IMPACTS OF CLIMATE CHANGE ON NUCLEAR SAFETY AND SUPPLY SECURITY

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Outline

- Contribution of new nuclear power plants to climate protection
- Contribution of nuclear power plants to energy supply security
- General consideration of ageing reactors
- Climate Change and nuclear power plants

1 Contribution of new NPPs to Climate Protection

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- **Expanding nuclear power is impractical as a short-term response to climate change**
  - *Planning and approvals can take a decade and construction another decade.*
  - *For Olkiluoto 3 the planning-to-operation (PTO) time is at least 20 years. For Hinkley Point C, a PTO time of 17 to 19 years is expected, but…*
  - *NPPs take 5–17 years longer to build than utility-scale solar or onshore wind power, so existing fossil-fueled plants emit far more CO_2 while awaiting substitution by the nuclear option. Note: In 2018, non-hydro renewables outpaced the nuclear program in China by a factor of two.*
- **Additionally there are comparatively high costs and investment risks of NPPs**
  - *Between 1951 and 2017, none of the 674 reactors was built with private capital under competitive conditions.*
  - *Nuclear energy is never profitable. Society will be asked to bear a very large part of the costs.*
- Considering the full nuclear chain, the overall CO_2 emissions from NPPs are about 10 times higher than energy production from onshore wind generators….
- **All in all, there is a negative contribution of new NPPs to climate protection**

2 Energy Supply Security in times of climate change

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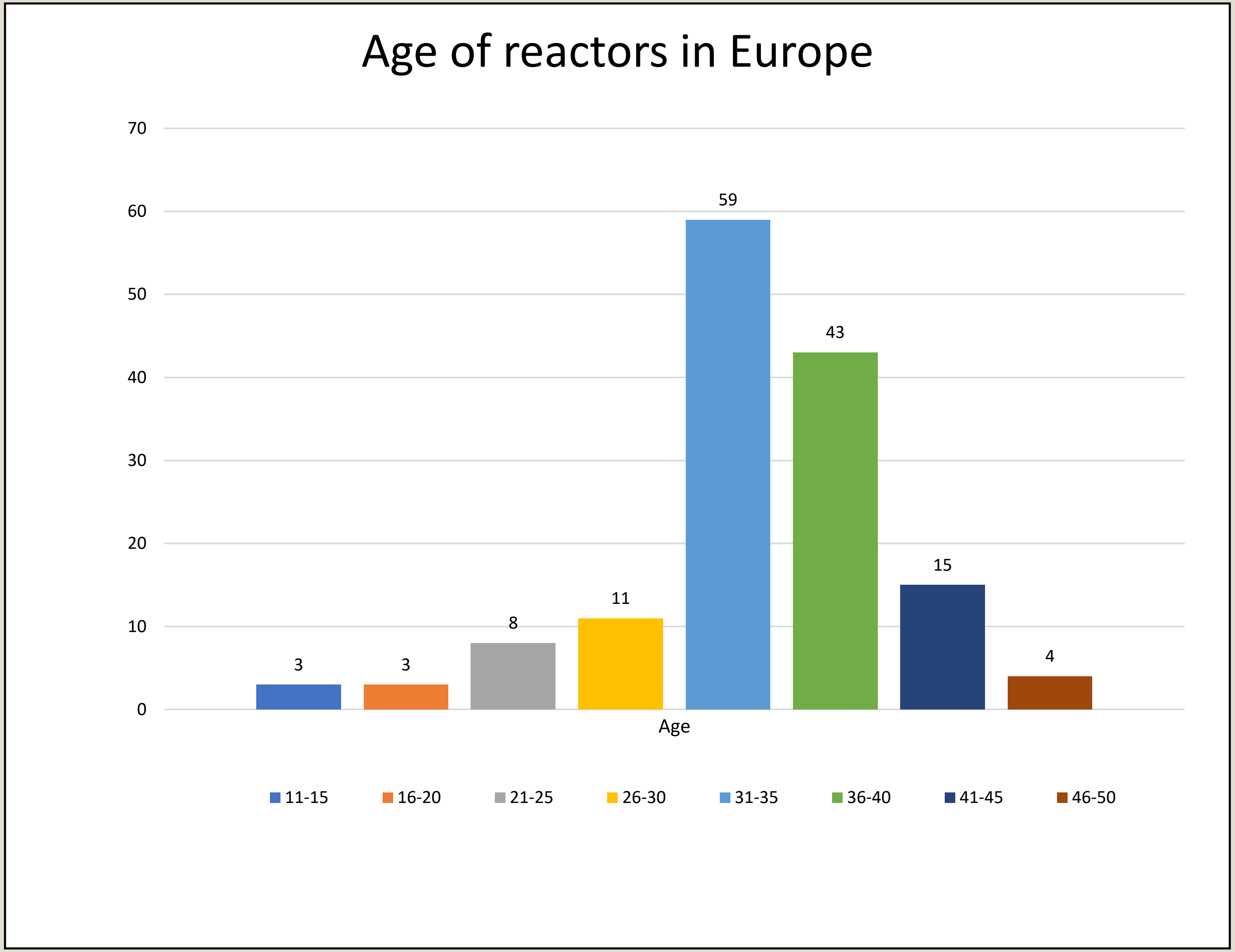
- There is limited contribution of ageing NPPs to energy supply security due to age related outages
  - *For example, due to continuous technical issues and extended outages, the average load factor of the Belgian fleet was 48.6 percent in 2018. Average age of its 7 reactors is about 40 years.*
- On top, there are several climate change related outages
  - *Near to 40% of the NPPs in Europe have already experienced cooling problems because of high temperatures.*
  - *Heat waves caused unplanned outages of NPPs*
  - *In 2018, for example, France saw an 0.7% loss of output due to reduce power during heat waves*

