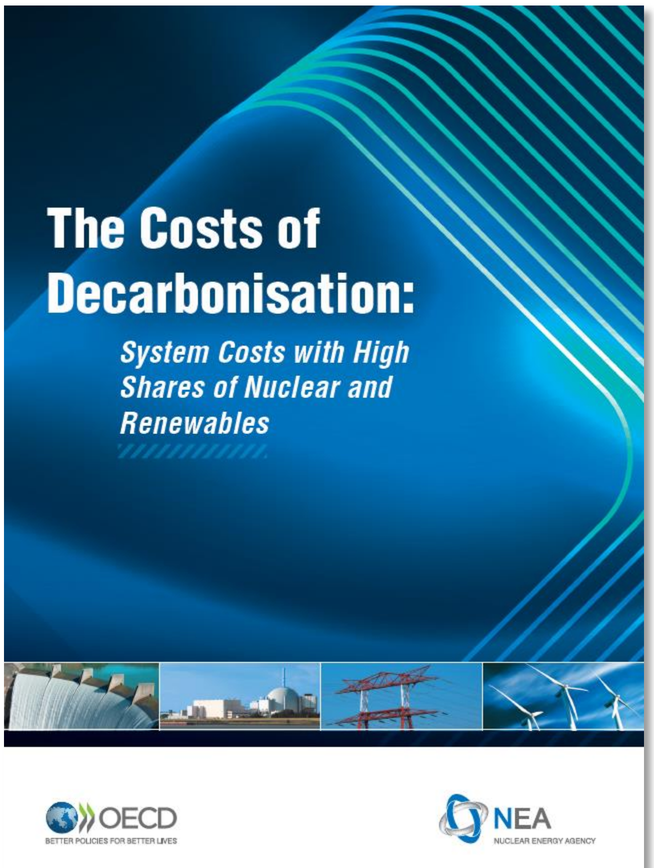


THE COSTS OF DECARBONISATION

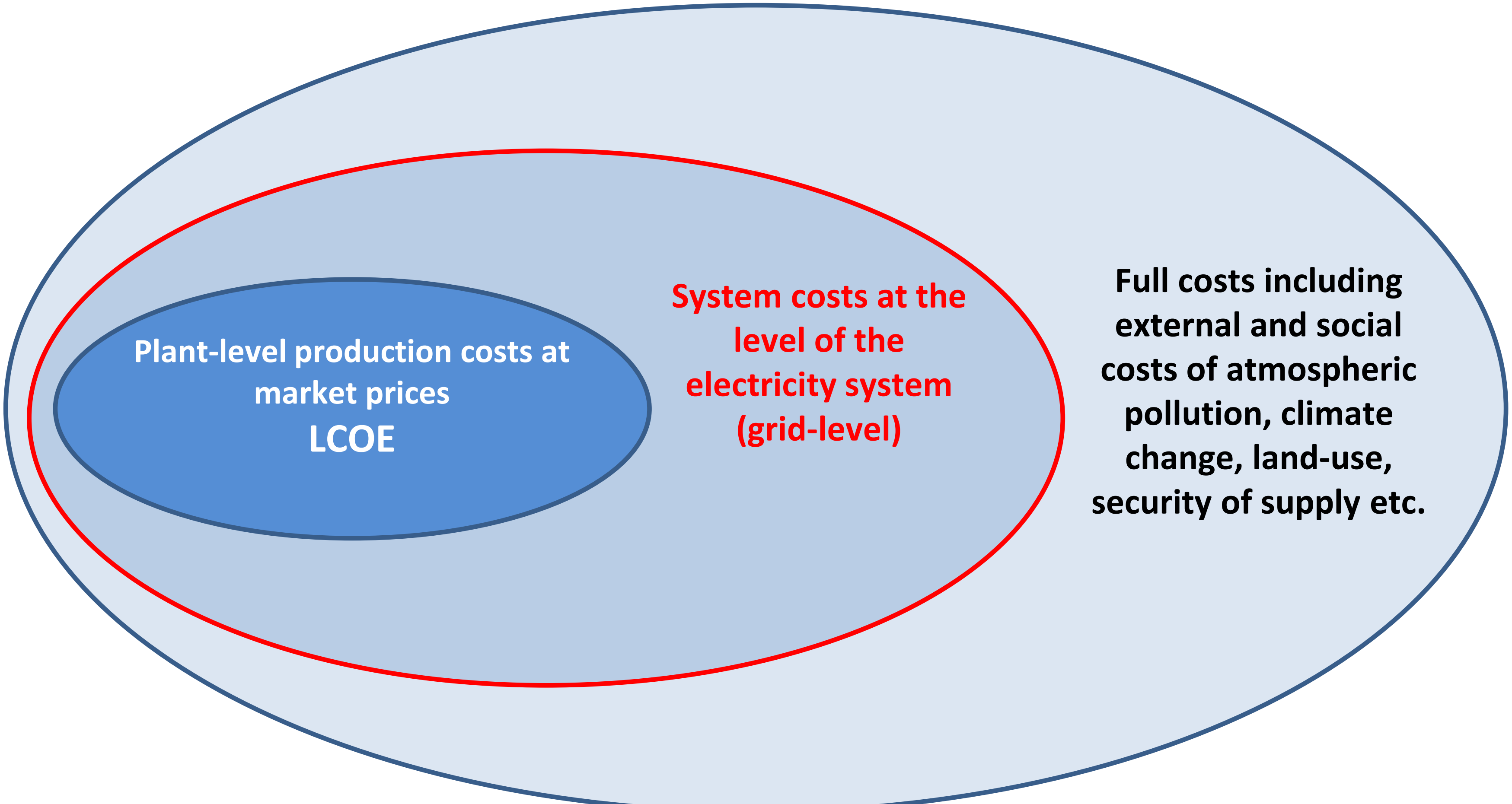
SYSTEM COSTS WITH HIGH SHARES OF NUCLEAR AND RENEWABLES

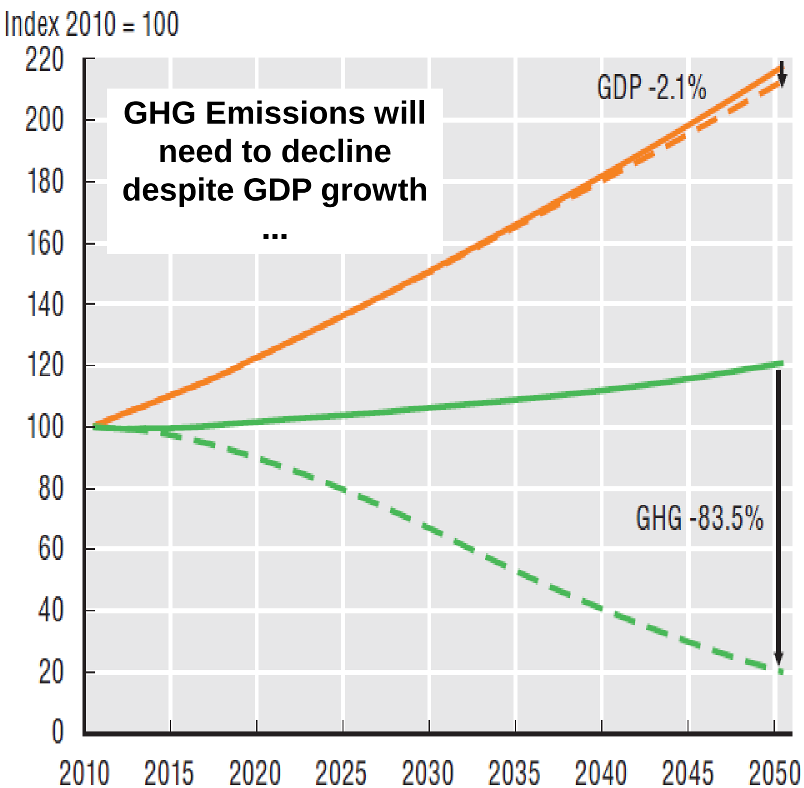
Insights from a New Study of the OECD Nuclear Energy Agency

Jan Horst Keppler and Marco Cometto

11 June 2019
8th European Energy Forum

A Taxonomy of Costs





Source: OECD Environmental Outlook

Paris Agreement implies a 50 gCO2/kWh target

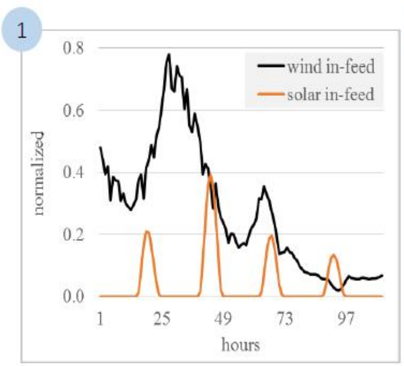
- Paris Agreement says hold “increase in global average temperature to well below 2°C”. This implies limiting GHG concentrations in the atmosphere to 450 ppm of $CO2_{equiv.}$.
- Annual CO_2 emissions will have to be reduced by 43% (global) and 61% (OECD).
- Electricity contributes 40% of global CO2 emissions and will play key role. Annual emissions from electricity will need to decline 73% (global) and 85% (OECD).
- Current emission intensity is 570 gCO2/kWh (global) and 430 gCO2/kWh (OECD).

