# Nuclear Energy in Electricity Decarbonisation: Long-Term Operation of Existing Reactors

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# NEA activity on Long-Term Operation of NPPs

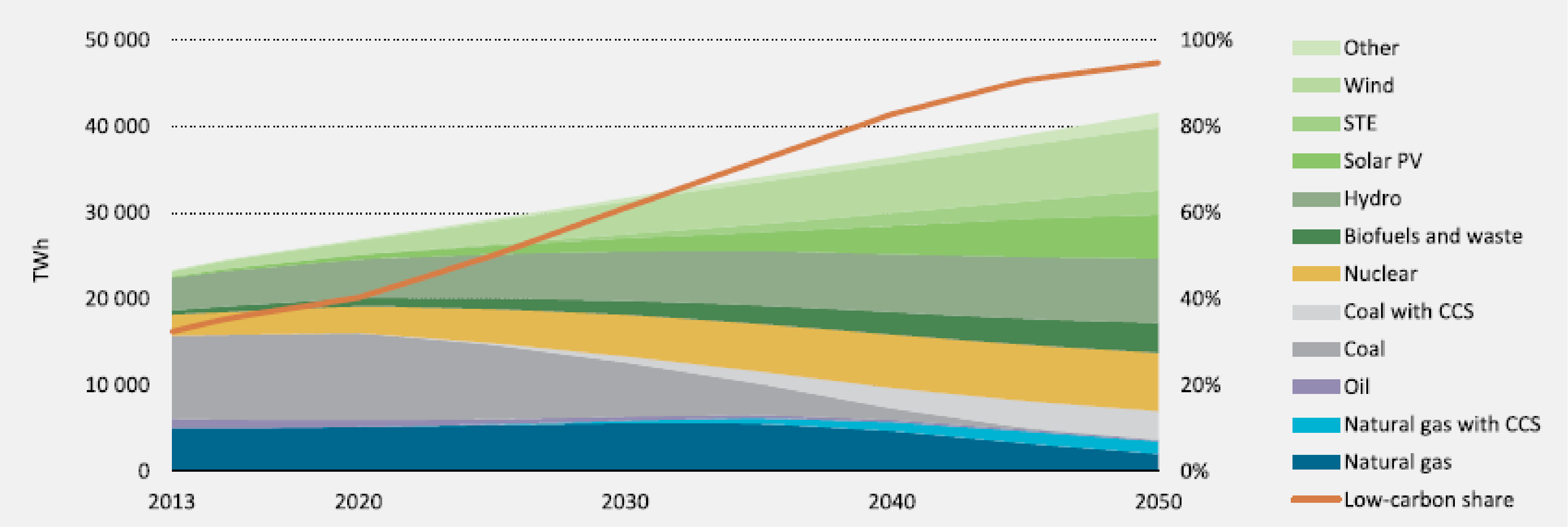

- NDD (2017/2018): "Maintaining Low Carbon Generation Capacity through LTO of Nuclear Power Plants: Economic, Technical and Policy Aspects".

# Outline

- Nuclear in a 2°C scenario (IEA projections)
- Long Term Operation – Economic prospects
- Technical aspects and Safety considerations