3 Ageing Reactors

Situation in Europe

- Europe is looking at a fleet of aging reactors, currently planning to continue their operation for a long time
- Status: End 2018



Physical Aging

- Physical aging, degradation of structures, systems and components (SSC), increases the risk for abnormal operational occurrences and accidents.
- Aging management program (AMP) works only well with known aging mechanisms and accessible and replaceable SSCs
- However,
  - *some components cannot be replaced (example: reactor pressure vessel RPV),*
  - *some components are difficult to access (example: piping in concrete),*
  - *not all aging effects are known*
- Moreover, due to the economic situation operators intend to avoid comprehensive checks and maintenance.
- Additionally, now long-lasting heat waves can lead to unexpected acceleration of ageing processes
- Thus, all in all ageing effects threaten the safety of old NPPs

Obsolescence (Conceptual/Technological Ageing)

- Safety design of NPPs is very important to prevent as well as to deal with accidents.
- Concerns are growing due to the Fukushima accident, as it revealed that there could be basic safety problems with the old units, whose design was prepared back in the sixties or seventies of the last century.
- Their safety design is outdated and showing deficiencies, which cannot be resolved by performing back-fitting measures.
- There are less requirements for redundancy, diversity, physical separation of safety systems; for protection against external hazards and to manage a core melt accidents.
- Therefore, compared to current safety standards, the probability of an accident is high and the ability to prevent a major release of radioactive materials is very low.

4 Climate Change and NPPs

Climate Change and NPPs Introduction (1)

- Sea-level rise, shoreline erosion, coastal storms, flooding due to local extreme rainfall - all potentially catastrophic phenomena associated with climate change – are expected to get more frequent. **Flooding** could lead to nuclear disaster.
- Of relevance for the safety of NPPs can be prolonged heat or cold waves.
- Heavy precipitation (rain or snow), high or particularly gusty winds, snowstorms, freezing rain, thunderstorms, lightning, hail with particularly large grains and tornadoes are also among the potential hazards.
- Snowstorms and ice build-up can block cooling water inlets, especially when wind is blowing at the same time.
- ……

Climate Change and NPPs Introduction (2)

- Climate Change affects nuclear energy production in several ways, e.g.:
  1. *Efficiency of NPPs decreases with increasing temperature,*
  2. *Some NPP sites may lose safety, with sea-level rise being of particular importance and*
  3. *Extreme weather events threaten the safety of NPPs. Frequency and intensity of extreme weather events increase*
- You have to distinguish climate change related phenomena between Gradual Climate Changes (GCC) (e.g. rising average temperature) and Extreme Weather Events (EWE).
- Decrease of efficiency of NPPs as well as location issues are primarily associated with GCC, while safety issues are more linked to EWE
- However, the effects of GCC and EWE are linked.

