Nuclear Energy: An Essential Element for Deep Global Decarbonisation

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12th Annual International Conference on Nuclear Power NE•RS 2019 – Prague, Czech Republic – Nov 6, 2019

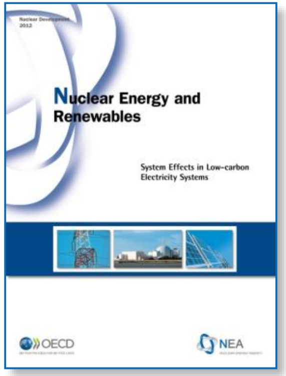
NEA Helps Governments Address Global Challenges

The Role of the NEA is to:

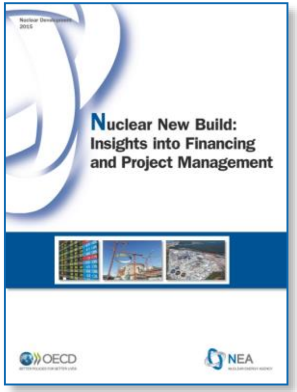
- Foster international co-operation to develop the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes.
- Develop authoritative assessments and forge common understandings on key issues as input to government decisions on nuclear technology policy.
- Conduct multinational research into challenging scientific and technological issues.

33 NEA countries operate more than 80% of the world's installed nuclear capacity

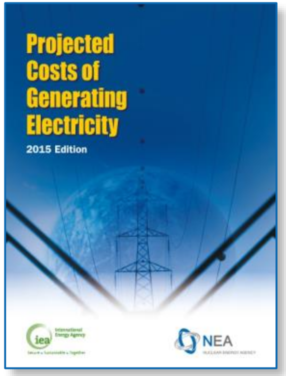
Ongoing NEA Work on Electricity Supply & Nuclear Economics



