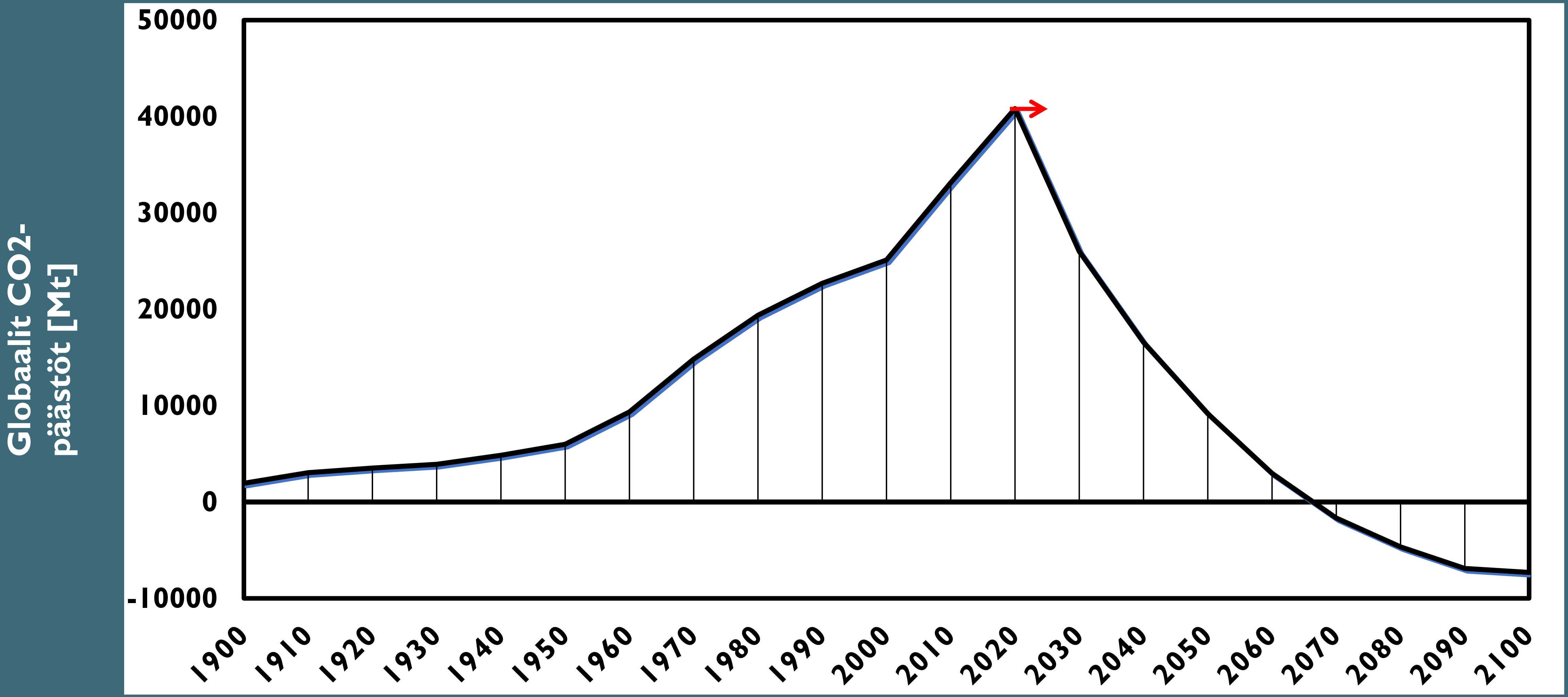
Why would a green politician endorse nuclear power?