# Power sector almost completely decarbonised in the IEA 2DS

## Global electricity production and technology shares in the IEA 2DS



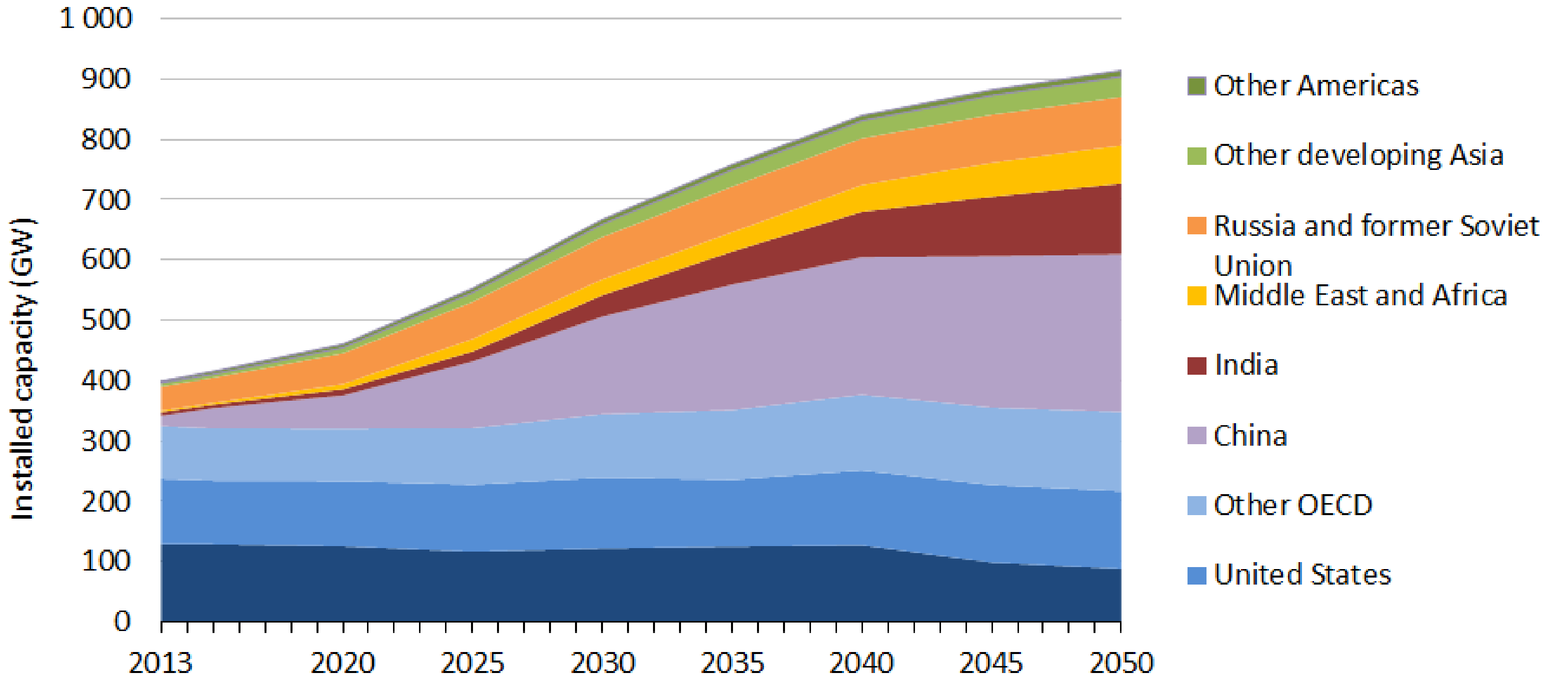

*Source:* IEA, ETP2016

2013:
68% fossil fuels
22% renewables
11% nuclear

2050:
17% fossil fuels
67% renewables
16% nuclear

- A complete reconfiguration of the electricity generation system is needed by 2050.
- Rise of nuclear would be accompanied by a *complete phase-out* of coal and oil, a drastic decrease of gas, large development of CCS and a massive increase of renewable energies.