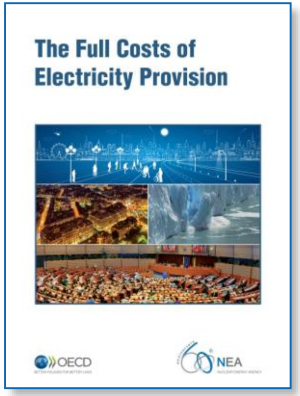
2012



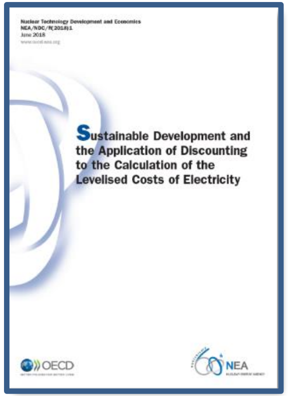
2015



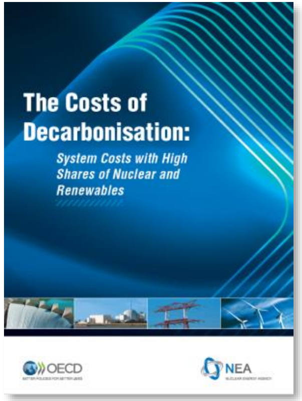
2015



2018

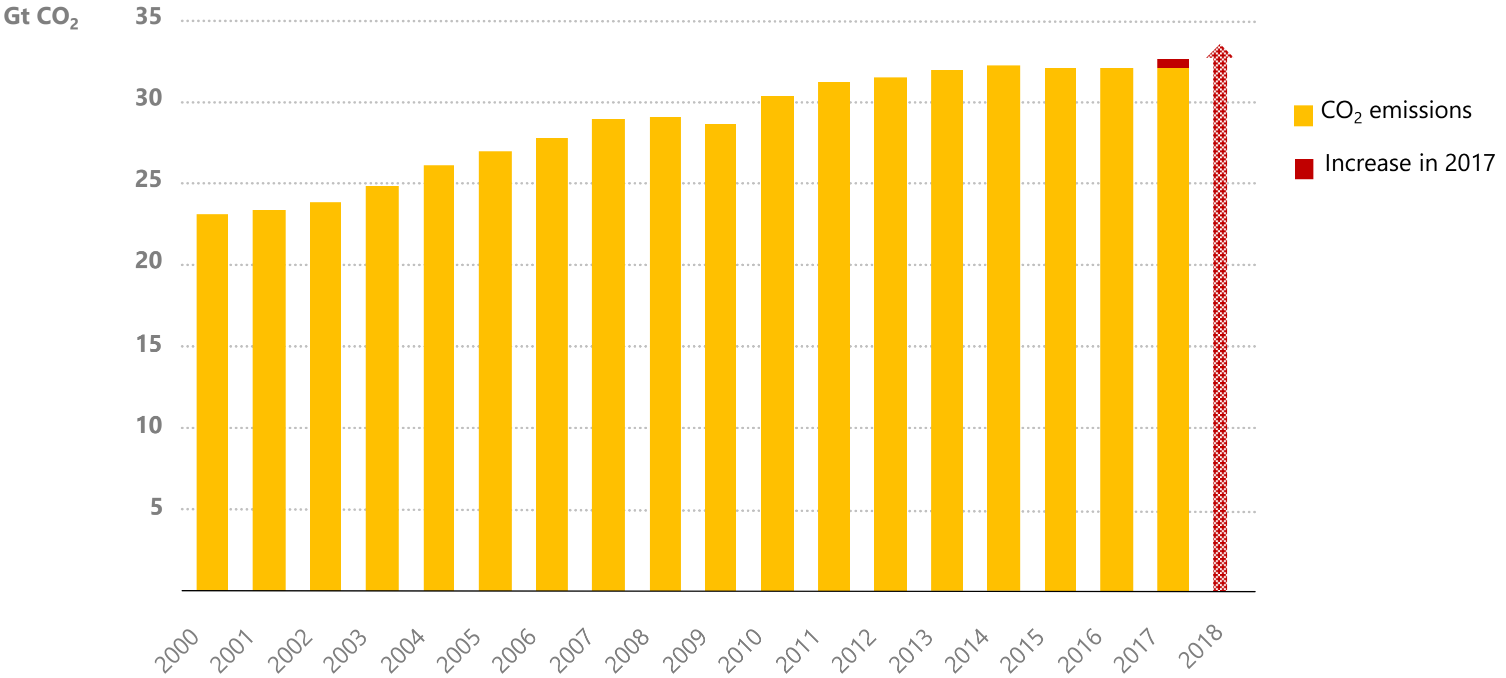


2018



2019

Global CO_2 emissions have continued to grow



Source: OECD/IEA

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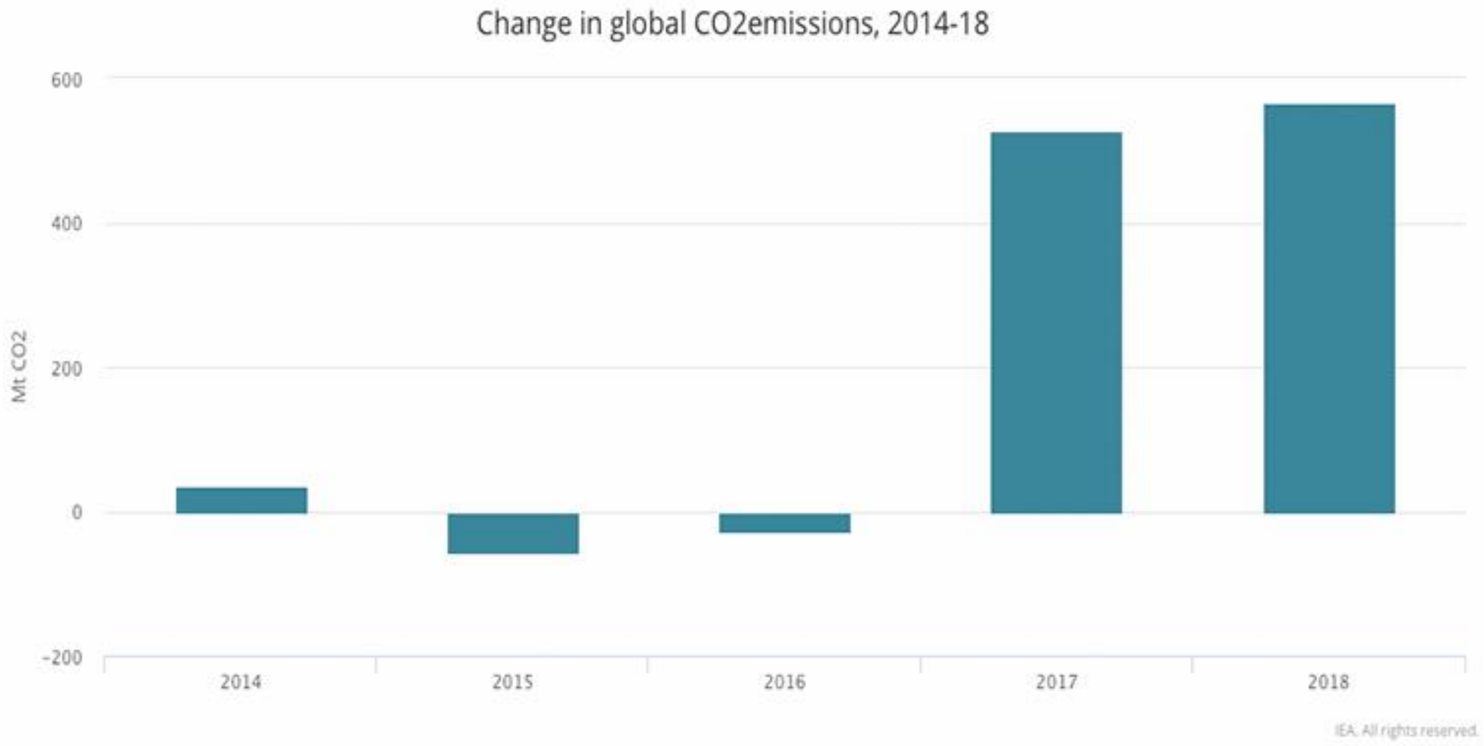
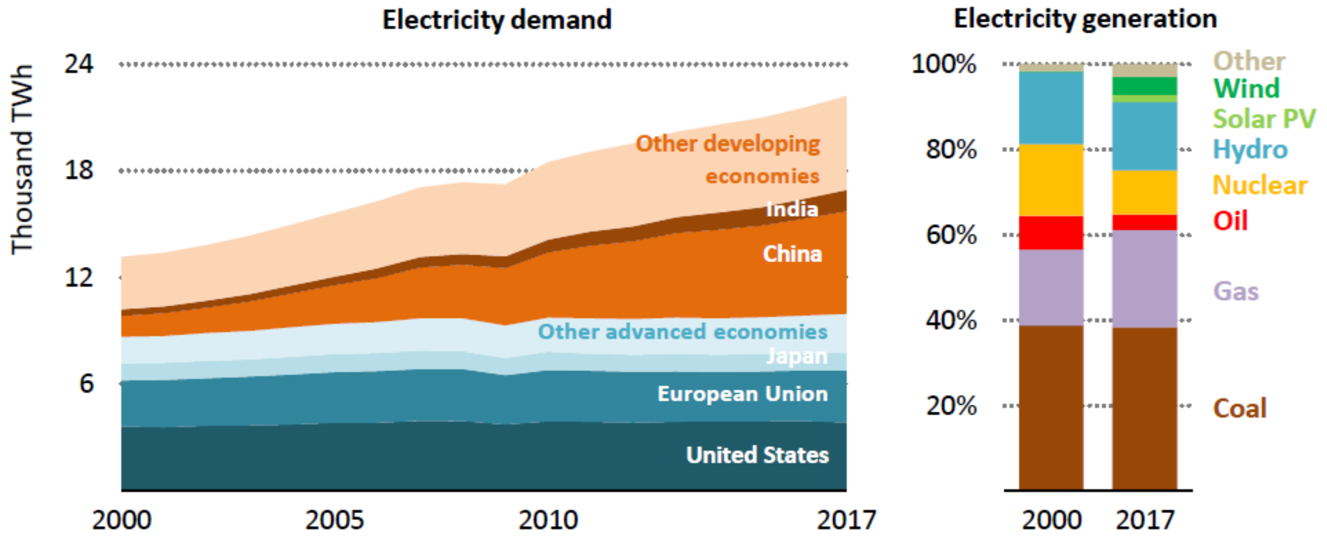


Source: OECD/IEA

Figure 7.1 ▷ Global electricity demand by region and generation by source, 2000-2017



Electricity demand has increased by around 70% from 2000 to 2017, while the power mix remains dominated by coal and gas, even with growth in renewables

Despite the impressive growth of solar and wind power, the overall share of clean energy sources in total electricity supply in 2018, at 36%, was the same as it was 20 years earlier because of the decline in nuclear

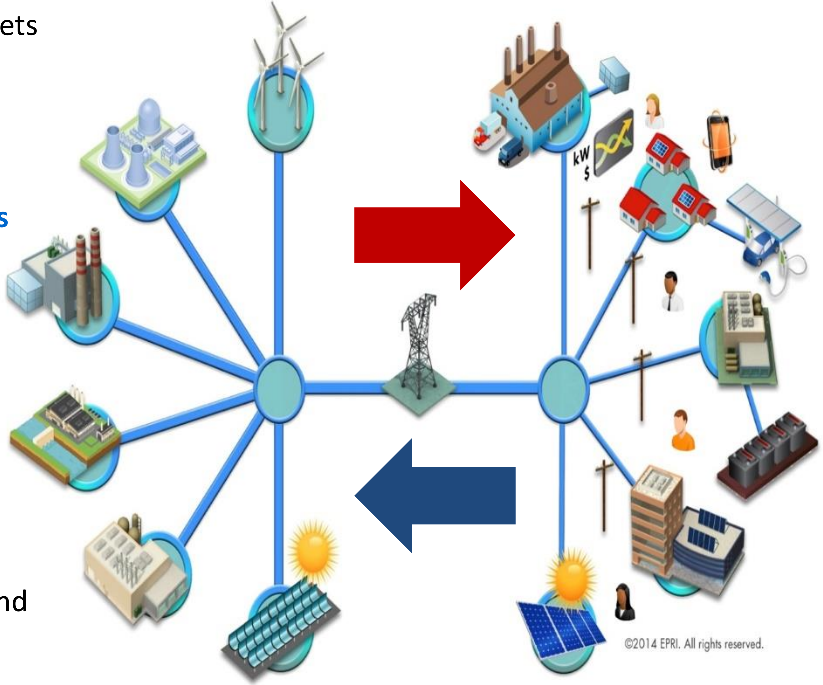
IEA WEO 2018

Electricity as the cornerstone of energy decarbonisation

- Low carbon electricity to play a key role in future **decarbonized** energy markets
  - Electrification of the transportation sector
  - Electrification of the industrial sector
  - Electrification of the buildings sector (heating/cooling)

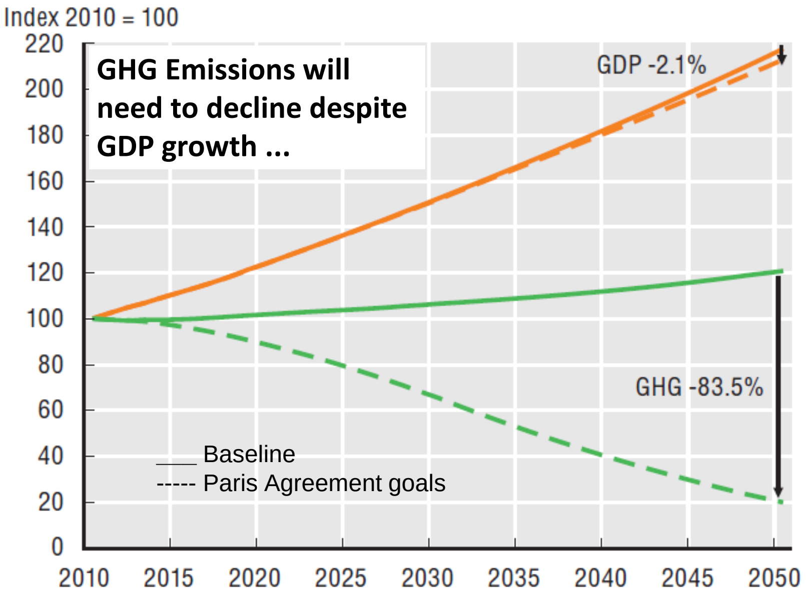
- **Decarbonisation** of electricity markets requires **all fuels and all technologies**
  - Energy efficiency (supply side and demand side)
  - Carbon capture utilization and sequestration (CCUS)
  - Energy storage
  - **Nuclear power**
  - Yet, renewables (Wind and Solar) are expected to lead