- **Electricity generation in OECD will need to become low carbon at around 50 gCO2/kWh.**
- **With hydro limited, VRE and nuclear will need to substitute for fossils fuels.**
- **New NEA study analyses system costs of different electricity mixes at 50 gCO2/kWh.**

Assessing the total costs of electricity systems

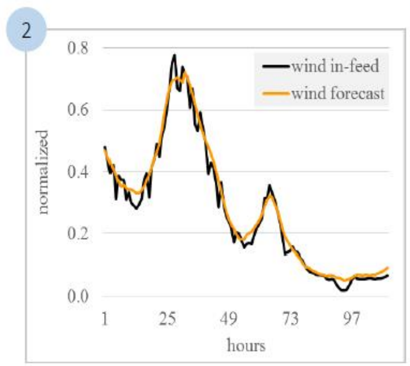
- Total system costs are the sum of plant-level generation costs and grid-level system costs
- System costs are mainly due to characteristics intrinsic to variable generation

Source: L. Hirth



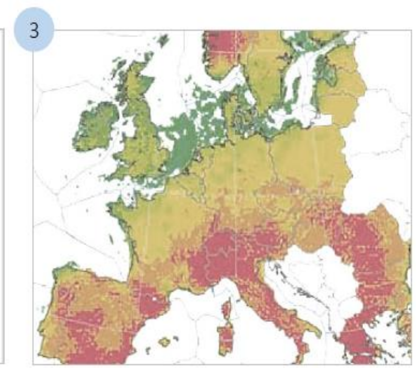
Wind does not always blow

Profile costs
(Changing mix)



Difficult to predict

Balancing costs
(Short-term variations)



Good sites are distant from load centers

Transmission and distribution costs

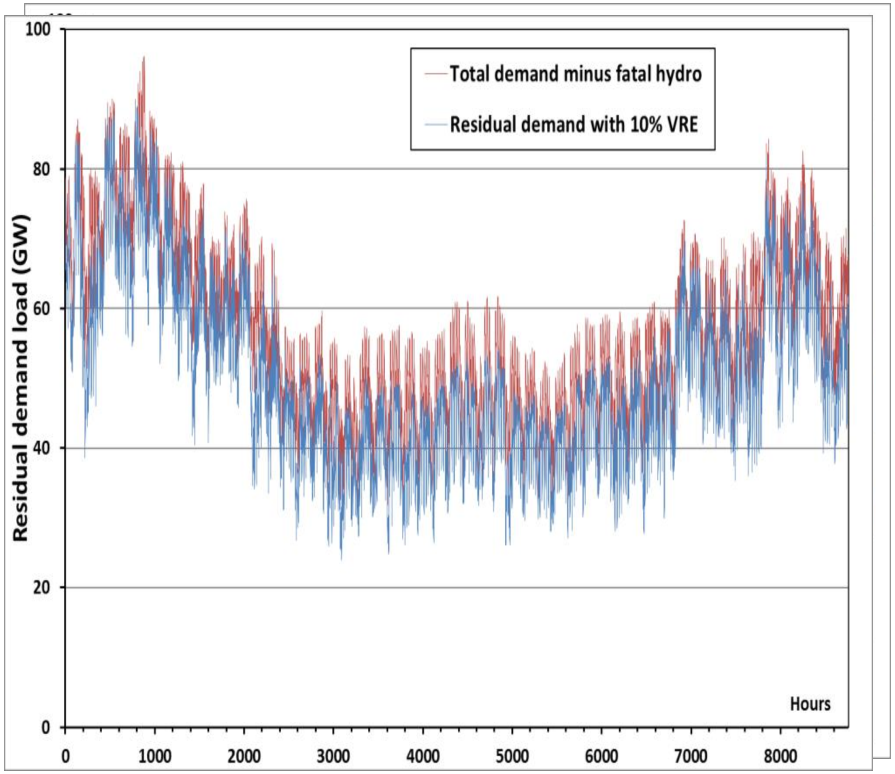
System costs depend on:

- Country characteristics and the existing mix
- VRE penetration and load profiles
- Flexibility resources (hydro, storage, interconnections)