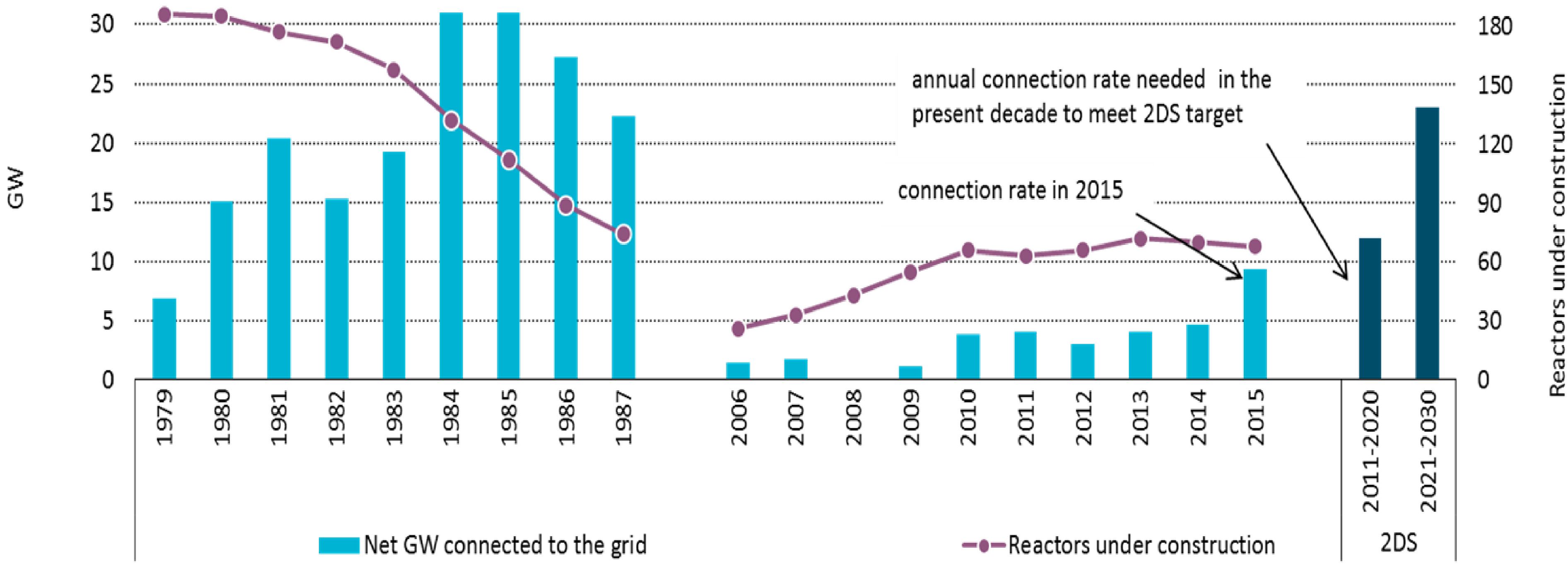
# IEA 2DS: role of nuclear




- Current nuclear capacity of 390 GW to more than double by 2050 to reach over 900 GW, share of nuclear electricity would increase from 11% to 16%.
- China sees largest increase in installed capacity and becomes largest nuclear power producer.
- Formidable challenge: multiply current capacity by 2.3 in 35 years and increase investments in nuclear up to USD 110 billion/year over the period 2016-2050 (21 USD billion in 2015).
- **Assumptions on LTO: 60 years in USA / 55 years elsewhere.**

o Similar trend by WNA and IAEA: WNA's objective of achieving 25% of supply by 2050.
IAEA says 385 or 632 GW (low or high growth) by 2030.

# Nuclear capacity additions, comparison with historic highs




- Required construction rates in 2DS scenario are in-line with past experience.
- **Nuclear is not on track to meet 2DS targets** – but situation improving with increase in construction starts and grid connections in 2015.
- **The successful Long Term Operation of existing NPPs is a key factor for nuclear reaching his expected 2DS targets.**