- Speech at Energiforsk Annual Nuclear Conference

Atte Harjanne 21.1.2025

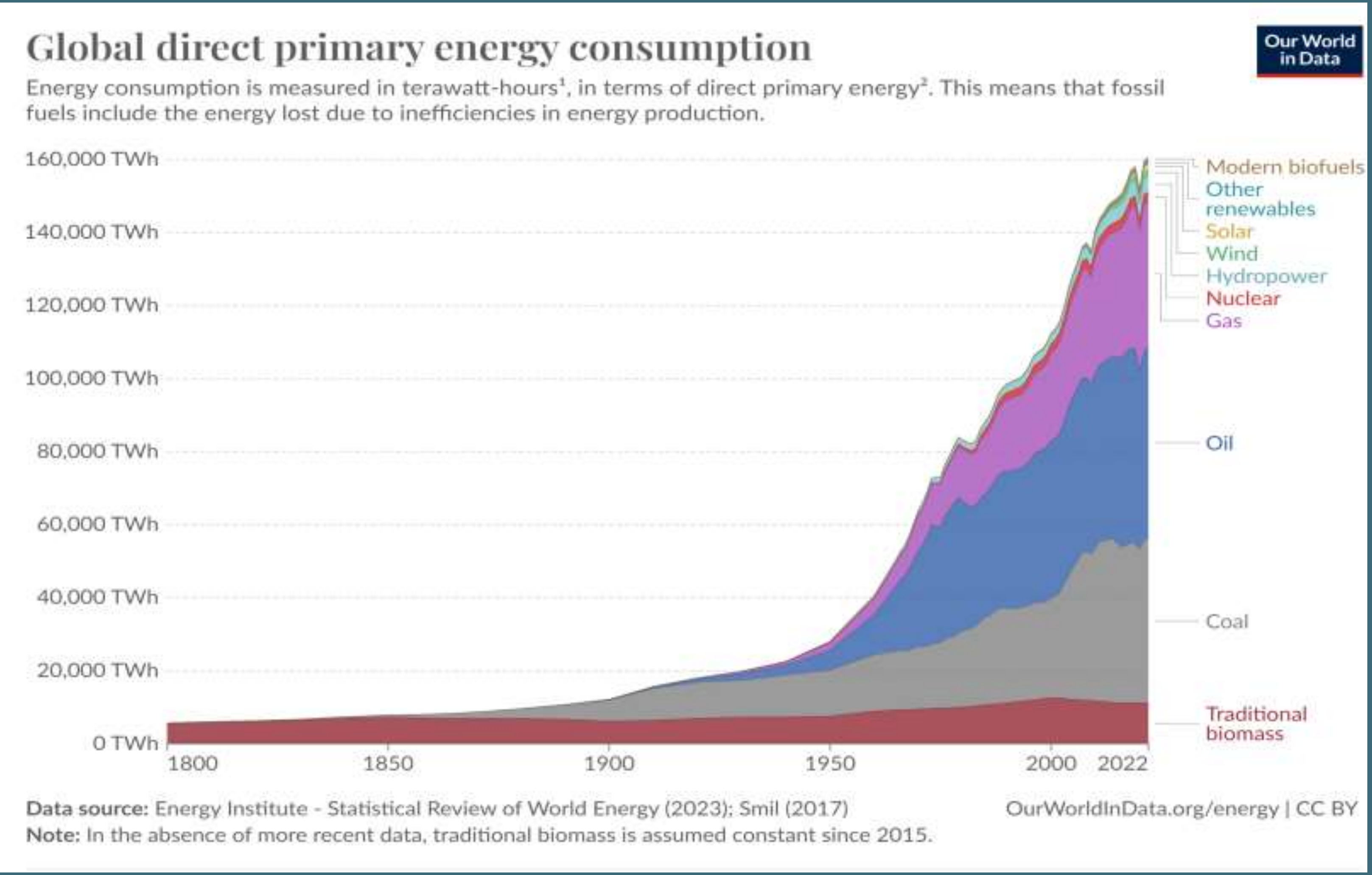
Photo: Unsplash / Mika Korhonen

Global emissions – the big picture



Lähteet: IIASA AR6 Scenario Explorer & Our World in Data

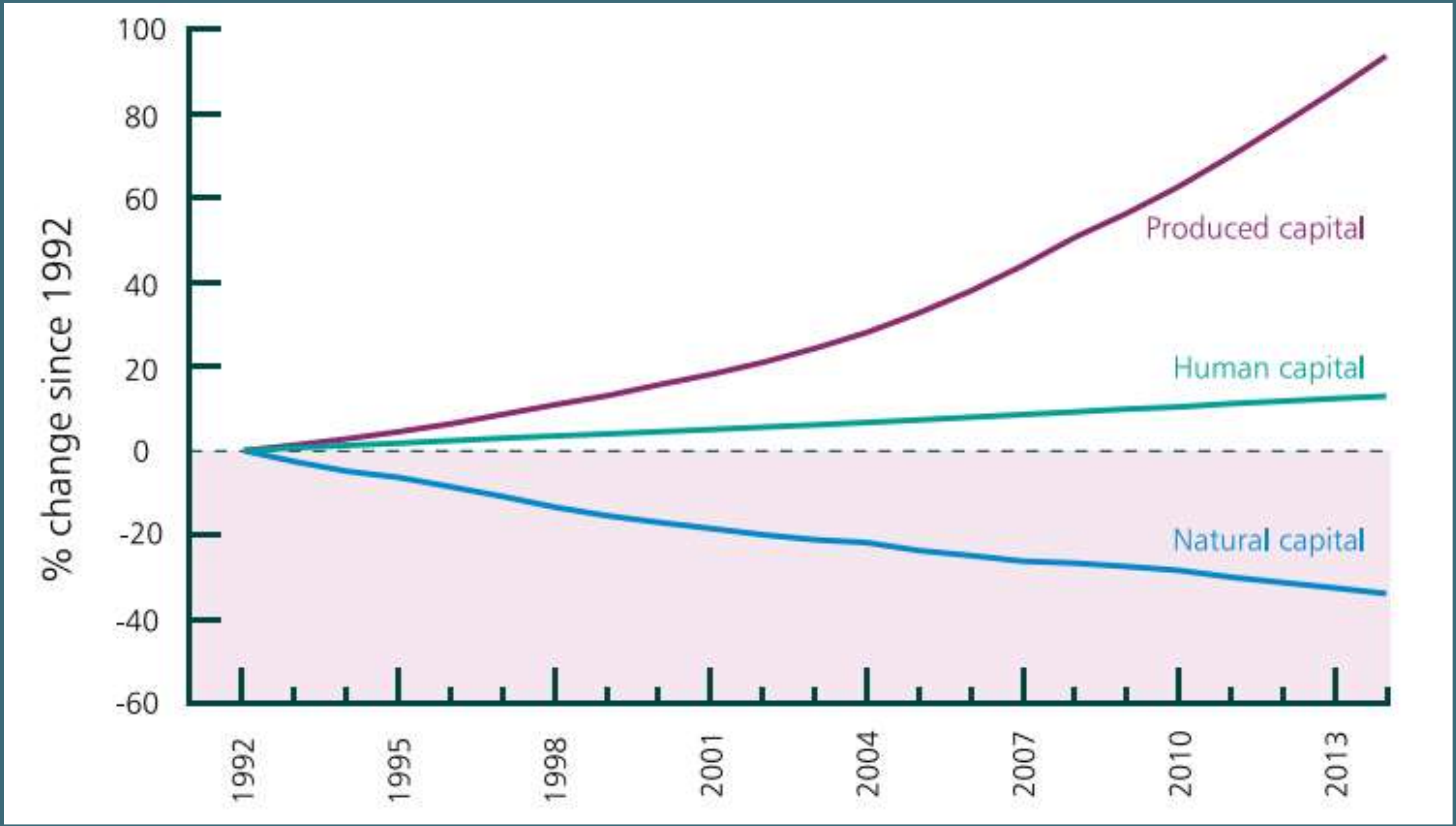
Global energy – the big picture



Oil, coal & gas ~ 80 %

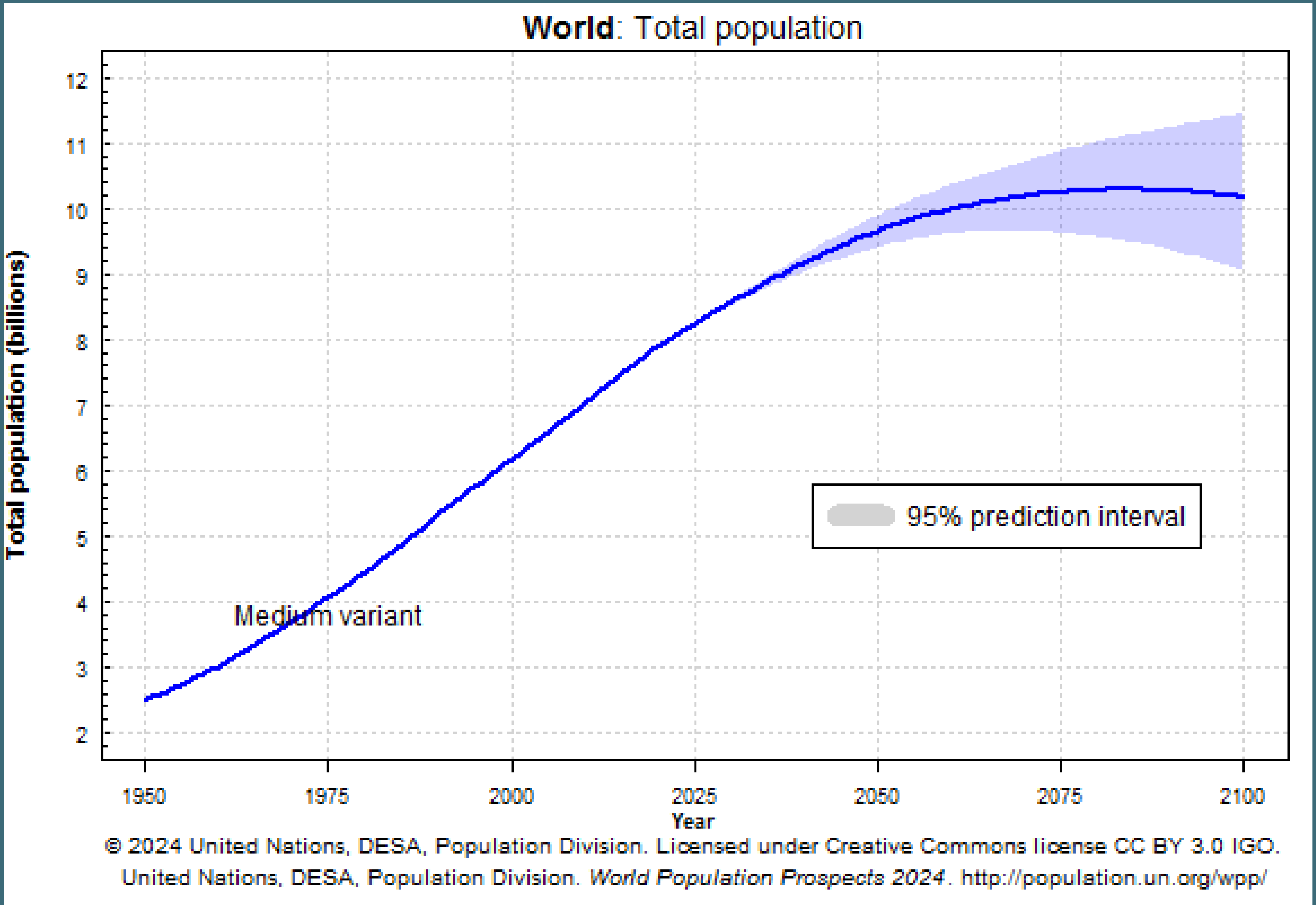
Unsustainable biomass ~ 7 %

Biodiversity – the big picture



Sources: Dasgupta Review / Managi & Kumar: Inclusive Wealth Report 2018: Measuring Progress Towards Sustainability

Global population – the big picture



2025: over 600 million people without access to electricity

Conclusions

- Enabling sustainable development requires massive amount of clean energy while at the same time limiting land and resource use
- Nuclear energy is essential tool in this challenge
- Security also a factor: reliance on fossil imports makes Europe vulnerable
- Nuclear vs renewables is a wrong dichotomy. We need both.
- Typical counter arguments and responses:
  - High cost & long construction time – not inevitable and even if partly true, nuclear is still needed
  - Waste – Can be safely managed (final repository in Finland starting soon), the volumes are small compared to the energy produced

Photo: Hannu Häkkinen, Finnish Heritage Agency database finna.fi

Kiitos!
Tack!
Thank you!