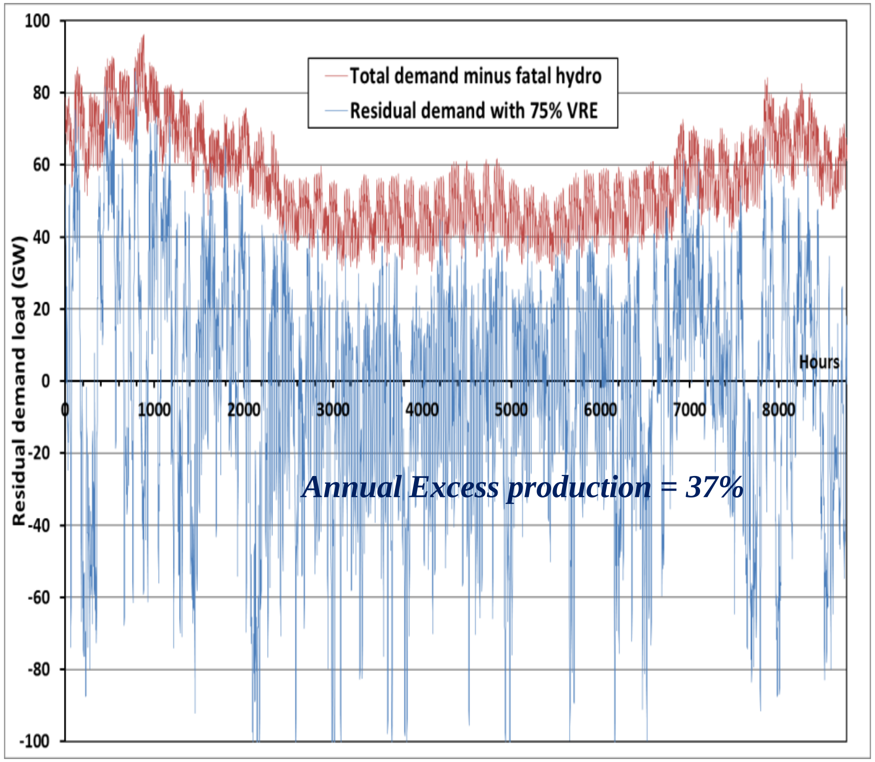
Additional impacts on load factors of dispatchable generators and prices.