- New **challenges**
  - Need for improved infrastructures to ensure interconnectivity
  - Need flexibility - interconnectivity is not enough
  - Need market signals fostering investment in infrastructure, capacity and flexibility
  - Need large level of coordination in policy and regulation



Graphic: Courtesy of EPRI

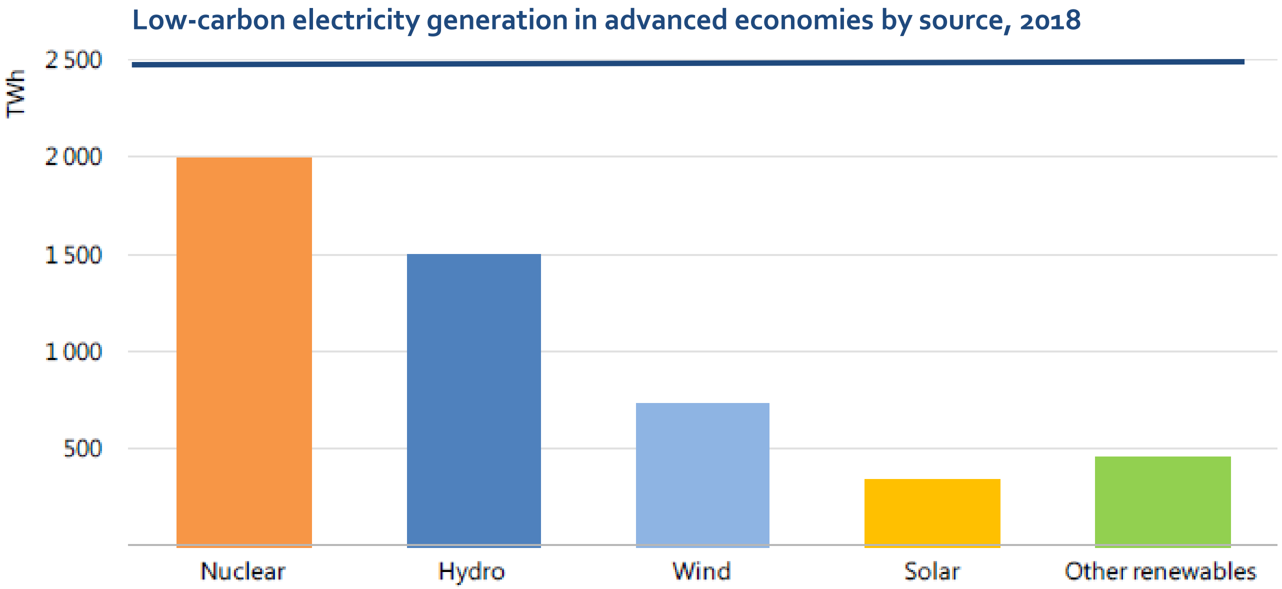
Paris Agreement Implies a 50 gCO2/kWh Target



Source: OECD Environmental Outlook

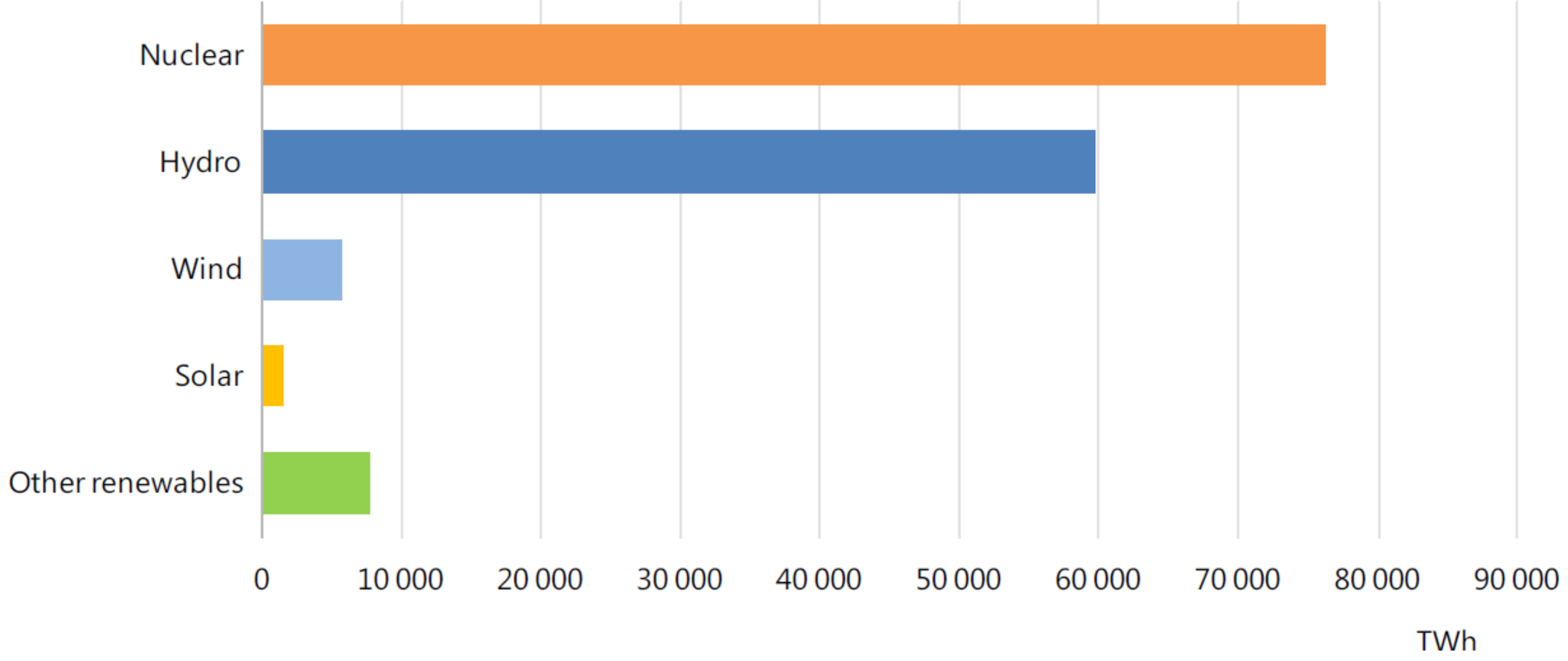
- Paris Agreement is intended to hold "increase in global average temperature to well below 2°C".
- Current emission intensity is **570 gCO2/kWh** - target is **50 gCO2/kWh**
- Electricity contributes 40% of global CO2 emissions and will play key role. Annual emissions from electricity will need to decline 73% (global) and 85% (OECD countries).

Nuclear remains the leading low-carbon source of electricity in advanced economies



Without nuclear power, CO_2 emissions from electricity generation would have been almost 20% higher over the last 50 years

Figure 3. Cumulative low-carbon electricity generation in advanced economies by source, 1971-2018



Nuclear power and hydropower account for 90% of low-carbon electricity since the 1970s.