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linkedin.com/in/atteharjanne

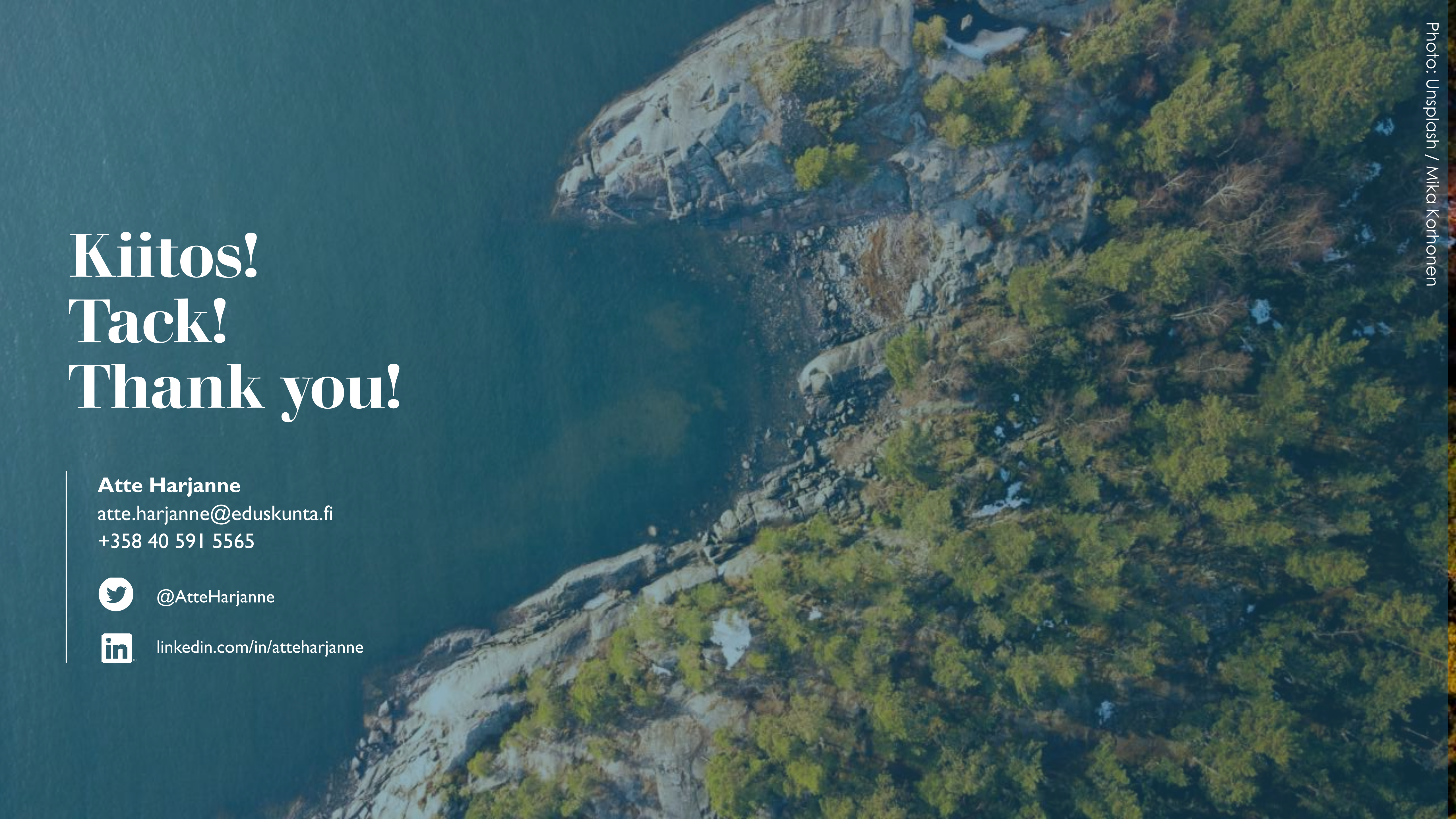


Photo: Unsplash / Mika Korhonen

80 is the new 60!

Long Term Operation of Nuclear Power

Johan Lundberg, CEO of OKG Aktiebolag

Global Uniper at a glance

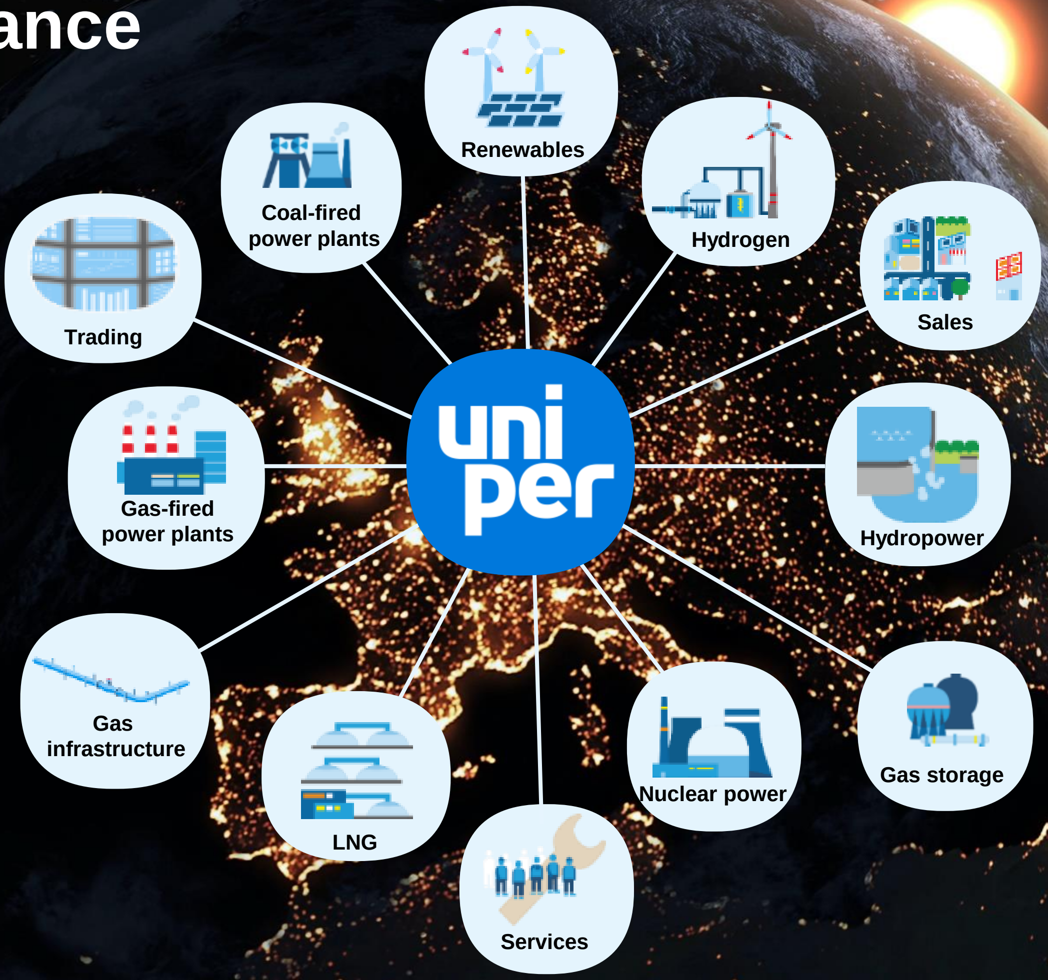
6,863 employees ensure security of supply in Europe

Active in more than **40** countries

170,92 billion euros in sales (2023)

6,367 billion euros Adj. EBIT (2023)

~ 22.4 GW generation capacity



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Uniper has a strong ownership in Swedish NPP´s

Ringhals (RAB)

RAB 1 (2020)
RAB 2 (2019)
RAB 3
RAB 4

Barsebäck (BKAB)

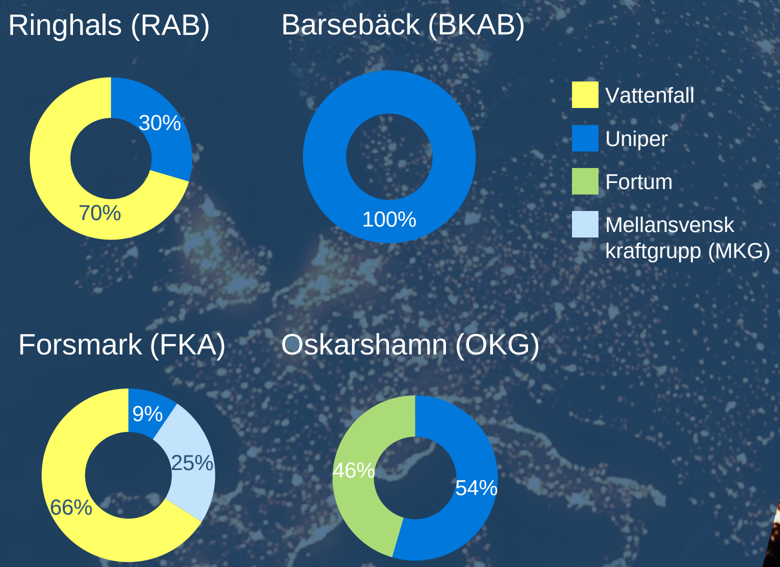
BKAB 1 (1999)
BKAB 2 (2005)

Forsmark (FKA)

FKA 1
FKA 2
FKA 3

Oskarshamn (OKG)

OKG 1 (2017)
OKG 2 (2016)
OKG 3



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Rationale for Lifetime Extension to 80 years

Nuclear power provides beneficial capabilities for a fossil-free electricity system with increased penetration of intermittent power production.

