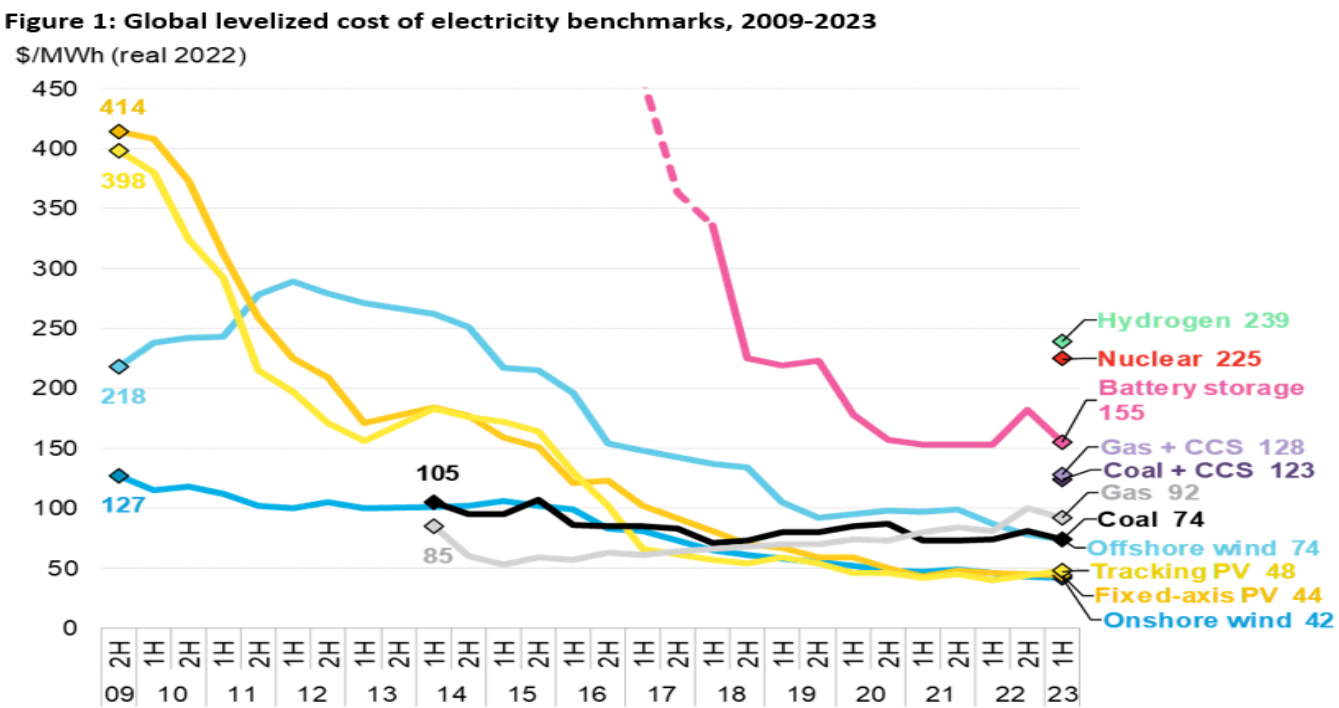




Source: IAEA

- All low carbon technologies have a very similar cost structure (high CAPEX, low OPEX), and therefore have similar “economic” characteristics.
- Economics of capital-intensive technologies strongly depends on total investment costs (*overnight cost, lead time, cost of capital – project risk*).