Nuclear power is part of a cost-effective clean energy transition

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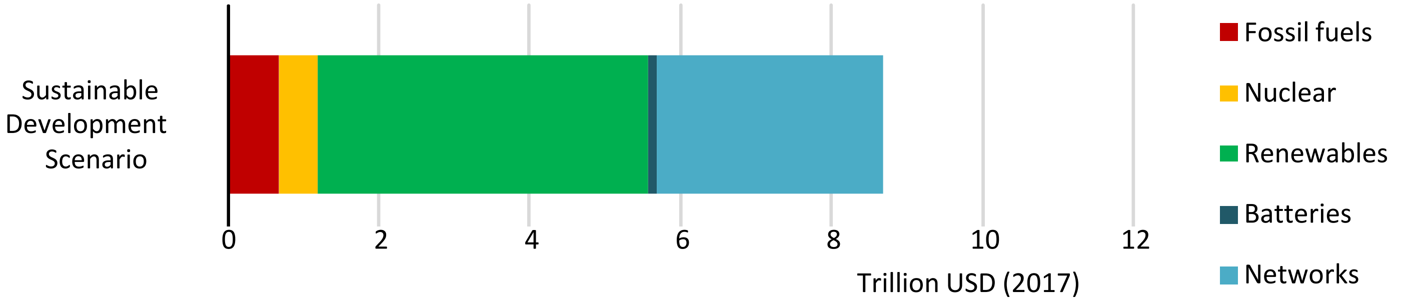
Nuclear power is part of a cost-effective clean energy transition

Power sector investment needs in advanced economies on a sustainable energy pathway, 2019-2040



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Nuclear power is part of a cost-effective clean energy transition

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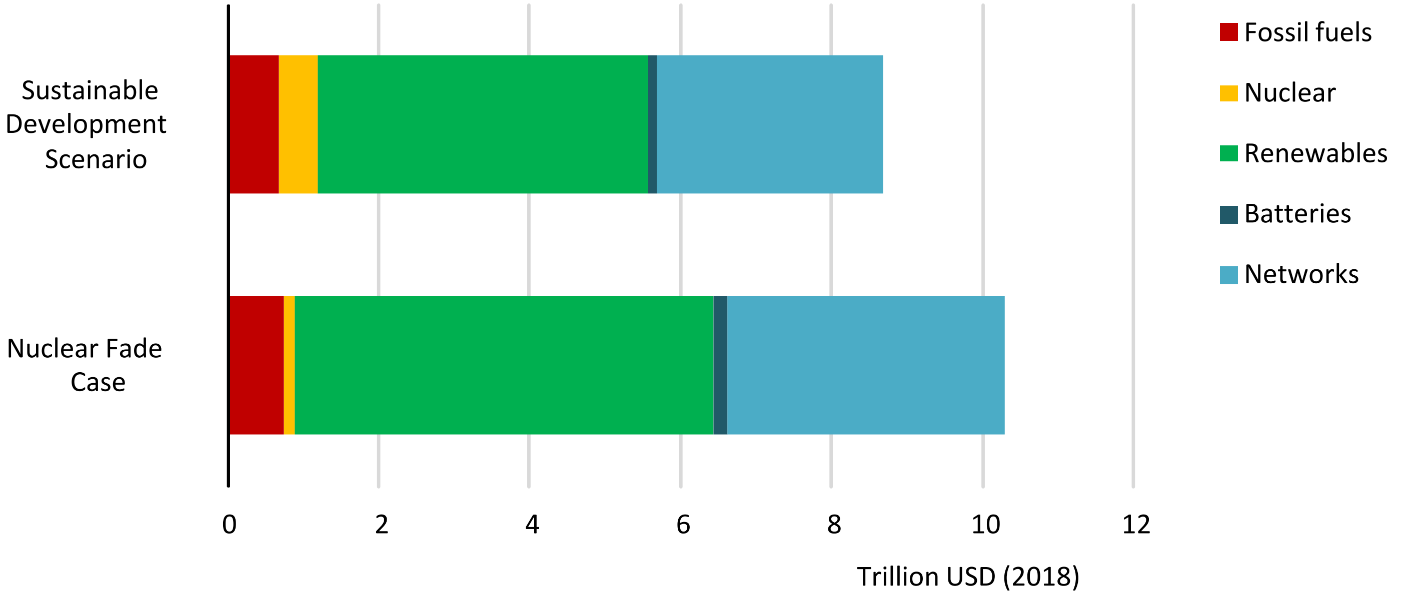

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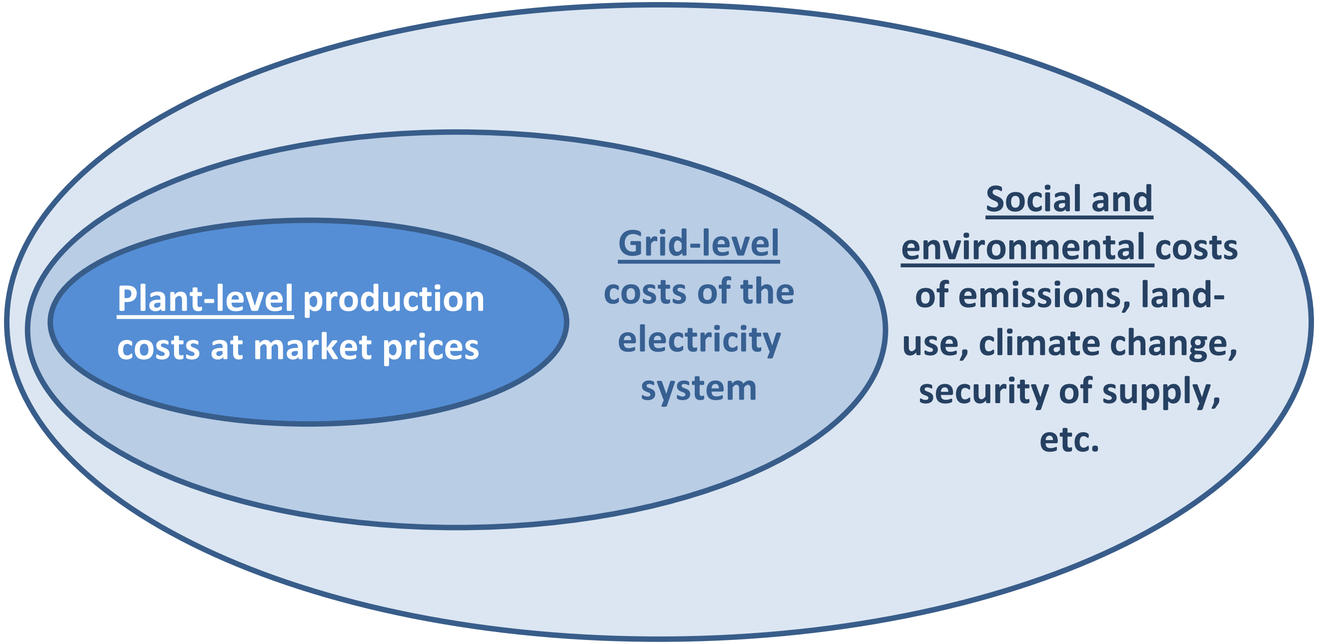
Investment needs to achieve the energy transition are $1.6 trillion higher without nuclear complementing renewables in the fight against climate change

Full Costs of Electricity



The actual cost of electricity should reflect not only plant-level GENERATION costs but also grid-level SYSTEM costs and SOCIAL & ENVIRONMENTAL costs.