High VRE share de-structures the remainder of the system

10% Variable Renewables



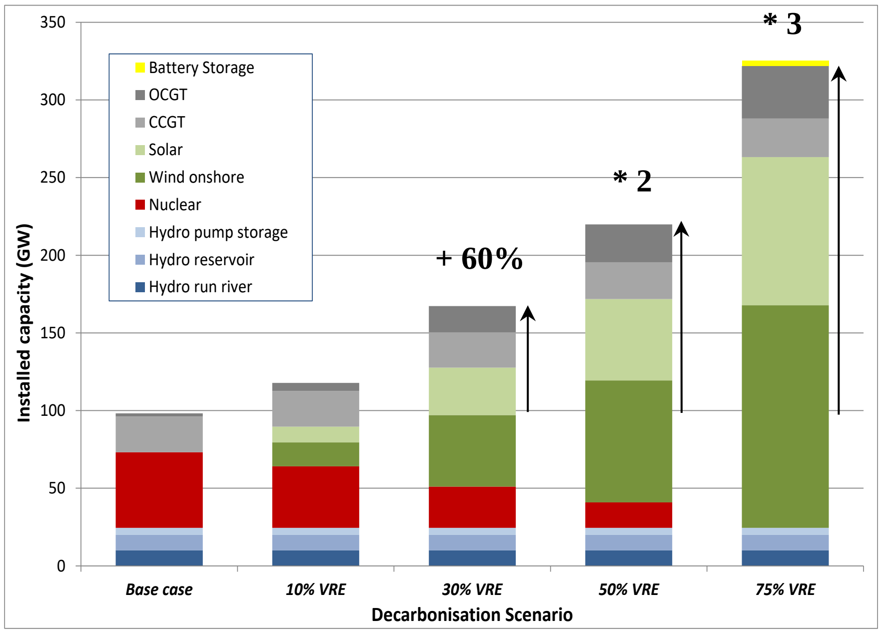
75% Variable Renewables



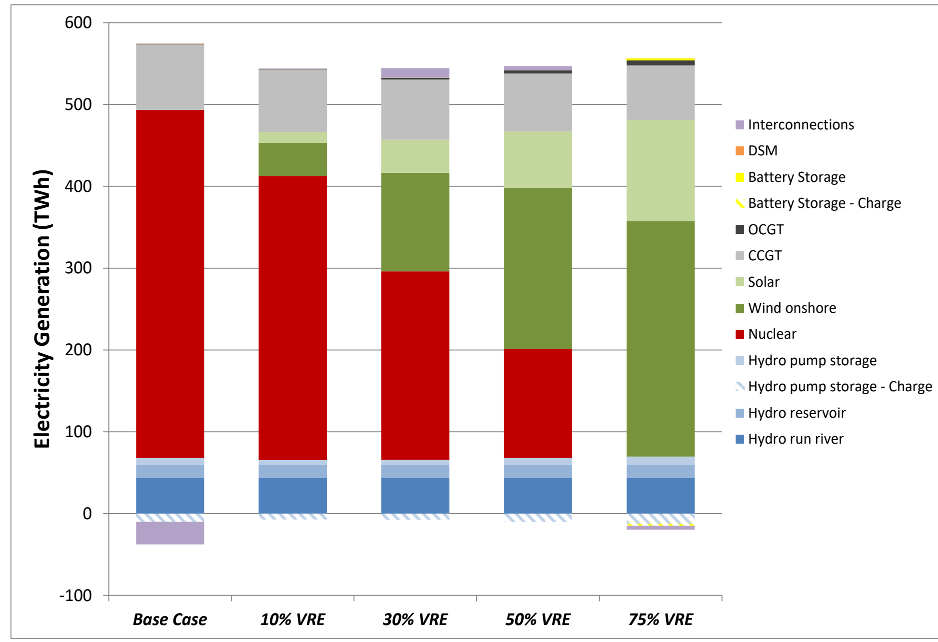
- Residual demand for dispatchable thermal operators loses its characteristic daily, weekly and seasonal patterns and becomes more volatile and unpredictable.