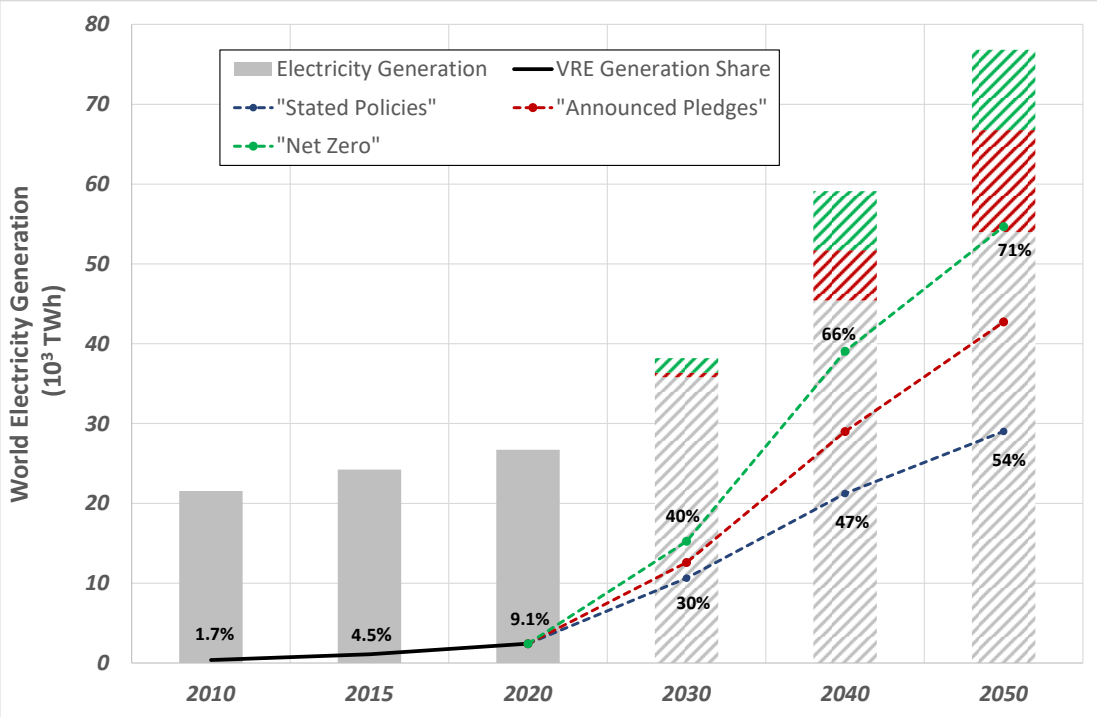
Cost trends of low-Carbon technologies



- Wind and solar PV pure generation costs (LCOE) have declined substantially and are now in many regions the cheapest electricity generation technology. This trend is expected to continue

VRE share is growing under all scenarios

World Electricity Demand and Generation from Wind & Solar PV



Source: IEA World Energy Outlook (2023)

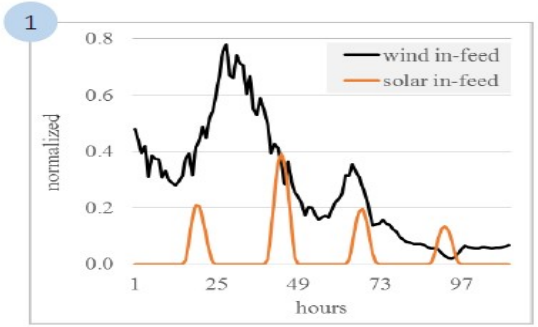
Integrating large shares of VRE in the power system is a major technological challenge and has far reaching technical and economic consequences, as well as impacts on SoS

Impacts of VRE integration

Integration of large shares of **fluctuating** electricity at **low marginal cost** from VRE has profound technical and economic impacts on the whole electricity system.

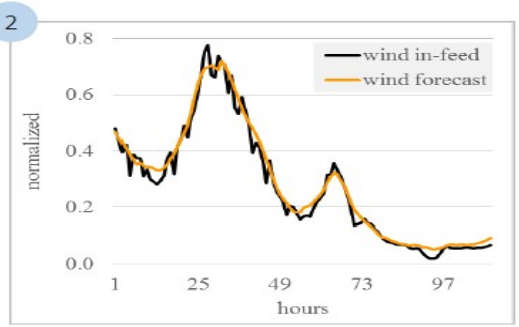
These effects are due to **characteristics** which are **intrinsic** to **VRE resources**.