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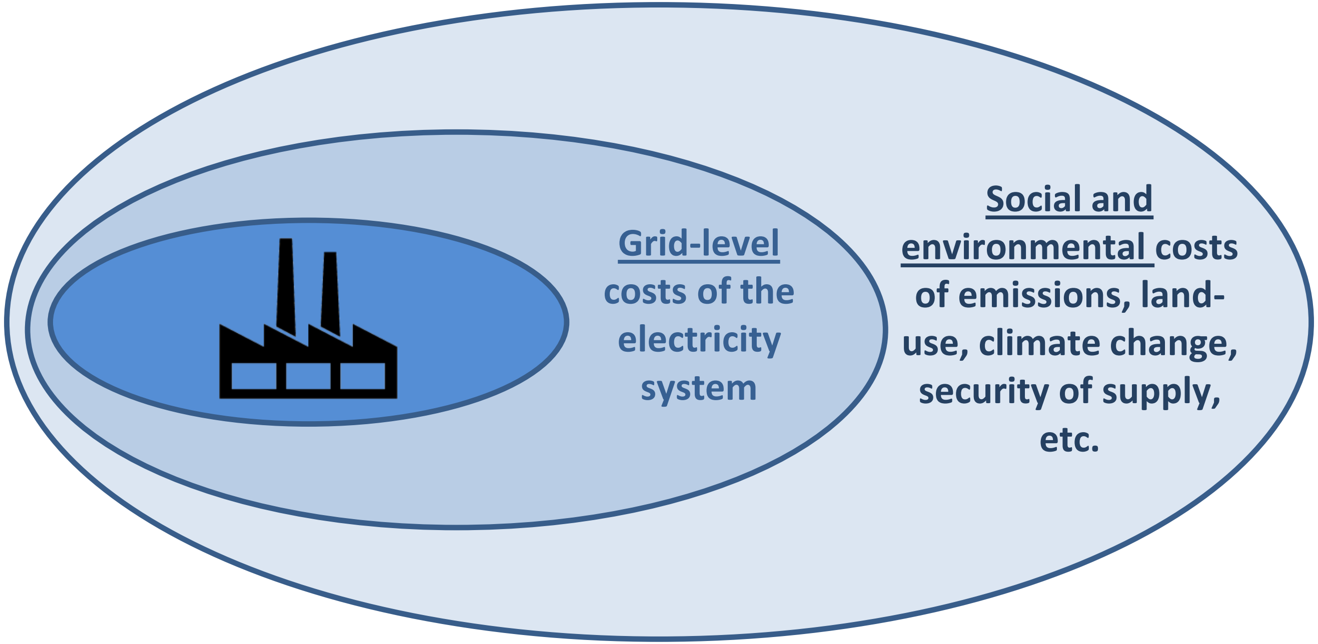

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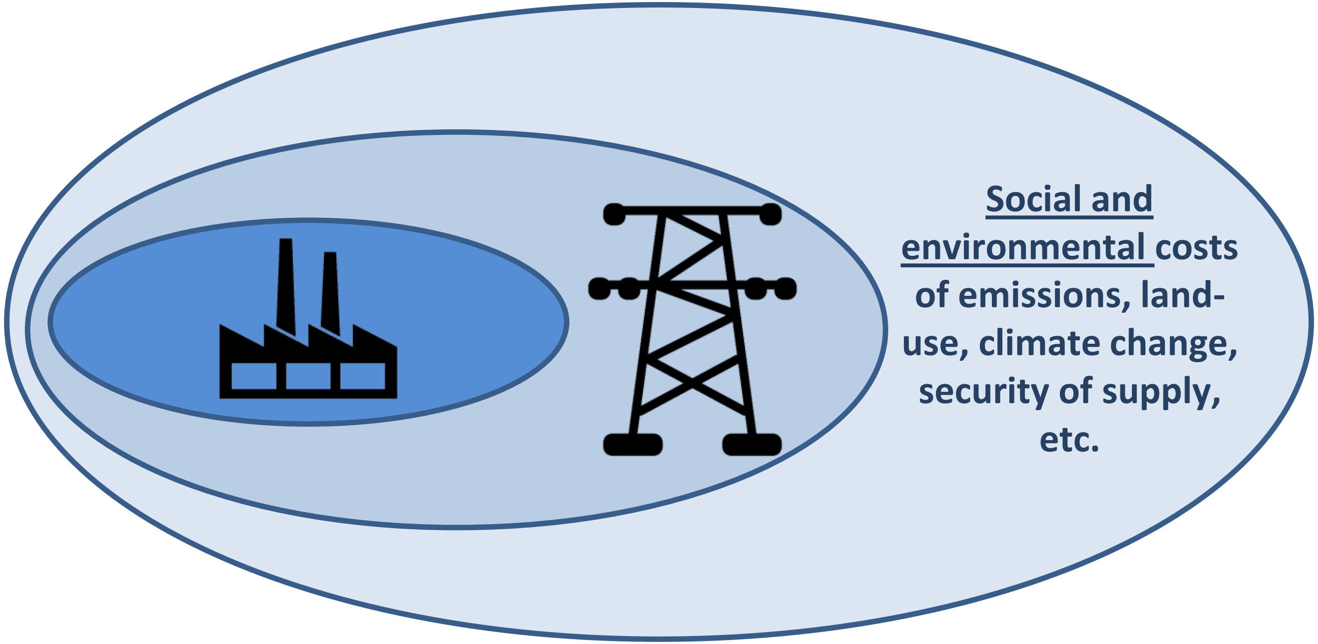

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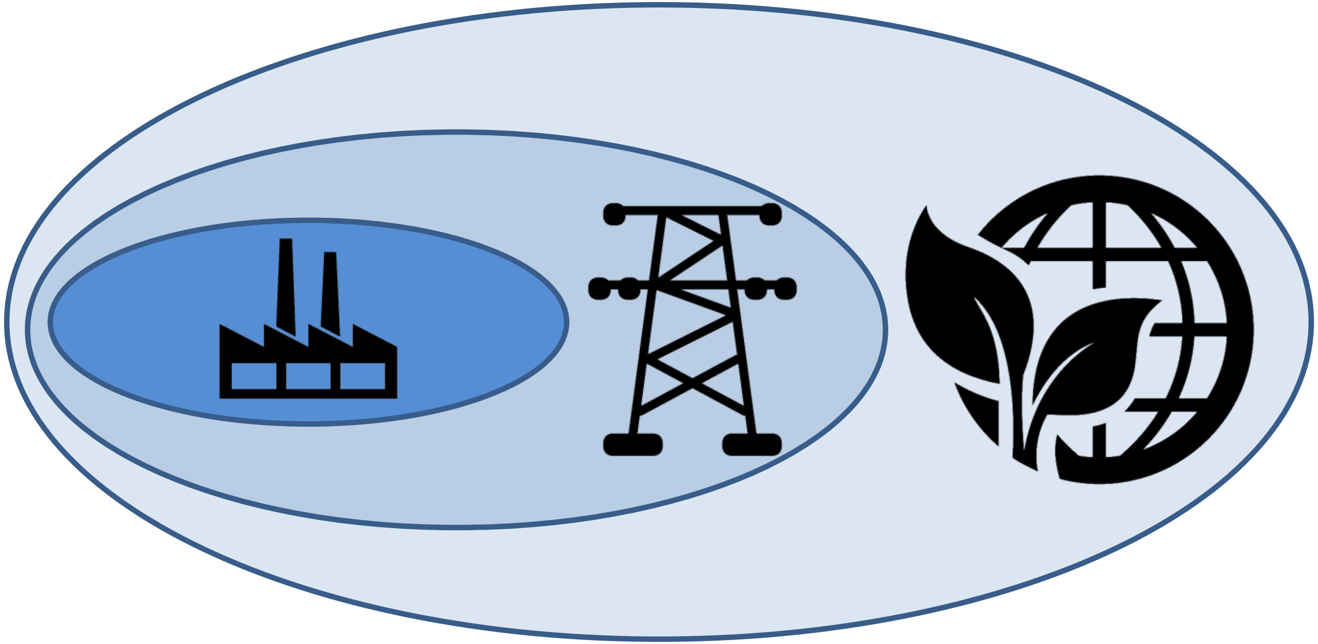