Lifetime extension is recognized as a cost- and resource efficient way to add fossil-free and plannable power production.

Positive experiences from lifetime extensions (40-60y) supports interest for further lifetime extensions (60-80y) with U.S. as a frontrunner.

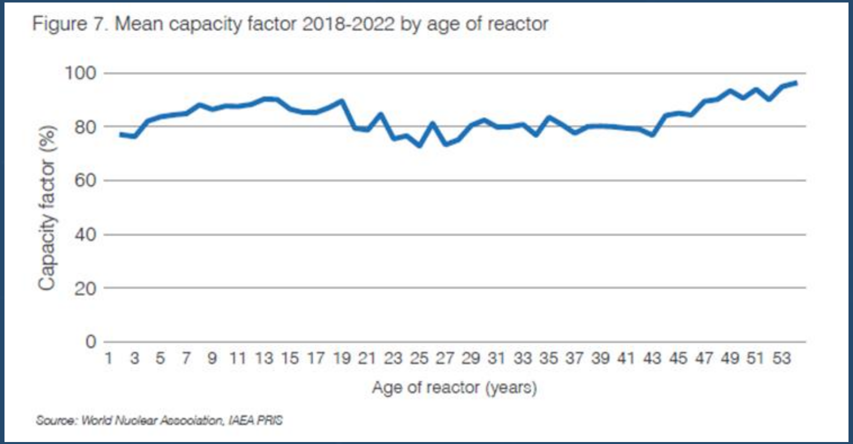
Additional lifetime extension of existing nuclear is a cornerstone in the Swedish national strategy to meet forecasted demand driven by electrification of industry and transportation.

It´s about the numbers…

With a decision to extend the operating time of the Swedish nuclear power fleet to 80 years, comes the potential to:

- Maintain fossil-free plannable power for 20 years **(~ 7.000 MW)**
- Expand fossil-free plannable power over 20 years **(~ 1.000 TWH)**

Age is not an issue…



Age and availability - not correlated!

- A result of proactive modernization measures and maintenance programs.
- Positive experience from national and international modernization programs.

Our ambition is that 80 will be the new 60 for O3

2020 Initial feasibility study of conditions for extending the operation of Oskarshamn 3 (O3) to 80 years.

2024 Decision-in-principle taken to proceed with necessary preparations and studies to take a final decision for extending the operation of O3:

- Aim for 80 years operation for O3
- Start preparation work for a final decision planned around 2030

ELTO – Step 2
(Extended Long Term Operation)

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ELTO Step 2 –
Planning and preparation for a final decision for O3

Technique

Define and refine scope, risks, technical issues, costs and time plan related to the plant scope developed in pre-study

Resources

Evaluate critical resources and competencies, both internally and externally for project phase of ELTO

Set-up ELTO

Define organizational set-up to coordinate and optimize the identified projects and activities required for ELTO

Co-operations

Develop a strategy for critical suppliers and technologies but also co-operations with other BWR-plants.

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Critical factors for a final decision of Lifetime Extension to 80 years for O3

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Lessons learned from previous modernizations

- Don´t underestimate the challenge of a modernization program, especially if several programs are run in parallel in Sweden!
- Combined modernization and power-uprate is extra challenging as plant configuration is changed.
- Chose suppliers carefully – they will hopefully be your future partners.
- Modernization programs gives excellent learning opportunities for next generation of nuclear professionals in all parts of the industry.

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Challenges for Lifetime Extension investments

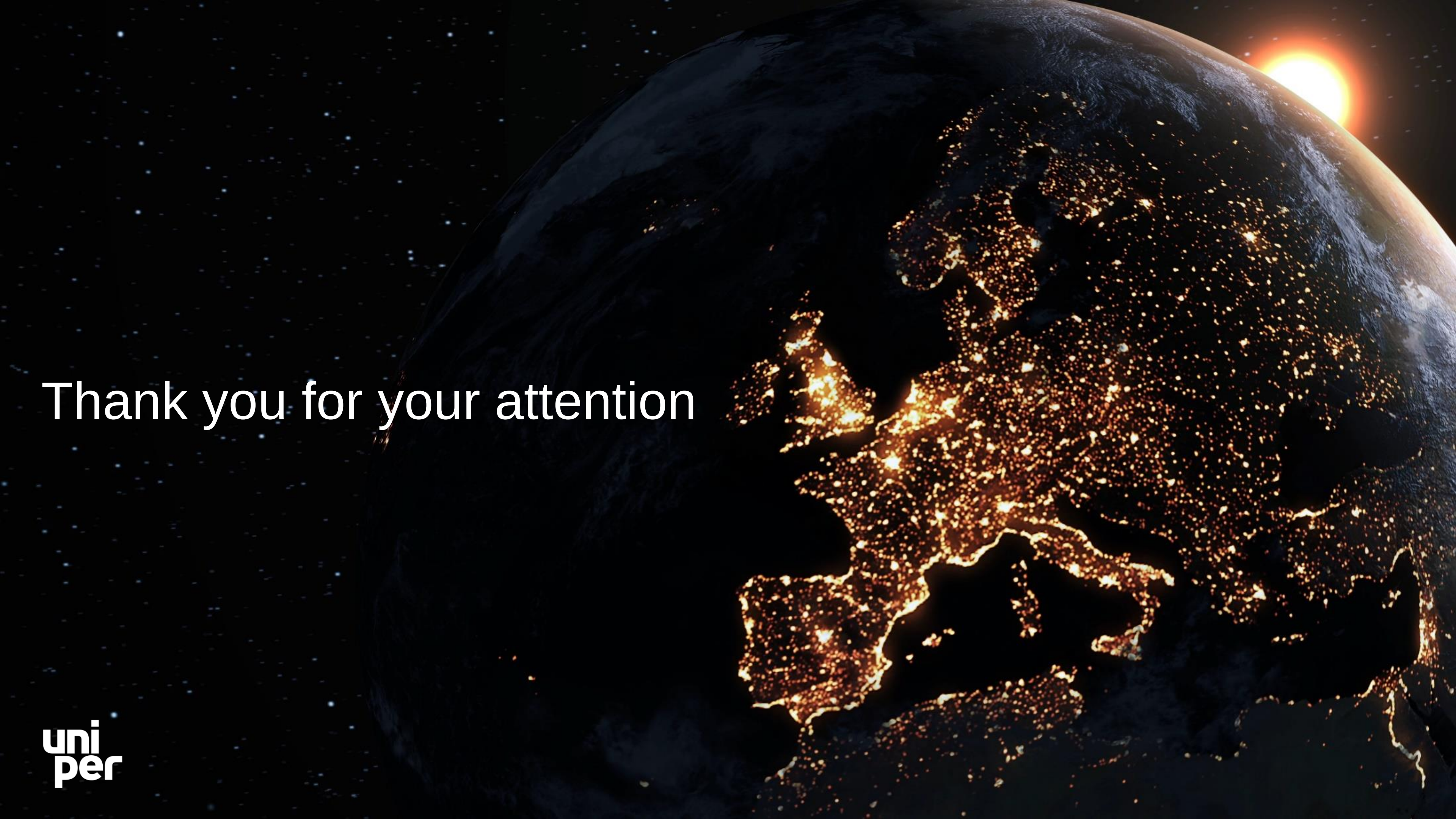
- Lack of insight that Sweden needs lifetime extension of existing reactors to reach national electrification, and climate goals by 2045.
- A large investment project must be founded on a stable business case and associated risk evaluation including all aspects of the life cycle.
- Electrification efforts may create challenging market situations eroding the basis for investment in lifetime extension.
- Political and regulatory risks (market risks included) are challenging to handle in a lifetime extension decision.