Variability



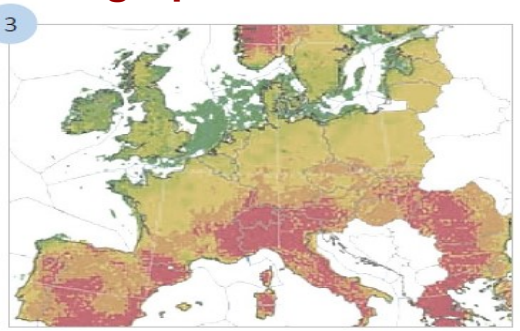
Profile costs

Unpredictability



Balancing costs

Geographical distribution



T&D costs

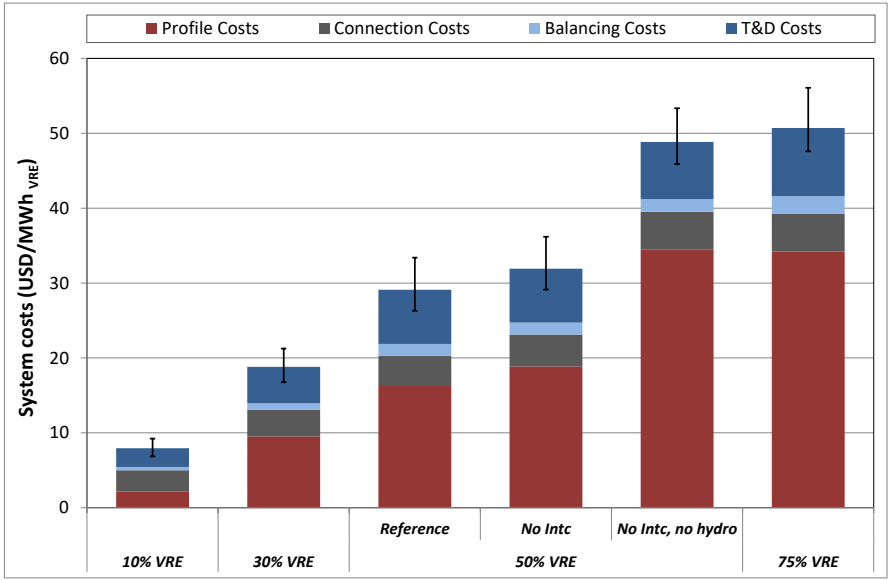
Thanks to L. Hirth

- Increasing need for flexibility in the electricity system
- Large effects on the electricity markets (lower prices, higher volatility)
- Significant impacts on the mode of operation of thermal power plants

Technical

VRE Integration and System Costs

Total system costs of VRE



"System cost" aims at capturing costs (and services) that a technology provides to the system

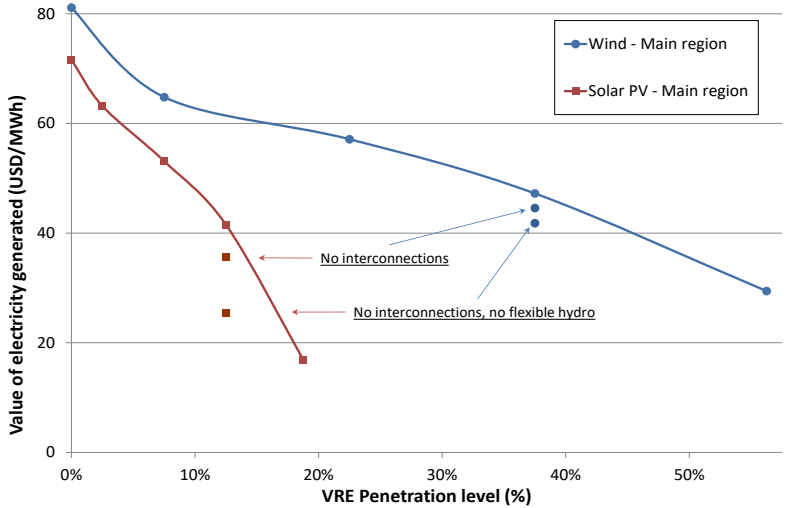
System costs depend strongly on:

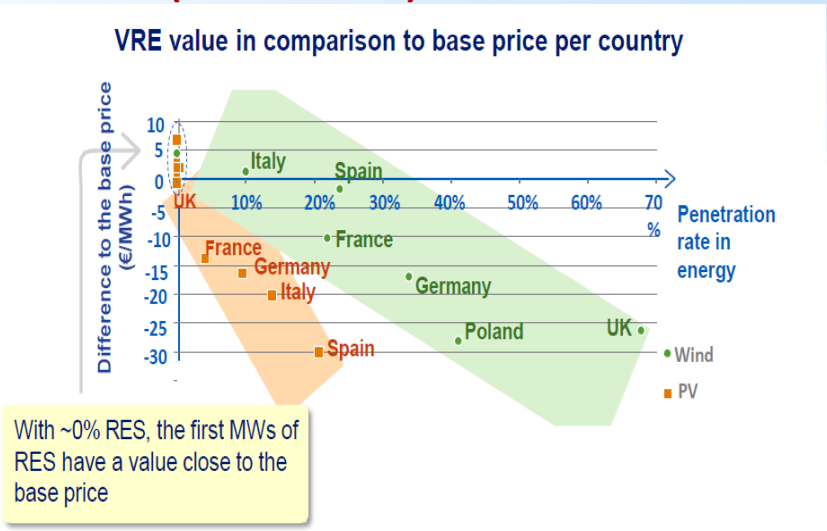
- the technology considered and on its generation share,
- Country characteristics and existing mix
- Availability (and cost) of flexibility resources (hydro, storage, interconnections, DSM).

- **System costs of VRE are large and increase substantially with their share:** profile costs are the dominant component, especially at high VRE share.
- Need to consider each generation technology as part of a whole energy system and to look at metrics "beyond LCOE" which capture the value of electricity and provision of system services.

Auto-correlation and declining market values of VRE

Market value of solar PV and wind (NEA and EdF)