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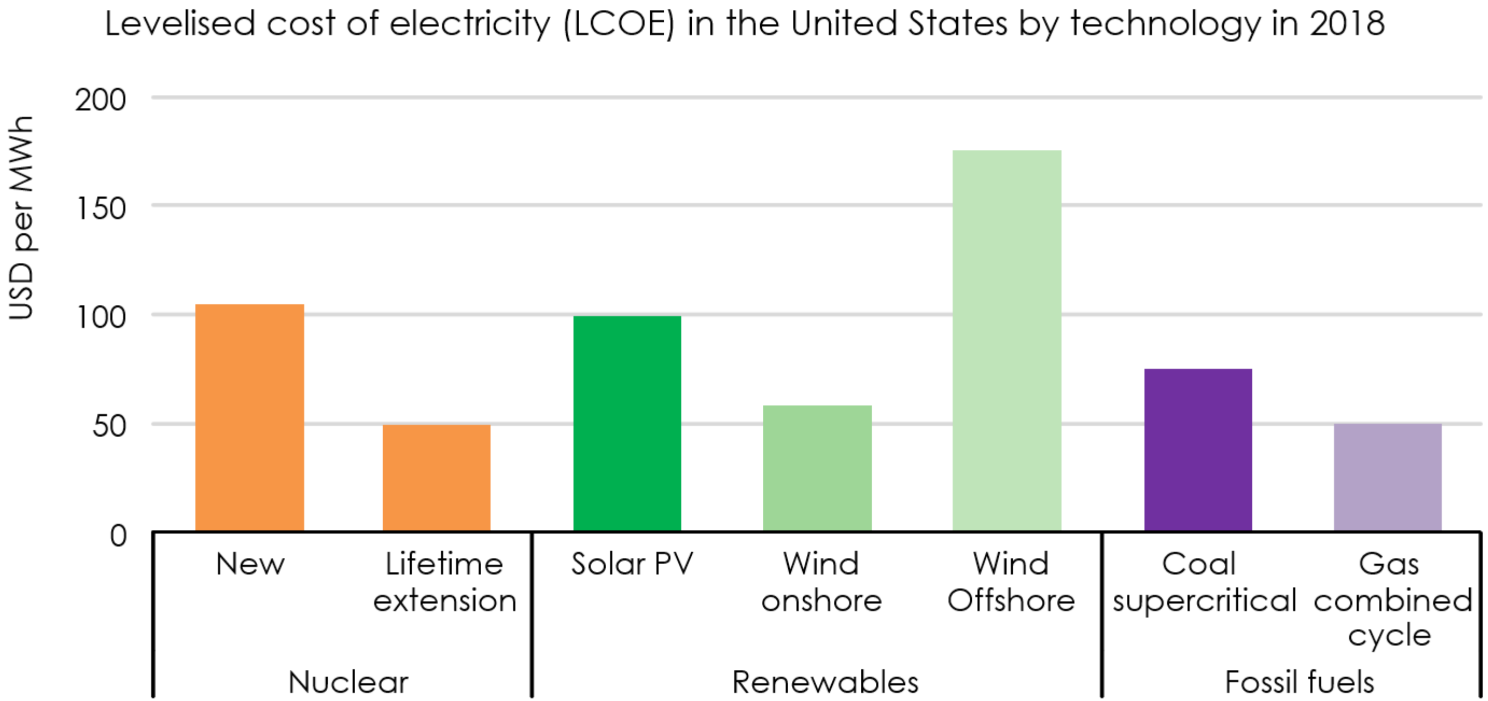
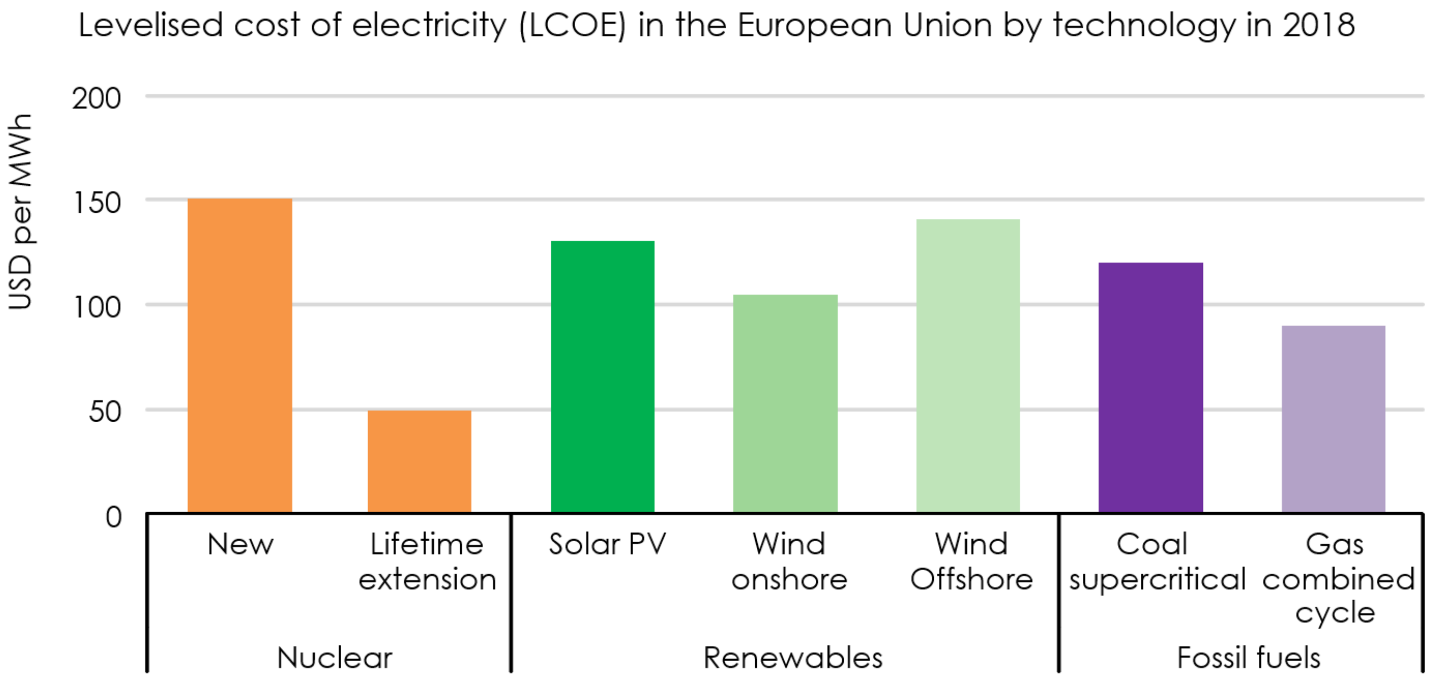
Cost competitiveness of nuclear energy



Source: OECD/IEA

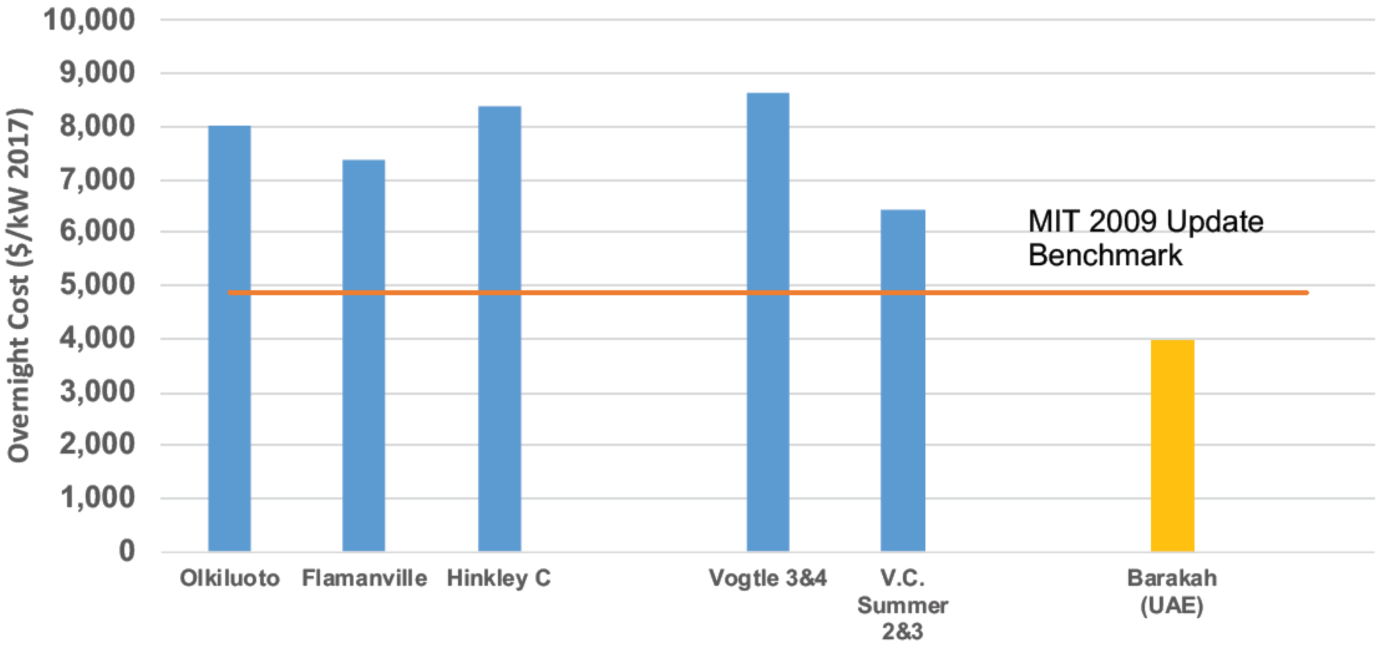
Cost competitiveness of nuclear energy



Source: OECD/IEA

New Nuclear Construction Recent Overnight Costs

Figure 2.3: Overnight cost of recent Gen-III+ builds versus benchmark



Source: MIT 2018

Sanmen units 1 and 2 (Image: SNPTC)