Summary

Nuclear power – a cornerstone in the Swedish electricity system providing value and stability for more than 50 years.

Uniper investigates the potential for continued operation of Oskarshamn 3 to 2065 (80 years). Conducted studies shows promising results.

We have the tools to carry out lifetime extensions, but several external factors have significant impact on the investments. Politics and market needs to cooperate to provide right conditions.


Thank you for your attention

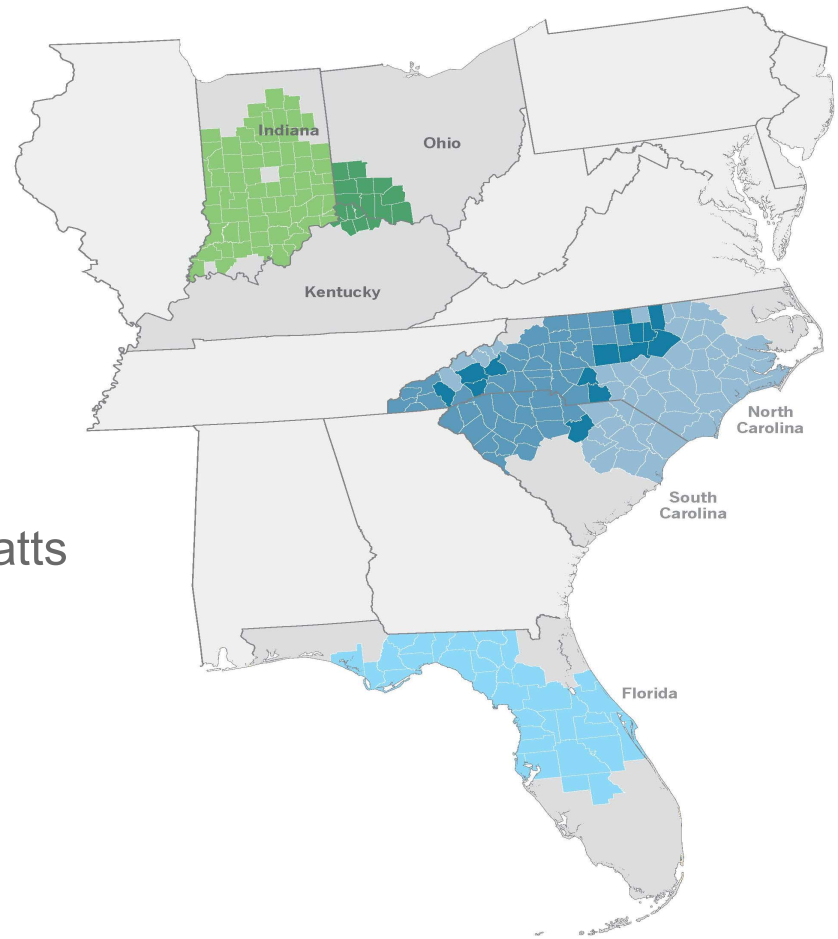
Subsequent License Renewal at Duke Energy

Gregory D Robison, PE
Director, Nuclear License Renewal

January 22, 2025

Duke Energy Overview

- Electric customers: 8.4 million
  - Six States: North Carolina, South Carolina, Florida, Indiana, Ohio, Kentucky
- Total generating capacity: 54,800 megawatts
- Total nuclear capacity: 10,773 megawatts
  - Six nuclear sites
    - Three in South Carolina
    - Three in North Carolina



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BUILDING A SMARTER ENERGY FUTURE ®

THREE NUCLEAR STRATEGIES
FOR A CLEAN ENERGY TRANSFORMATION

- **TODAY**, continue safe, reliable, innovative and efficient operations
- **TOMORROW**, renew current operating licenses and produce more energy by upgrading components and gaining efficiencies
- For the **FUTURE**, invest in new nuclear technologies and build advanced nuclear plants

Nuclear generation is the only carbon-free energy source that is always on and available 24 hours a day, complementing renewables like solar and wind power.

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License Renewal Road

1980's

1990's

Aim: Stable license renewal regulatory process

Focus: Renewal aging programs on passive hardware

2000's

2010's

Investment: Longer business window allows upgrades

2020's

Direction: Renewal Road supports today's business direction

2030's

Understanding: Value of strong maintenance investments

Recognition: Holistic aging management view – both active & passive hardware

Achievement: Initial license renewals to 60 years

Pursuit: Subsequent license renewal to 80 years

Opportunity: Next Generation

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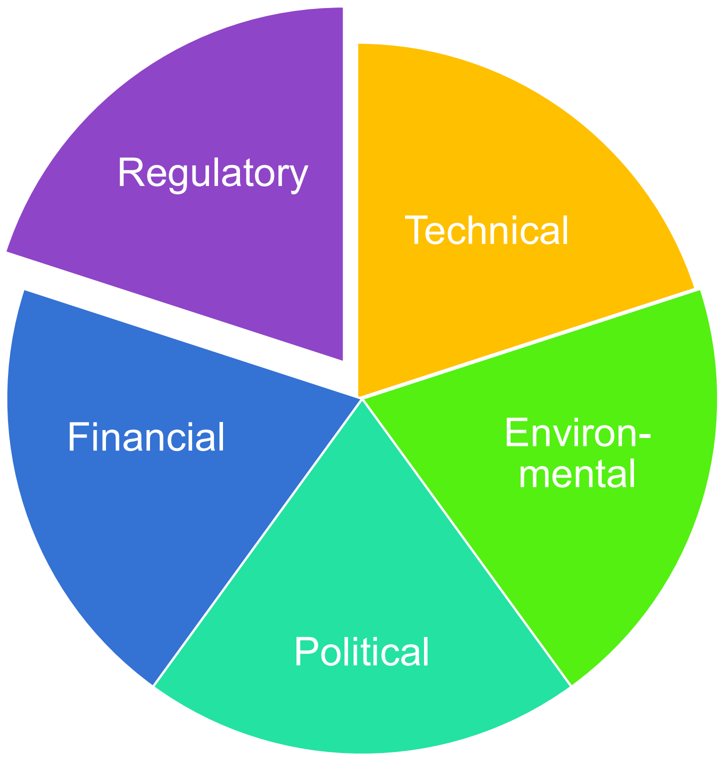
Keys for Subsequent License Renewal

Continued Stable Regulatory Renewal Program

- The ongoing, stable regulatory renewal program has continued to mature as we now "Think 80"
- The regulatory renewal program is:
  - Appropriately designed to focus on the key technical safety and environmental topics
  - Captured in useful regulatory guidelines
  - Built as a learning program where operating experience will continue to inform
- Continued operations under this program will be the backbone of the clean energy transformation

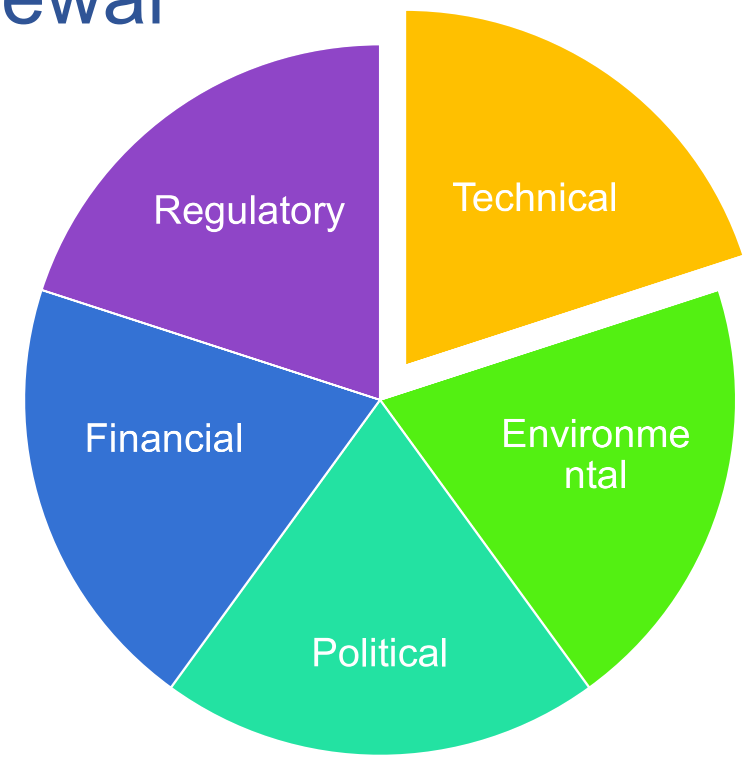


Keys for Subsequent License Renewal

Technical Challenges

- Mature the Aging Management Programs
  - Using contemporary technology
  - Learning from operating experience
  - Letting insights lead to actions