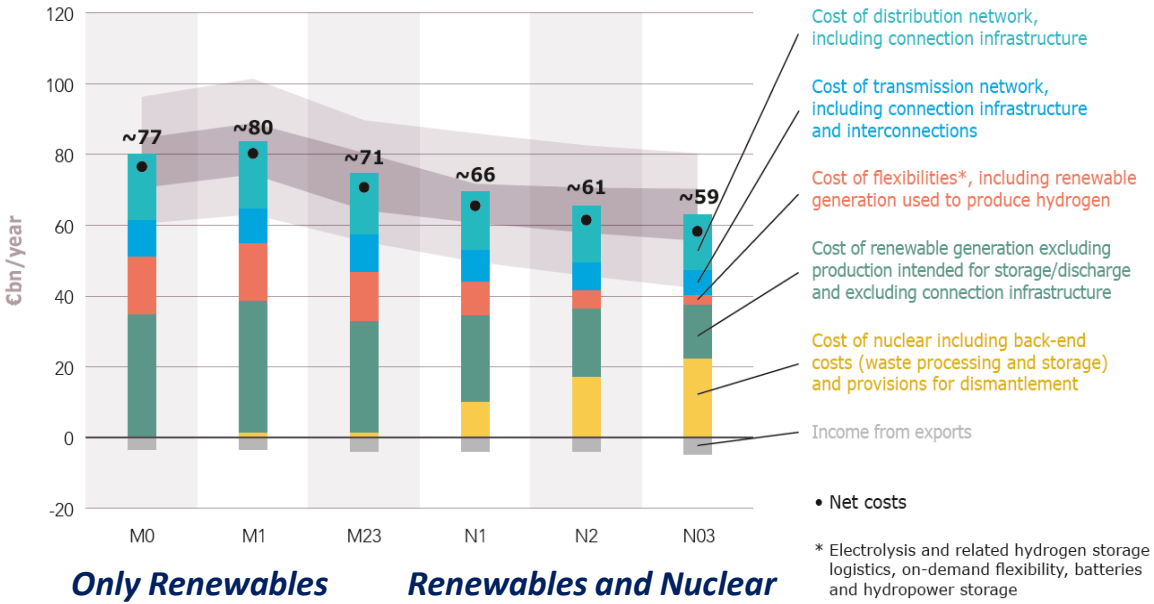


- The *auto-correlation* of VRE production reduces its effective contribution to the system and thus its **market value** at increasing penetration level.
- Absence of interconnections and storage further reduce the value of VRE
- ***"The difference in the service provided to the system is translated by a market value loss when compared to other technologies"***
- In competitive markets, profile costs are internalised through the declining market value (capture price)

The RTE study “Energy Pathways to 2050” (2)

At the request of the French Government, RTE launched a wide-ranging study on the evolution of the French power system to achieve net zero emissions by 2050.

Annualised total costs of different scenarios in 2060



Reducing consumption is key.

Carbon neutrality cannot be achieved without significant VRE development.

Building new nuclear reactors makes economic sense, particularly if it allows a 40 GW fleet to be in place in 2050.

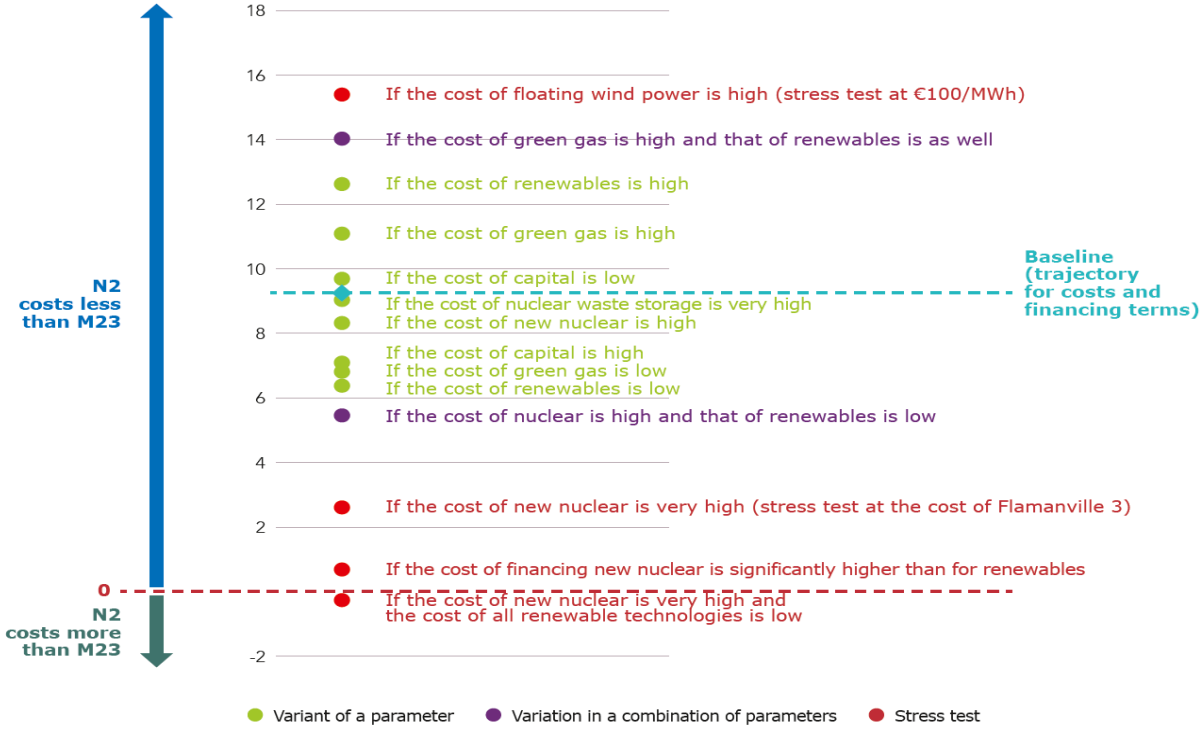
The system will require very different types of **flexibilities** to ensure security of supply. Needs will be massive – and very costly – for a 100% renewable system.