Result 1: Considerable excess capacity needed to meet demand

Installed Capacity



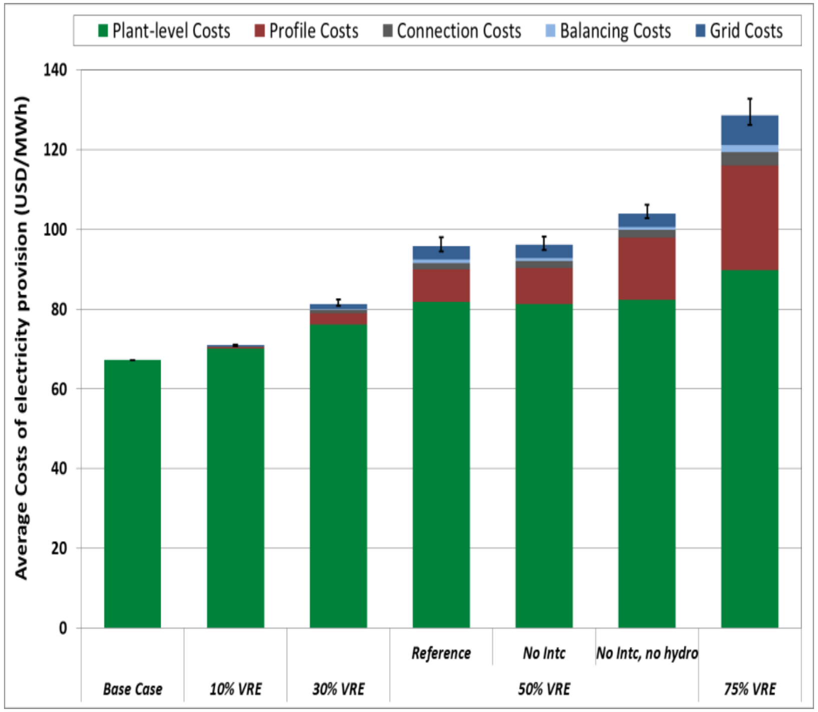
Electricity Generation



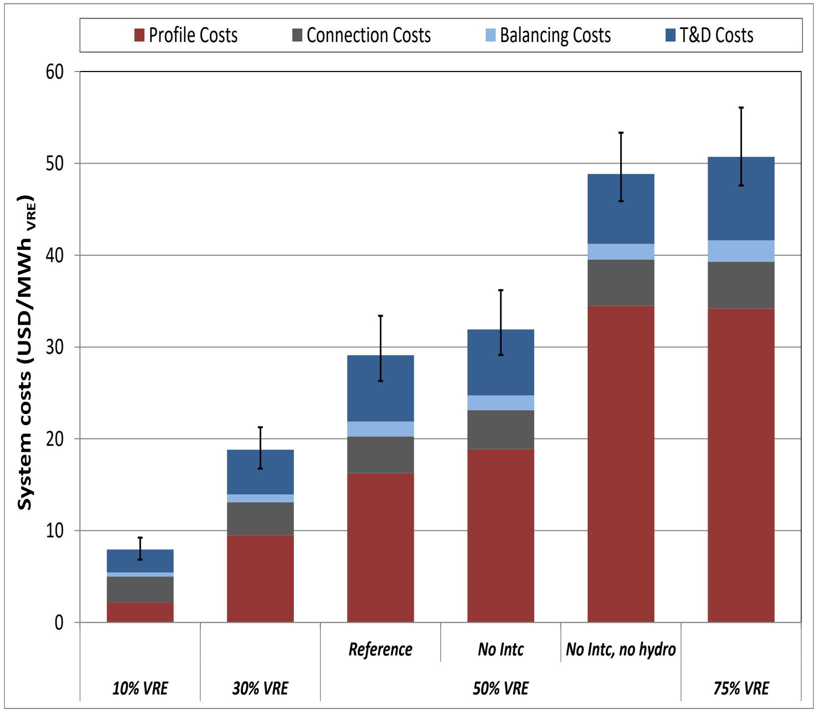
- Rising VRE share results in significantly larger capacity needs.
- Due to carbon constraint, coal no longer included, but gas provides flexibility. Battery storage deployed only at high VRE penetration levels.