- Know the Seasoned Challenges
  - Reactor vessel
  - Reactor vessel internals
  - Concrete structural issues
  - Buried piping
  - Electrical cables



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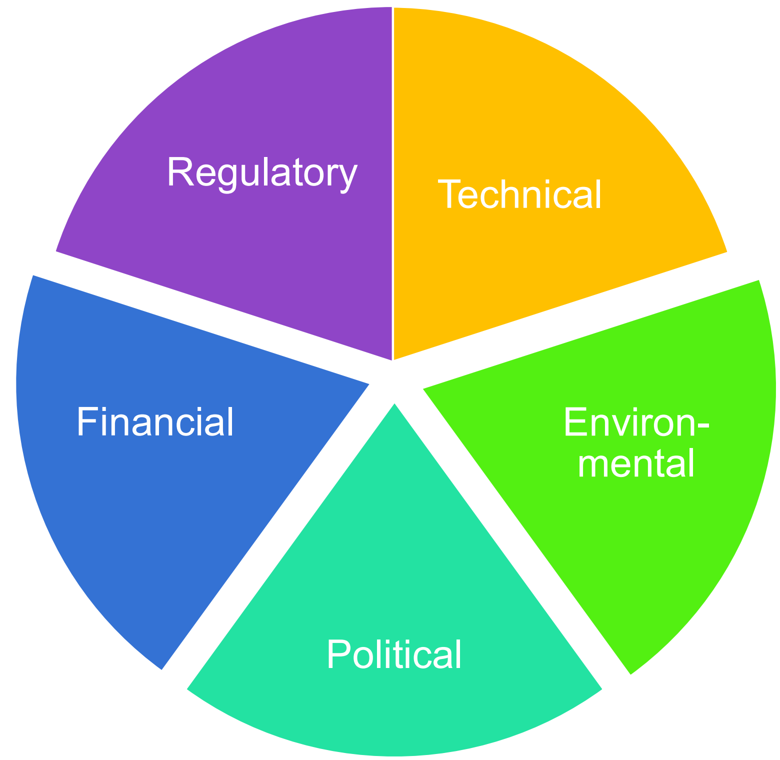
Keys for Subsequent License Renewal

North Carolina Clean Energy Legislation

- Law: North Carolina House Bill 951 signed into law in 2021
  - Directs a 70% reduction in carbon dioxide emissions by 2030 (from 2005 levels), and
  - Net-zero carbon emissions by 2050

- Order: North Carolina Utilities Commission Carbon Plan Order
  - Subsequent License Renewal is foundational to Duke Energy meeting its clean energy goals and achieving the Carbon Plan mandates
  - Pursuit of subsequent license renewal of the existing nuclear fleet is reasonable and appropriate



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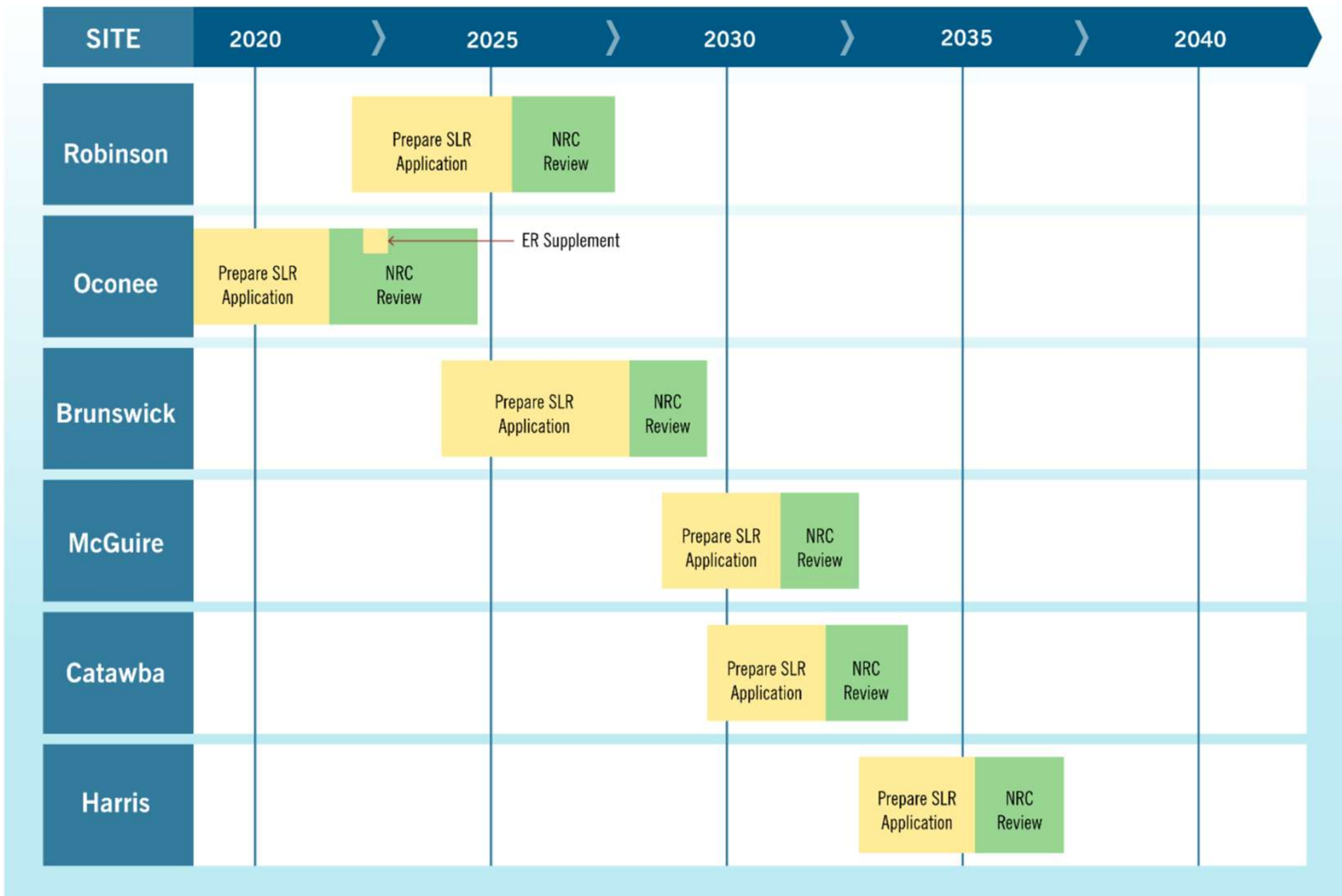
Duke Energy Subsequent License Renewal Timing



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Subsequent License Renewal Makes Business Sense

- Backbone of the clean energy transformation, as nuclear power is recognized as a vital clean energy source to be maintained in the Carolinas.
- Bridge to new carbon-free baseload technology
- Insurance policy that allows the opportunity to operate the nuclear plants to 2050 and beyond.
- Opportunity, not obligation, to operate for 80 years – investment payback is less than one fuel cycle.
- Prepares Next Generation to continue the same focus on safety, reliability and cost efficiency.