Barakah unit 2 (Image: ENEC)

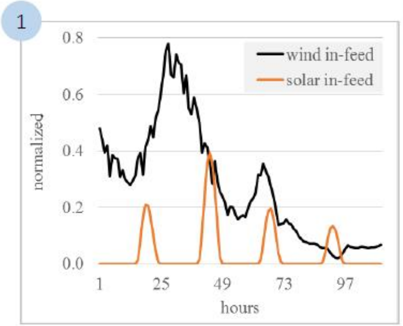
Taishan 1 (Image: CGN)

Novovoronezh II-2 (Image: Rosatom)

Assessing the True Costs of Electricity

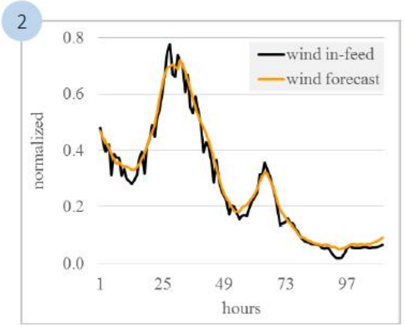
- Total system costs are the sum of plant-level generation costs and grid-level system costs
- System costs are mainly due to characteristics intrinsic to variable generation

Source: L. Hirth



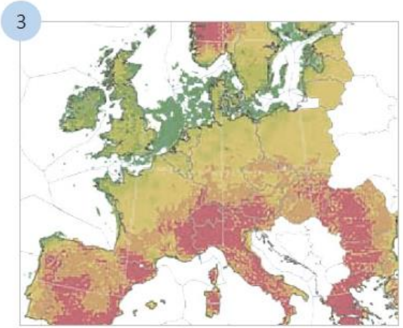
VREs are not always available

Profile costs (Changing mix)



VREs are difficult to predict

Balancing costs (Short-term variations)



Good VRE sites are distant from load centers

Transmission and distribution costs

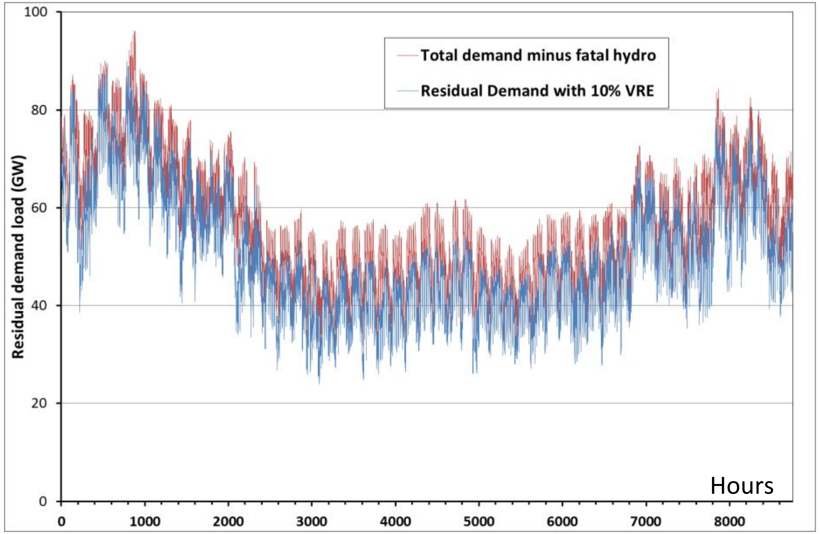
System costs depend on:

- Local & regional factors and the existing mix
- VRE penetration and load profiles
- Flexibility resources (hydro, storage, interconnections)

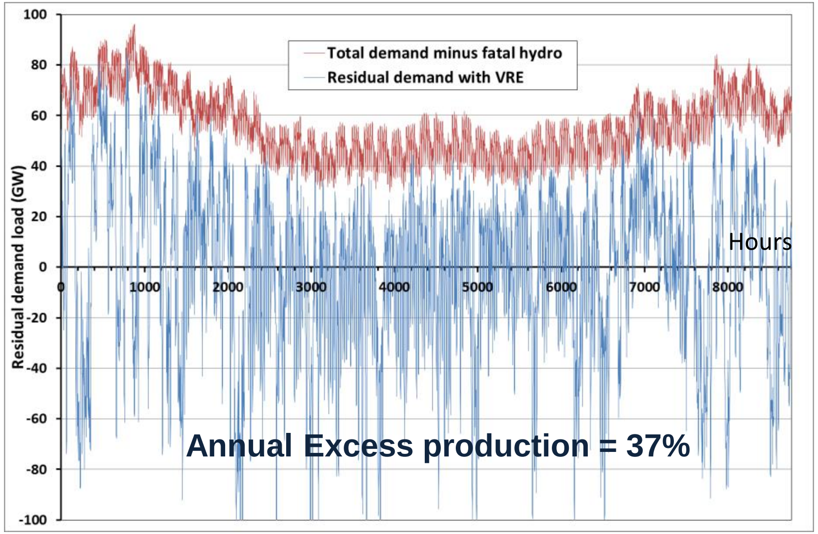
Additional impacts on load factors of dispatchable generators and prices.

High VRE Result in Large System Inefficiencies

10% Variable Renewables



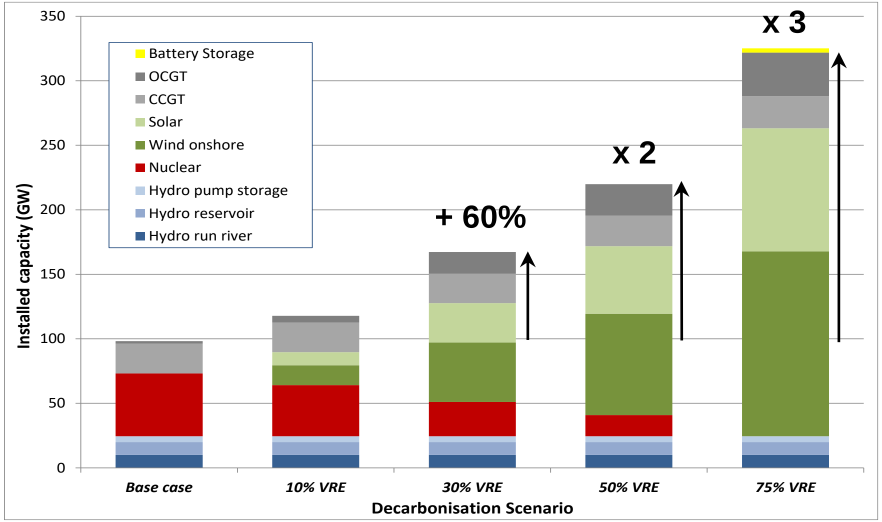
75% Variable Renewables



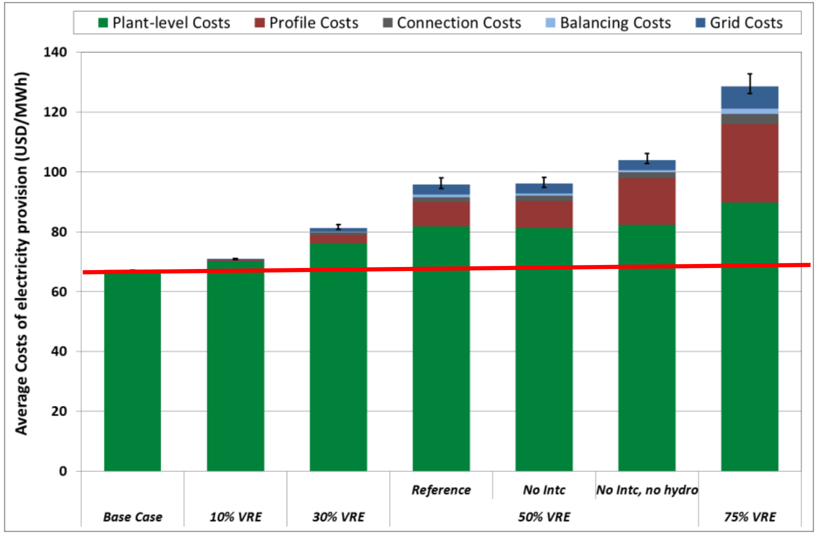
- High VRE penetration result in challenges for system management.
- Residual demand (**BLUE** line) – the available market for dispatchable generation becomes volatile and unpredictable.