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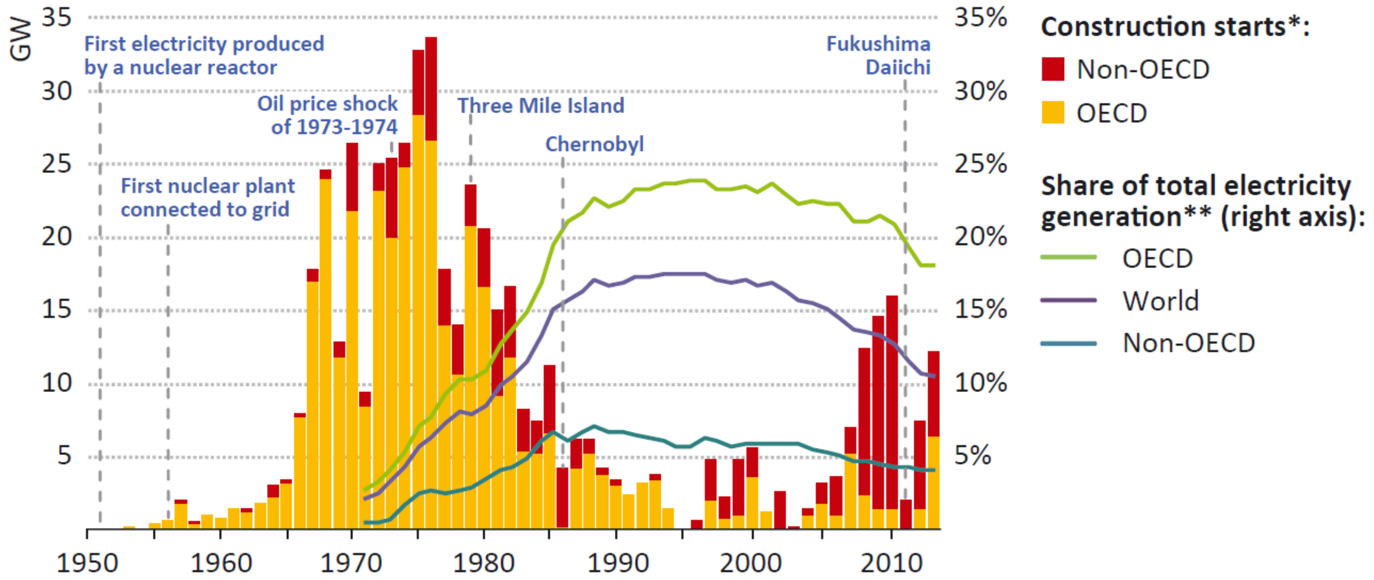
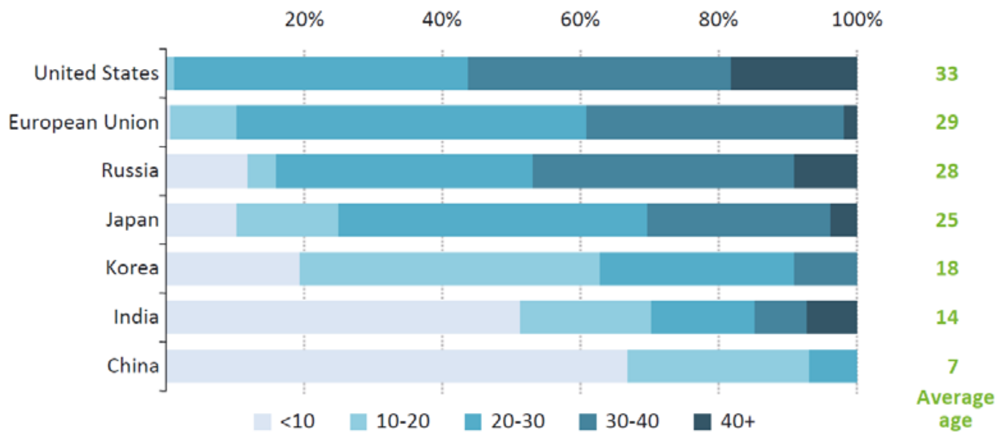
# New build in non-OECD countries - ageing in OECD countries