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Long-term operation of Loviisa NPP

Elina Brunner, Director Engineering and investments, Loviisa NPP / 22.1.2025

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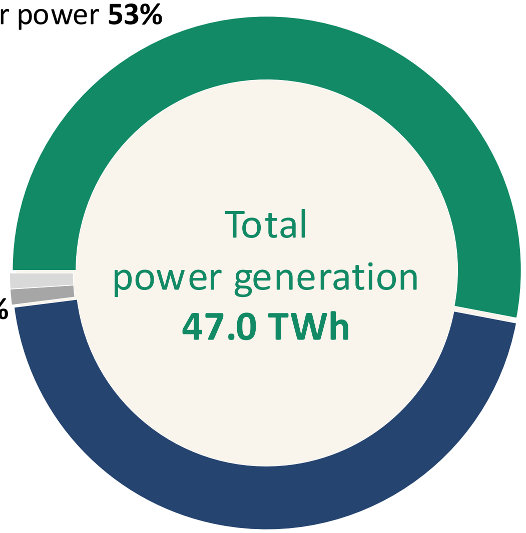
Fortum - We are a strong Nordic nuclear operator

Key figures 2023

Nuclear generation	**24.8 TWh**
Total nuclear capacity	**3.2 GW**
Share of Fortum's total power generation	**53%**
Nuclear professionals	**~750**

Fortum's power generation in 2023

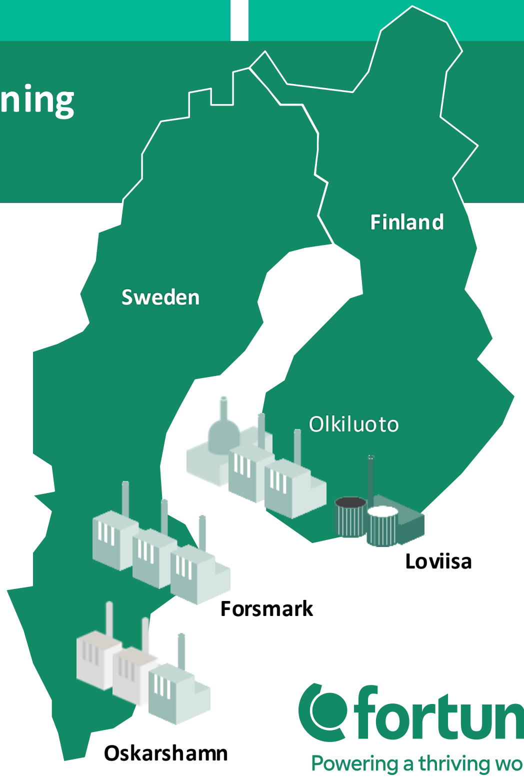


We have 40+ years' track record of safe nuclear operations and we are forerunners in responsible waste management

Fully-owned nuclear power plant in Loviisa, Finland	Co-owned nuclear power plants in Finland and Sweden	Nuclear services provider with innovative products and services	New Nuclear Feasibility Study in Finland and Sweden	In-house engineering and project competences

Expertise from new build to decommissioning and final disposal of nuclear waste

Unit	Mwe (net)	Fortum Share %
Loviisa 1 Loviisa 2	507 507	100 100
Olkiluoto 1 Olkiluoto 2 Olkiluoto 3	890 890 1600	26.6 26.6 25
Forsmark 1 Forsmark 2 Forsmark 3	988 1120 1172	23.4 23.4 20.1
Oskarshamn 3 Oskarshamn 1 Oskarshamn 2	1400 decom decom	43.4 43.4 43.4



Units fully owned by Fortum
Co-owned units
Units under decommissioning

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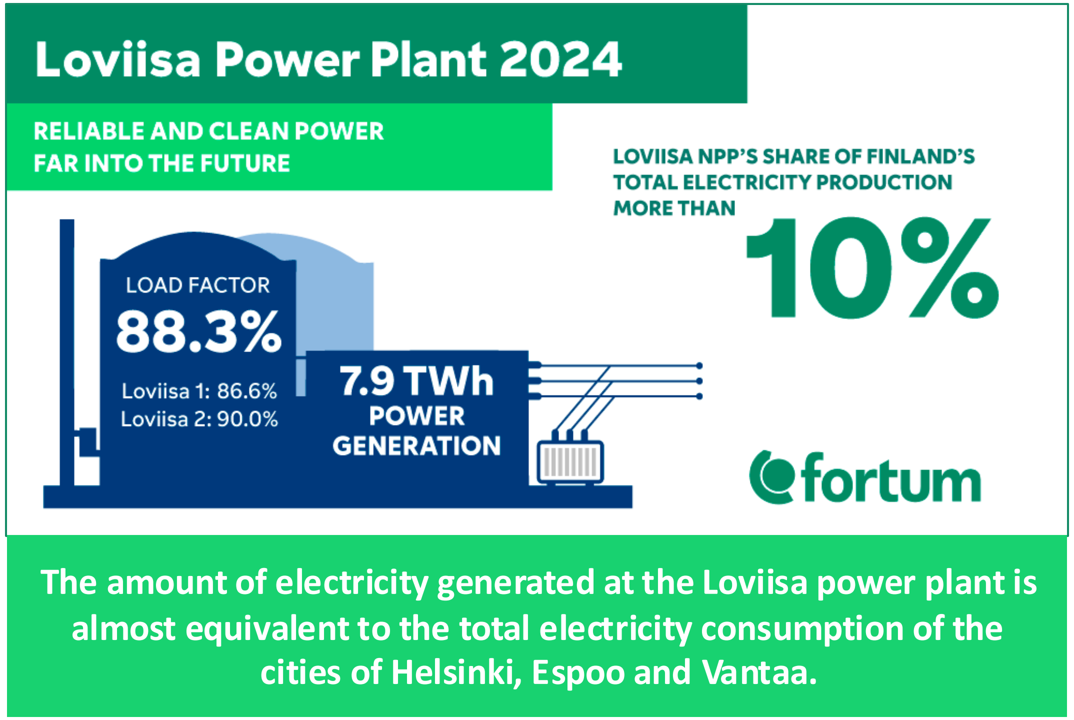
Reliable and clean power far into the future

- Loviisa power plant has two VVER pressurised water reactors, with capacities of 507 MW net
- Loviisa power plant produces more than 10% of Finland's total electricity production
- Loviisa 1 was commissioned in 1977 and Loviisa 2 in 1980
  - Old operating licenses were coming to end 2027 and 2030
  - New operating licence for both units is valid until the end of 2050



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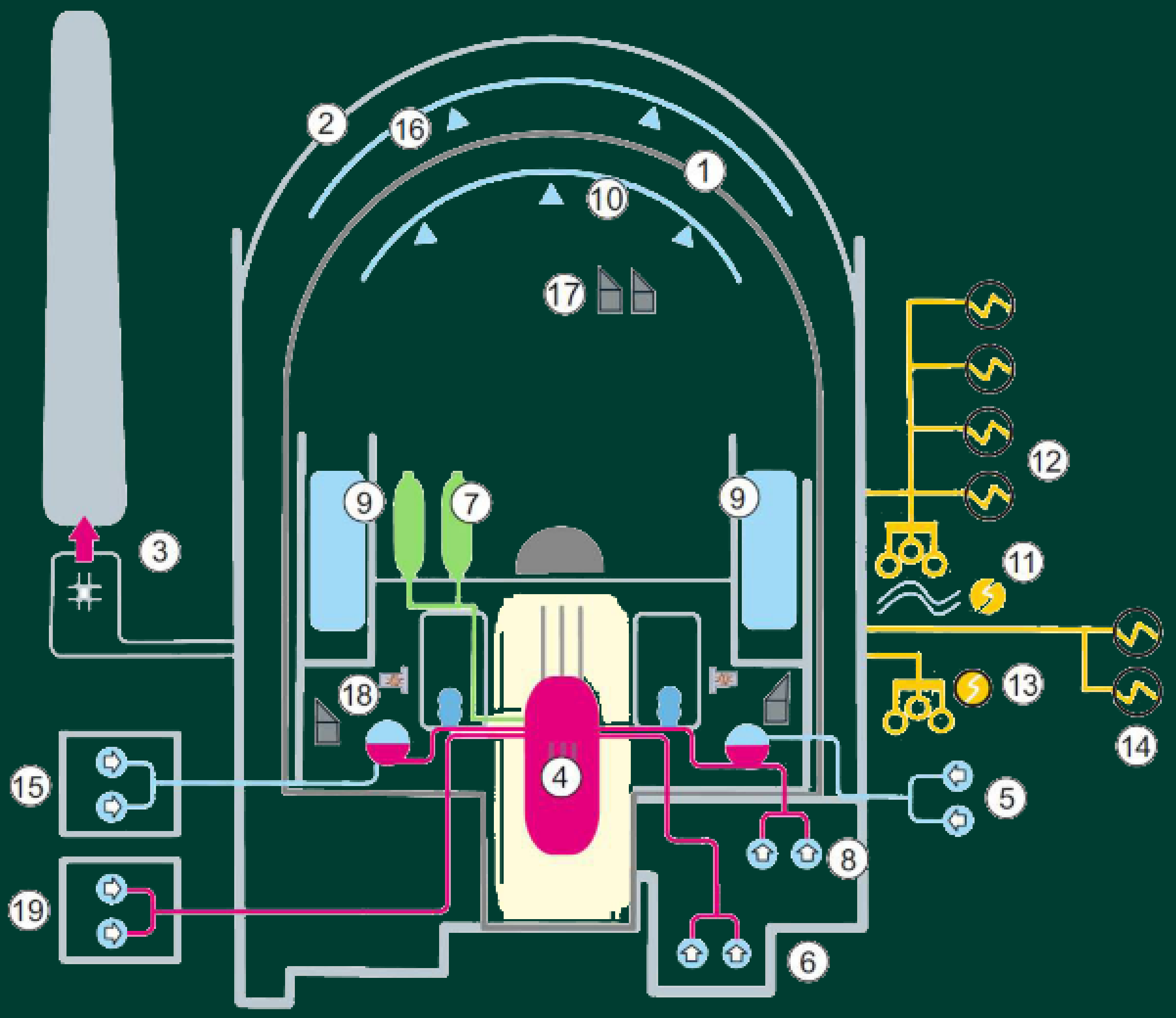
Safety systems at Loviisa power plant