Result 2: As VRE share increases system costs increase

Total Costs



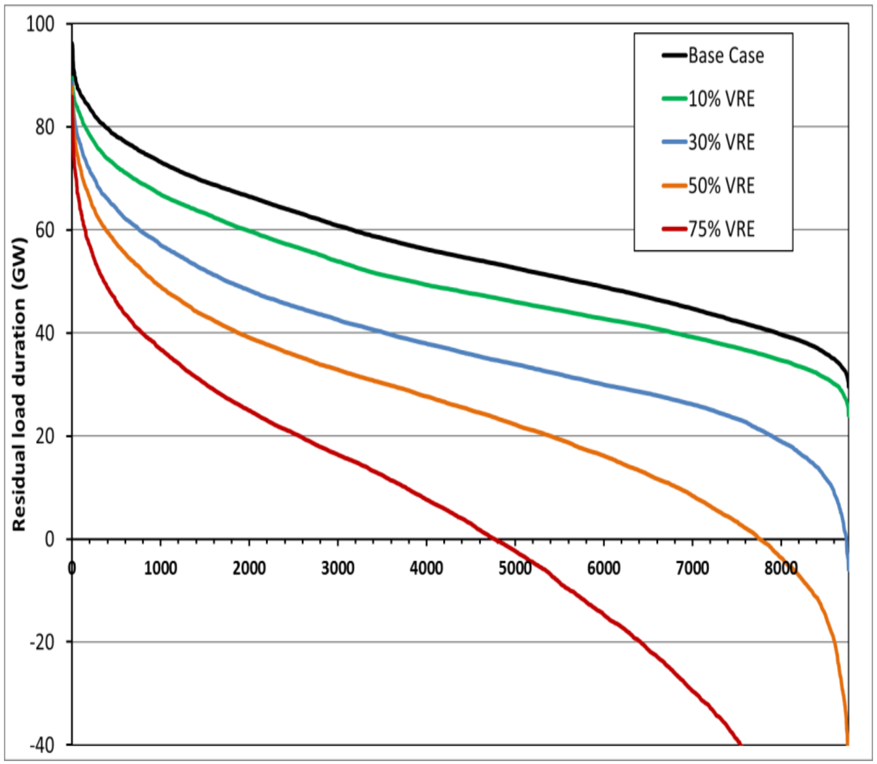
Breakdown of System Costs



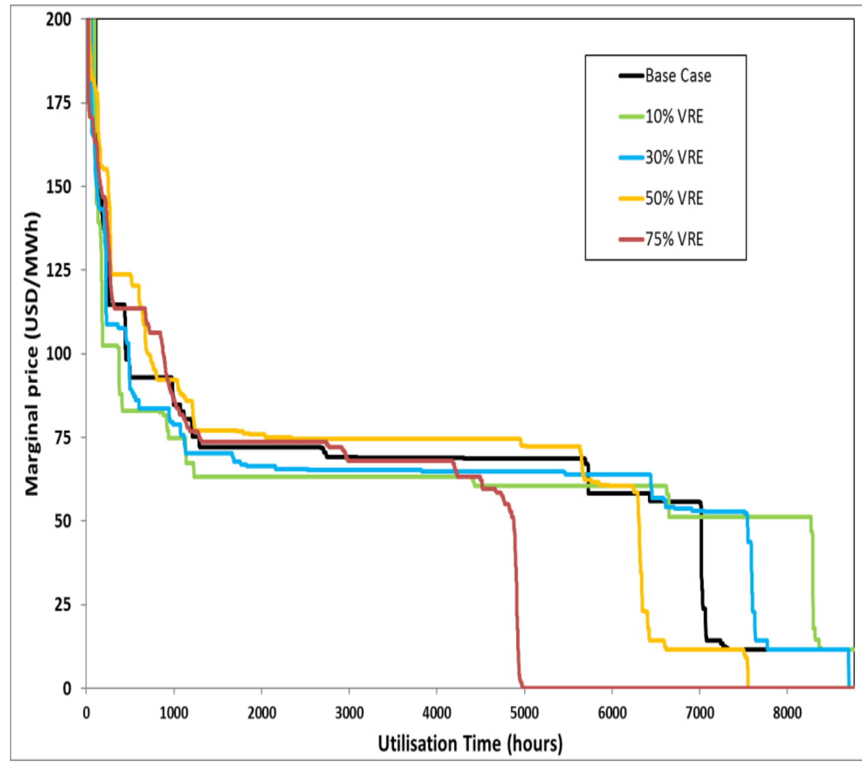
- Estimate of system costs with data from literature (T&D, connection and balancing).
- System costs are large and increase with VRE generation share.
- Profile costs are the dominant component, especially at high VRE generation share.

Result 3: Decreased load and volatile electricity prices discourage investment

Load Duration Curves

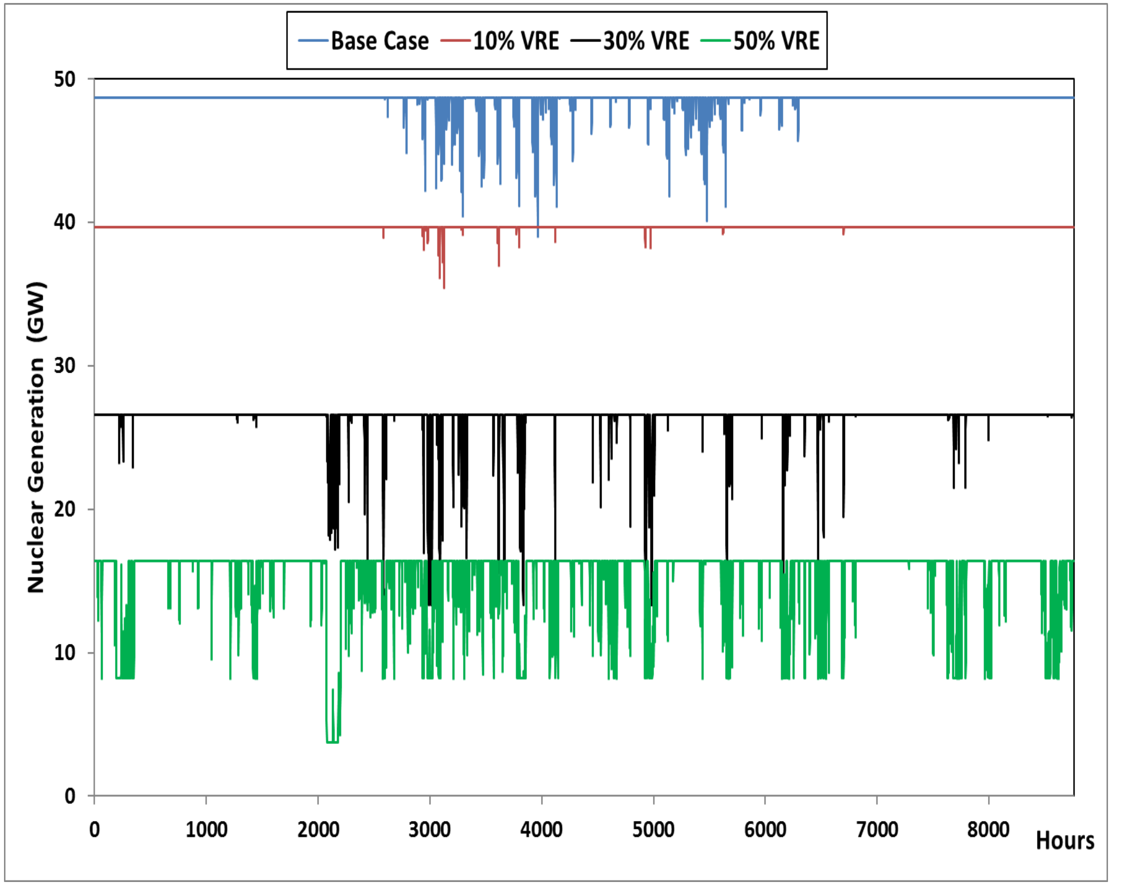


Price Volatility



- Increase of hours with zero price (over 3750 hours *p.a.* at 75% VRE), compensated by greater number high-price hours (>100 USD/MWh).
- Price volatility increases uncertainty, investment costs and risks to capacity adequacy.