Sea level rise

- According to IAEA's current global safety standards, published in 2011, operators should only take into account a sea-level rise of 18- to 59-cm projected by 2100.
- However, these values of the Intergovernmental Panel on Climate Change (IPCC), published 2007, are outdated.
- The IPCC report, published in 2014, see a sea level rise up to 1 m by 2100.
- Other experts derive a possible non-linear rise in sea level of 1 m within the next 50 years, and a rise of another 1.4 m within the following decade from ice surface losses in Greenland
- By the time Hinkley Point C is finished, possibly in 2028, the concrete seawall will be 12.5 meters high, and should withstand sea-level rise and the storm surge
- But the plans were drawn up in 2012, before the increasing volume of melting of the Greenland ice.

Extreme Weather Events

- Various types of EWE can affect critical safety systems and increase the risk
- Many safety threats from EWEs can be minimized by shutting down the reactors until an event has passed, but this strategy leads to increasing outages.

- EWE can also cause a failure of the electric power supply or the heat sink.
- After the Fukushima accident, measures to cope with these situations are implemented.
- However, these measures are often only the deployment of mobile equipment, which would be difficult to use in an accident situation.

Example for new Extreme Weather Events

- We are observing **persistent weather patterns more and more frequently**
  - *The summer of 2016 in Europedemonstrated that a single weather pattern can trigger both localised intense precipitation with flash floods and large-scale precipitation with river floods.*
  - *Following the events, it should be clear that extreme amounts of precipitation within a very short time are possible almost anywhere.*

- A scientist warned 2019 about **super-storms and related giant waves**, able to push 2300-ton boulders along the ocean floor, higher than the one that damaged the Fukushima power plant.

Example for Flooding Event

- In December 27, 1999: The French electricity grid was hit by storms
- A flood caused by the rising tide with exceptionally strong winds resulted in the partial flooding of the Blayais NPP site.
- Winds pushed the water over the dike.
- Water surged into underground service tunnels and broke through doors. (*Before this incident, EdF declared that the underground tunnels were perfectly safe.*)
- Water flooded and destroyed pumps and other equipment
- Before the flood, EdF had been planning to raise the dike by 50 cm, as required. But work had been delayed and outdated: The wave rose to more than 1 m above dike level.

Lessons Learned ?

- On 12 October 2012, TEPCO **admitted that the company had failed to prevent the Fukushima accident**.
  - TEPCO **did not learn a lesson** from the **flooding at the Blayais NPP on December 27, 1999**
  - Management assumed a **severe accident was extremely unlikely** and **feared that retrofitting safety systems would increase anxiety among the public**,
  - TEPCO also feared back-fitting would require a **costly shutdown period**.

Lessons learned from Fukushima

- Fukushima accident highlighted the importance to address external hazards.
- In September 2014, the WENRA published its Safety Reference Levels (SRLs), including a new SRL T for Natural Hazards:
  - A protection target for events of a frequency of 1/10,000 per year is set;
  - the protection concept to minimize threats should rely preferably on **passive features**; (*however, this is often not possible for old plants*)
  - Sufficient margins should exist before **cliff edge effects** may occur. (*impossible or too expensive to implement for old plants*)
- Further detailed analysis of an event will not be necessary, if it is shown that its occurrence can be considered **with a high degree of confidence to be extremely unlikely.**

Difficulties for Sufficient Protection

- Estimation of probabilities and intensity for extreme events resulting from climate change is extremely difficult due to fact that there is no sufficient database.
- Past events are becoming an increasingly inappropriate basis for the prediction of future events.
- Furthermore, because the situation is constantly evolving, any data may be outdated by the time their evaluation is concluded.
- The time lag is still more drastic for the drafting of new rules and regulations by the authorities, and their implementation by the NPP operators.
- It seems hardly possible to win this race against time – particularly in face of economic pressure that might lead to result that only low-cost measures are realised.
- In addition, it is *normal* practice to delay backfitting measures for decades.

Conclusions

- New NPPs have a negative contribution to climate protection
- NPPs are prone to insolvable economic and environmental problems. Additionally, they are connected to problems of reactor safety, waste storage, weapons proliferation, and vulnerability to attack.
- Long term operation of the aging fleet of nuclear reactors increases the risk for significant radiological releases in Europe.
- Climate change increases the risk of accidents, while the energy supply security further decreases.
- Thus, climate change guarantees lower profits but requires expensive backfitting measures.
- Adaption measures to climate change are delayed or even avoided, so the risk of ageing plants continues to increase.
- Energy and climate policy should therefore target a quick withdrawal from nuclear energy.
- Subsidies for life-time extensions are not recommended because they support the risky, uneconomical nuclear industry.