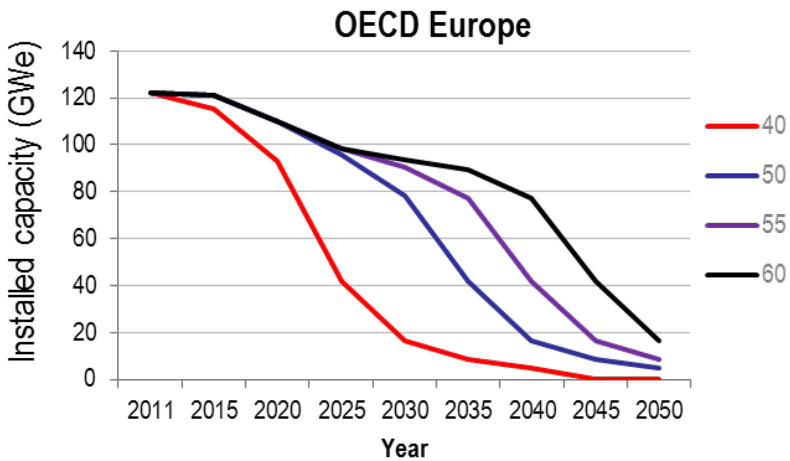



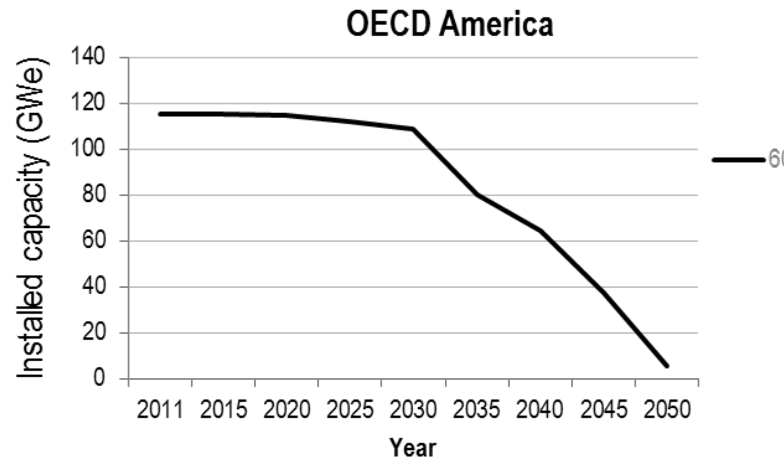

In 2013, 73% of all reactors in operation in the world were > 25 y. old

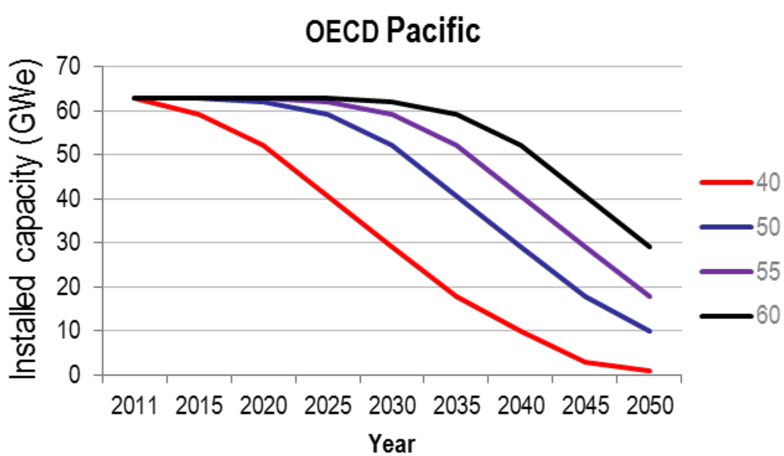
Source: IEA WEO (2014)

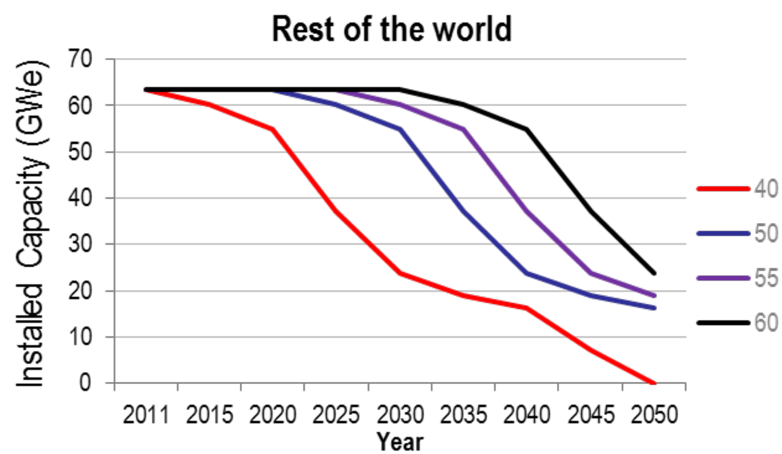
- Refurbishment and LTO of existing NPPs is important to the competitiveness of nuclear industry in OECD countries as they produce low-carbon electricity at stable and low cost.