Under all scenarios, the size of the power grid will need to be adapted rapidly.

Scenarios with nuclear power are cheaper than those based on VRE alone, and these results are robust towards different changes in economic assumptions

The RTE study “Energy Pathways to 2050”

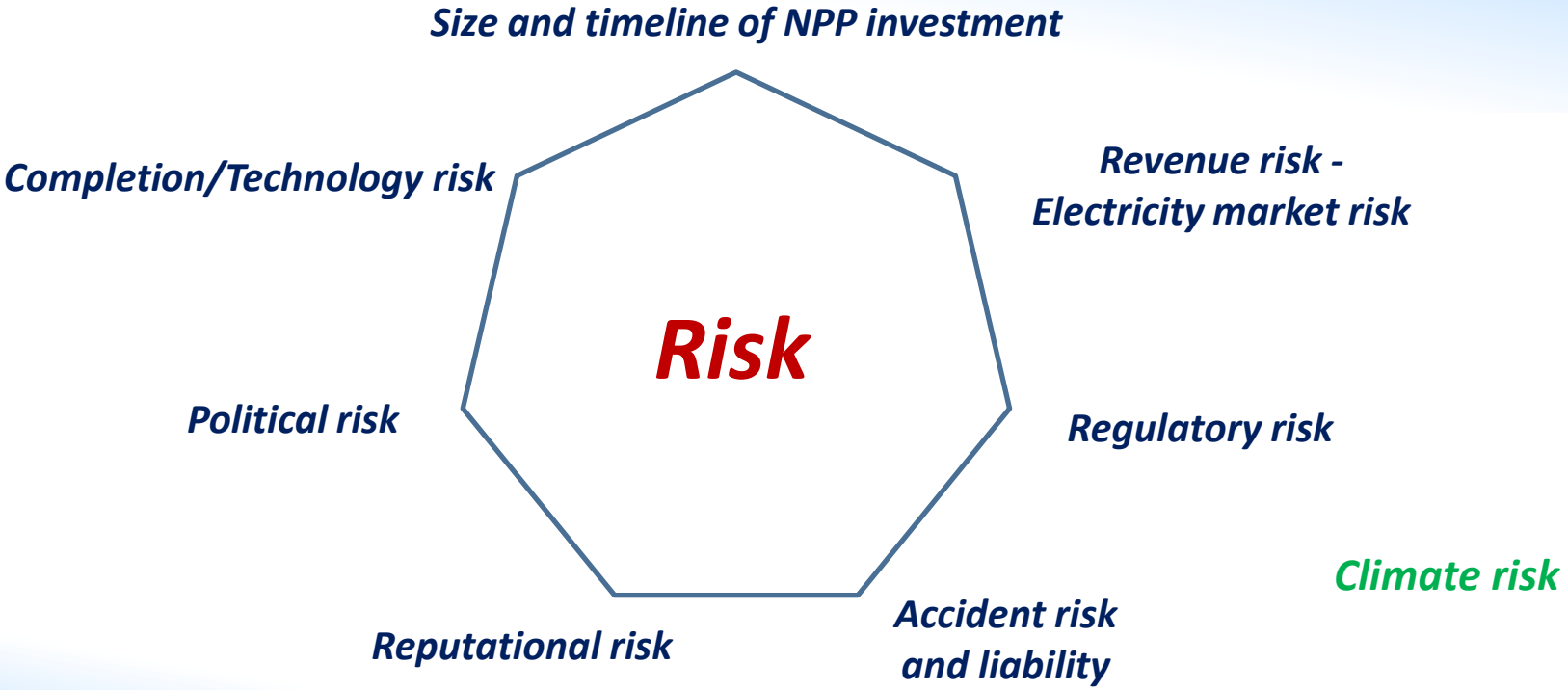
Difference in annualised cost of nuclear vs VRE scenarios for different economic parameters