High VRE Systems Result in Large Excess Capacity and Increased Costs

Installed Capacity



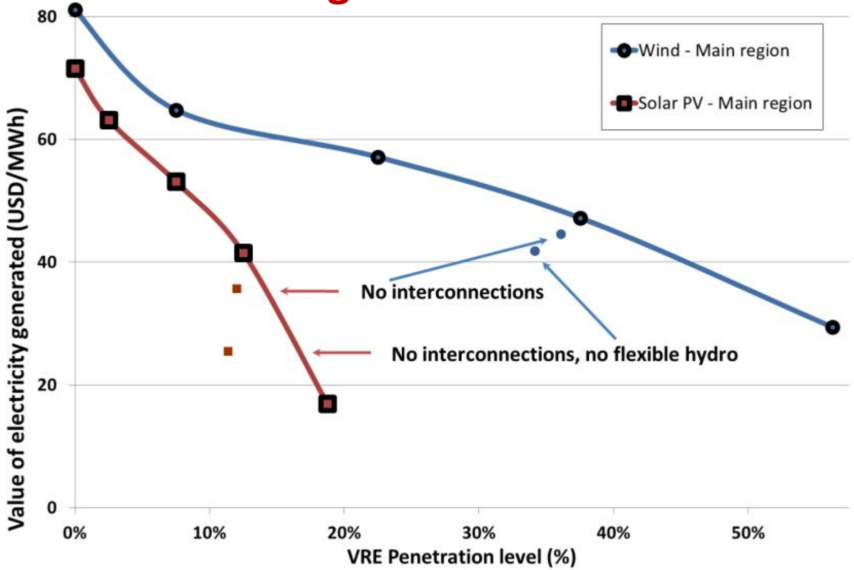
Total Costs



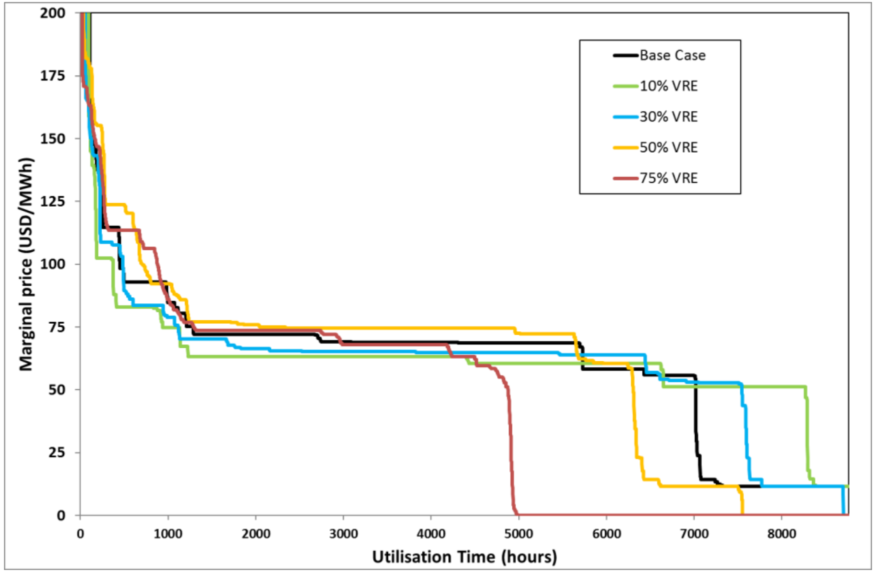
- Rising VRE share results in significantly larger capacity needs.
- System costs are large and increase with VRE generation share

Volatile Electricity Prices Discourage Investment

Declining Market Value of VRE



Price Volatility



- 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.
- Price volatility increases uncertainty, investment costs and risks to capacity adequacy.

Expanded Concept of Flexibility for Nuclear Generation

Attribute	Sub-Attribute	Benefits
Operational Flexibility	Maneuverability	Load following
	Compatibility with Hybrid Energy Systems and Polygeneration	Economic operation with increasing penetration of intermittent generation, alternative missions
	Diversified Fuel Use	Economics and security of fuel supply
	Island Operation	System resiliency, remote power, micro-grid, emergency power applications
Deployment Flexibility	Scalability	Ability to deploy at scale needed
	Siting	Ability to deploy where needed
	Constructability	Ability to deploy on schedule and on budget
Product Flexibility	Electricity	Reliable, dispatchable power supply
	Industrial Heat	Reliable, dispatchable process heat supply
	District Heating	Reliable, dispatchable district heating supply
	Desalination	Reliable, dispatchable fresh water supply
	Hydrogen	Reliable, dispatchable hydrogen supply
	Radioisotopes	Unique or high demand isotopes supply

Source: Adapted from EPRI

Beyond electricity, nuclear can support the decarbonisation of other energy sectors

Sectors where nuclear can play a role

ENERGY

Electricity
- High shares of VRES
- Hydro
- Nuclear (electricity)
- Others: CCS, biofuels, etc
- Fossil

Storage/integration
- Battery, pumped storage, heat, H2
- Hybrid Energy Systems

- Fossil
- Biofuels
- Hydrogen (Steam Methane Reforming, Electrolysis, T-C cycles)
- Nuclear (heat)

Transport
- EV
- H2 Fuel Cells or Combustion
- Synthetic fuels
- Fossil

Building
- heating/cooling
- PV elec production

Industry
- Low C process heat
- Fossil

Water
- Desalination

Nuclear energy will have a place in tomorrow's energy markets if:

- It can **compete with alternative low carbon** electricity generating technologies (costs on a €/kWh basis, financing, …)
- High level **waste management** implemented (long term storage, deep geological repositories for final disposal) + safety and non-proliferation maintained at highest levels + public support.
- Its **attributes can be appropriately valued** (CO_2-free, security, reliability, dispatchability – and contribution to grid stability/quality).
- It can **operate flexibly** in electricity systems with large shares of var. renewables (without compromising its economics).
- Its **"product flexibility"** (i.e. possibility to generate electricity but also non-electric products – process heat, hydrogen, desalinated water, …) can be recognised and marketed appropriately.

There is a wide **range of technologies**, (large) LWR – (small) LWR (SMR) – other advanced reactors (non LWR SMRs / Gen IV) – various attributes, markets, etc

DESIGN / TECHNOLOGY
ECONOMICS
POLICIES

Nuclear Energy: An Essential Element for Deep Global Decarbonisation

Radically decarbonising the electricity sector to 50 gCO2/kWh in a cost-effective manner while maintaining security of supply requires:

- Ambitious decarbonisation targets require the optimum use of **all low-carbon technologies**
- **Recognising and allocating system costs** to the technologies that cause them
- Fostering **truly competitive short-term markets** for the cost-efficient dispatch of resources
- Encouraging new **investment in all low-carbon technologies** by providing stability for investors
- **Designing markets** that value adequate capacity, transmission and distribution, and flexibility
- Implementation of **carbon pricing** – an efficient approach for decarbonising electricity

Thank you for your attention

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