# Evolution of nuclear capacity for different (assumed) lifetimes




- In the next decade some 160 units could be retired by 2030 if no LTO is pursued.
- Without LTO, nuclear capacity (and in general low-C generation) would thus fall dramatically

# Cost summary of LTO and refurbishment programmes in selected countries

- ✓ Direct **comparisons of LTO costs are difficult** (different sites, units, legislations, cost structure, etc.) → Each operator has its own definition of LTO scope/cost.
- ✓ Typical investment in LTO is in the range of **500-1100 USD/kW$_e$**.
- ✓ Costs of **post-Fukushima modifications** are **~10-20%** of initially projected LTO investment.
- ✓ **At 7% DR, LCOE is about 37-49 USD/MWh (10 years LTO) and 34-42 USD/MWh (20 years)**
- ✓ **LTO of existing NPPs is one of the lowest cost options to produce low-carbon electricity.**

| Country | Specific investment in LTE (Order of magnitude) | Comment |
|---|---|---|
| **Belgium** | USD$_{2010}$ 650/kWe | Including ~11% increase due to post-Fukushima measures. |
| **France** | USD$_{2010}$ 1090/kWe | Including all investments from 2011 to 2025: maintenance, refurbishment, safety upgrades, performance improvement; and ~10% increase due to post-Fukushima measures |
| **Hungary** | USD$_{2010}$ 740-792/kWe | Including 10-17% increase due to post-Fukushima measures |
| **Korea (PWR)** | USD$_{2010}$ 500/kWe | Including ~10% increase due to post-Fukushima measures. |
| **Switzerland** | USD$_{2010}$ 490-650/kWe | Specific future investment in NPP refurbishment and maintenance (approximately the double of the specific LTO investment) is USD$_{2010}$ 980-1 300/kWe. |
| **United States** | About USD$_{2010}$ 750/kWe | EPRI survey data and current spending on capital improvement. |
| *Russia* | *About USD$_{2010}$ 485/kWe* | *Data for Novovoronezh 5 unit (first series of VVER-1000: V-187).* |
| *Ukraine* | *About USD 300-500/kWe* | *Public statements by Energoatom and Ukrainian prime minister.* |

(Source: OECD/NEA, 2012)

# Recent economic developments

**The economic context has significantly worsened for utilities in many OECD countries. OECD Europe and the US in particular are experiencing:**

- Decrease in wholesale electricity prices in US and Europe affecting all generation sources and in particular baseload technologies (hydro and nuclear).
  - Electricity demand that is flattening or declining.
  - Overcapacity on generation side due to overoptimistic macroeconomic forecasts.
  - Decline in gas prices (shale gas) as well as coal.
  - Deployment of large shares of subsidised renewables (wind, solar) affecting all baseload sources including hydro & nuclear (Europe)
- Absence of an effective signal on carbon emissions
- Taxes imposed on nuclear power generation (Sweden, Finland, Germany)

**In some cases, NPP operators can barely cover their costs**

**Earlier than planned shut downs of NPPs for economic reasons (US, Sweden) even for plants that have had 60 years lifetime extensions (US).**

➡ **Is it worth investing in LTO and what are the conditions for enabling such investments?**