The optimal way for decarbonisation requires integration of ALL low-C sources including hydro, VRE and dispatchable (nuclear and/or CCS)

Specificities of financing NPPs

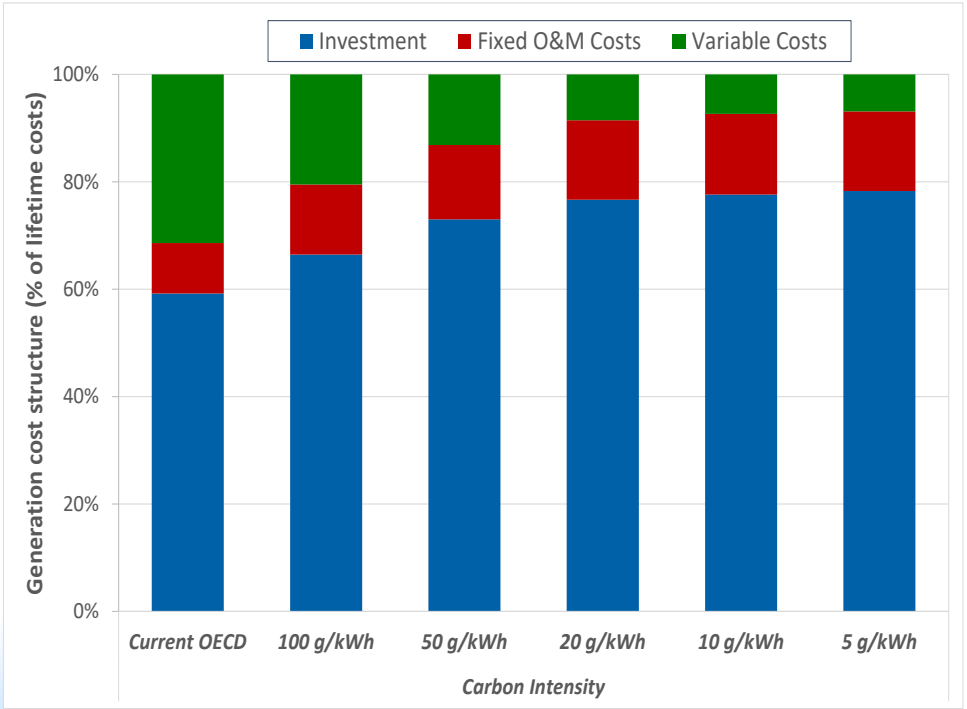
NPP financing has historically been on of the biggest challenges for NPP development



- These risks are common to all energy sources (but not to the same extent for all).
- Risks have a major impact on the cost of financing (and thus on the economics of a NPP project).

Towards a more capital-intensive generation mix

Electricity Generation Cost Structure



- A low-carbon generation mix is inherently more capital intensive than current mix, and this increases with carbon constraint
- High shares of VRE increase the volatility of electricity price : large number of hours with zero or negative prices combined with more hours with very high prices
- Price volatility increases **revenue uncertainty**, the financial risk faced by investors and thus the cost of energy transition.

Competitive markets (based on variable costs) are not a natural fit for a system dominated by capital or fixed costs