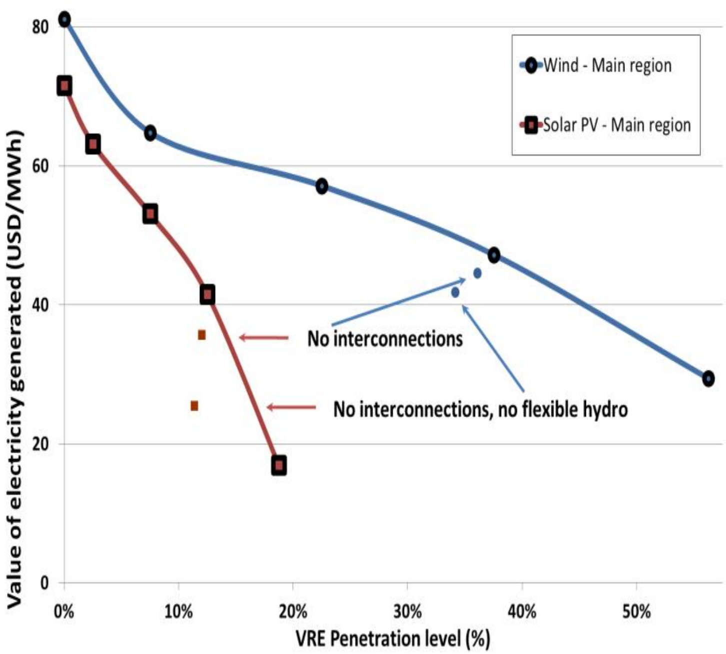
Result 4: Increasing demand on flexibility of nuclear power plants



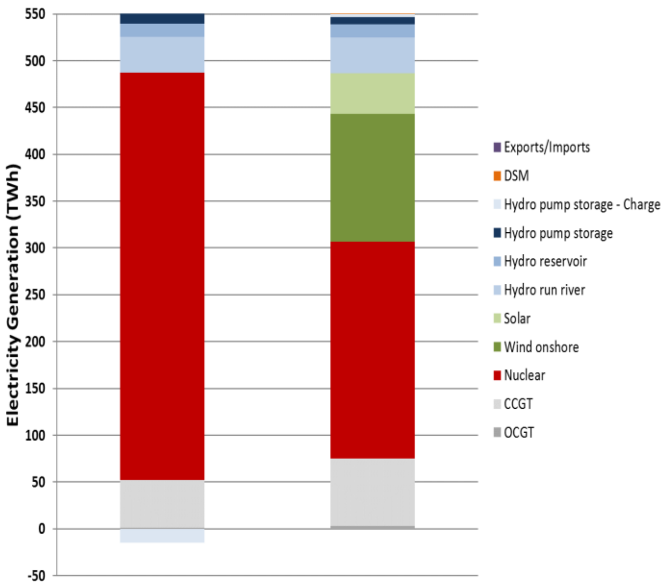
- With increasing VRE shares nuclear capacity declines.
- The number and steepness of the ramps for load following (cycling) increases.
- This poses the question of sector coupling, *i.e.*, combining electricity generation with the production of another “storable” product (heat, desalination, hydrogen…).

Result 5: Market-based introduction of VRE is intrinsically difficult

Declining Market Value of VRE



Even Low Cost VRE Limited Market Entry



- VRE earn less than average market prices due to auto-correlation during production hours. This effect increase with their share and is larger for solar PV. Flexibility resources improve value.
- Future expected cost declines of VRE (e.g., 60% PV, 50% wind off-shore, 33% wind on-shore) will allow self-entry into the market. The level will depend strongly on local conditions.

General policy recommendations for efficient decarbonisation

Radically decarbonising the electricity sector to 50 gCO_2/kWh in a cost-effective manner while maintaining high levels of security of supply requires five complementary policy measures:

- Implement carbon pricing, as the most efficient approach for decarbonising the electricity supply
- Encourage new investment in all low-carbon technologies by providing stability for investors
- Foster competitive short-term markets for the cost-efficient dispatch of available technologies
- Ensure adequate levels of capacity and flexibility, as well as transmission and distribution infrastructure
- Recognise and fairly allocate the system costs to the technologies that cause them

Successfully decarbonising the electricity sector requires suitable policies for the rapid deployment of *all* available low-carbon technologies in the most cost-effective manner