# Outline

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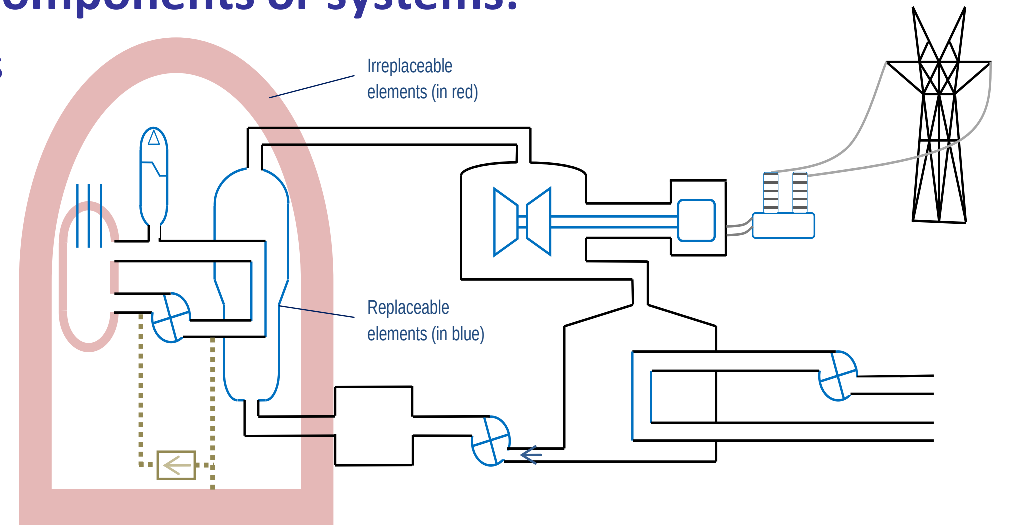
# Technical issues: Lifetime-limiting factors

**Fundamental challenge is demonstrating reactor components and systems continue to be fit for purpose as they age:**

- How predictable are aging mechanisms, and do they accelerate?
- Can degradation be monitored or measured?
- What is the risk that the behaviour of materials is not in accordance with extrapolations?

**Primary concerns are hard-to-replace components or systems:**

- Reactor Pressure Vessel and internals
- Concrete structures (containment)
- Some cables and instrumentation




**Sources of aging include:**

- Corrosion (in air, water, etc.),
- Embrittlement (due to thermal aging, irradiation),
- Fatigue
- Combinations – e.g. environmentally assisted stress corrosion cracking

**Considerable R&D has been conducted on material degradation of main NPP components**

# Regulatory considerations

## Ensuring the plant remains fit for the extended period of operation:

- Adequacy of technical knowledge base on aging
- Reliability of extrapolations
- Sufficiency of performance margins to account for uncertainties
- Requirements for inspection programmes to monitor degradation

## Different regulatory approaches in different countries:

- Licence renewals and Periodic Safety Reviews are the two basic regulatory approaches adopted for authorising LTO.
- No legal limit of the licence. Nuclear facilities can operate for as long as the licensee can demonstrate that it is safe to do so via PSR (France, UK, Korea) or via continuous monitoring (Switzerland).
- Operating lifetime is limited to the original lifetime (30 y in Russia and 40 y in the USA). Licences can be renewed for a longer period (20 y in USA) upon satisfaction of safety and environmental criteria.

# Conclusions

- Nuclear plays a major role in decarbonisation scenarios, possibly one of the main low C source of electricity to 2050 and beyond.
- Long Term Operation of NPPs is important to maintain low-carbon generation capacity for the next 2-3 decades.
- Currently, LTO programmes cost in the range of $USD_{2010}$ 500 - 1100/kWe, depending on the extent of prior refurbishments and additional regulatory requirements or other plant performance improvement (e.g. power uprates).
- LTO of existing NPPs is one of the lowest cost options to produce low-C electricity.
- Regulators are looking at how to ensure safe long-term operation of NPPs and that the NPP continue meeting the stringent safety criteria of nuclear industry.
- Research in ageing of systems and materials is needed to support safe Long Term Operation of existing NPPs for 60 years of operation or more.
- There are several risks and uncertainties that can influence LTO programmes: public acceptance, changes in national policies, security concerns or changing economic conditions.

# Thank you for your attention

**NEA studies are available on-line**

http://www.oecd-nea.org/ndd/reports/2012/7054-long-term-operation-npps.pdf

http://www.oecd-nea.org/ndd/pubs/2015/7257-techroadmap-2015.pdf

http://www.oecd-nea.org/nsd/docs/2012/cnra-r2012-5.pdf

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