Safety Systems:

1. Containment
2. Reactor building
3. Filters for ventilation exhaust
4. Reactor and control rods
5. Emergency feedwater system
6. Low-pressure safety injection system
7. Pressurised hydro accumulators
8. High-pressure safety injection system
9. Ice condenser
10. Containment spray system
11. Power supply from hydro power station
12. Emergency diesel generators
13. Diesel generators plant
14. Severe accident diesel generators
15. Auxiliary emergency feedwater pumps
16. Containment external spray system
17. Hydrogen removal (passive autocatalytic recombiners)
18. Hydrogen removal (igniters)
19. Boron supply system

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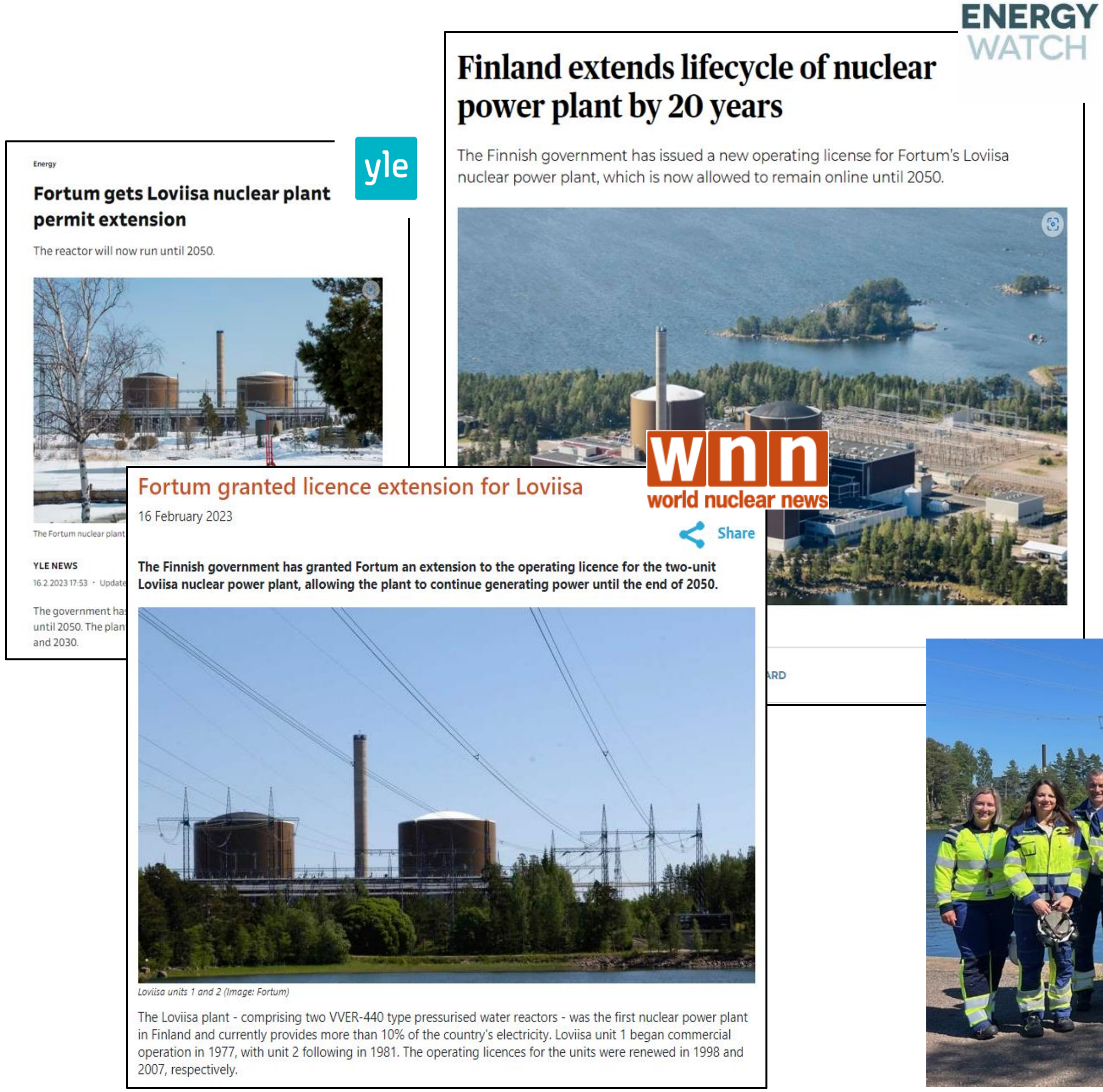
New operating licenses granted

In February 2023, the Finnish Government granted a new operating license for Fortum's fully-owned Loviisa NPP until 2050 and in March 2023 for the LILW final repository until 2090.

Reliable backbone of the energy transition	• New operating licence until 2050 offers up to 177 TWh of additional CO_2-free power
Competitive economics	• Very reasonable addition of nuclear supply with limited capital expenditure of estimated approx. EUR 1 bn. • Investments will be evenly distributed over the extended lifetime.
Solution for waste	• Finland is a forerunner in nuclear waste management and has a solution for final disposal. • Fortum offers solutions and services for customers.
Public backing	• Fortum is the local reliable operator for decades. • Nuclear acceptance both nationally and locally high.

The new operating licence has gained a lot of interest nationally and around the world



Energy

Fortum gets Loviisa nuclear plant permit extension

The reactor will now run until 2050.

yle

YLE NEWS

ENERGY WATCH

Finland extends lifecycle of nuclear power plant by 20 years

The Finnish government has issued a new operating license for Fortum's Loviisa nuclear power plant, which is now allowed to remain online until 2050.

wnn world nuclear news

Fortum granted licence extension for Loviisa

16 February 2023

Share

The Finnish government has granted Fortum an extension to the operating licence for the two-unit Loviisa nuclear power plant, allowing the plant to continue generating power until the end of 2050.

Loviisa units 1 and 2 (Image: Fortum)

The Loviisa plant - comprising two VVER-440 type pressurised water reactors - was the first nuclear power plant in Finland and currently provides more than 10% of the country's electricity. Loviisa unit 1 began commercial operation in 1977, with unit 2 following in 1981. The operating licences for the units were renewed in 1998 and 2007, respectively.

Loviisa NPP Operating Licence project

2017
- Technical and financial studies

2018
- Project starts

May Aug 2020
- Periodic Safety Review to STUK
- Environmental impact assessment (EIA) Programme

Sep 2021
- Environmental impact assessment report

Jan 2022
- Ministry of Economic Affairs and employment Reasoned conclusion on EIA

Mar 2022
- Fortum Board of directors decision to apply new operating licence
- Submittion operating licence application

Jan 2023
- STUK positive decision for safety assessment

Feb 2023
- Government grants new operating license for Loviisa NPP

Mar 2023
- Government grants new operating license for Low and intermediate level radioactive waste final repository

Safety review, STUK

Environmental Impact Assessment programme and report documents in Finnish, Swedish, English, summaries also in Estonian, Latvian, Lithuanian, Norwegian, Polish, German, Danish, Russian

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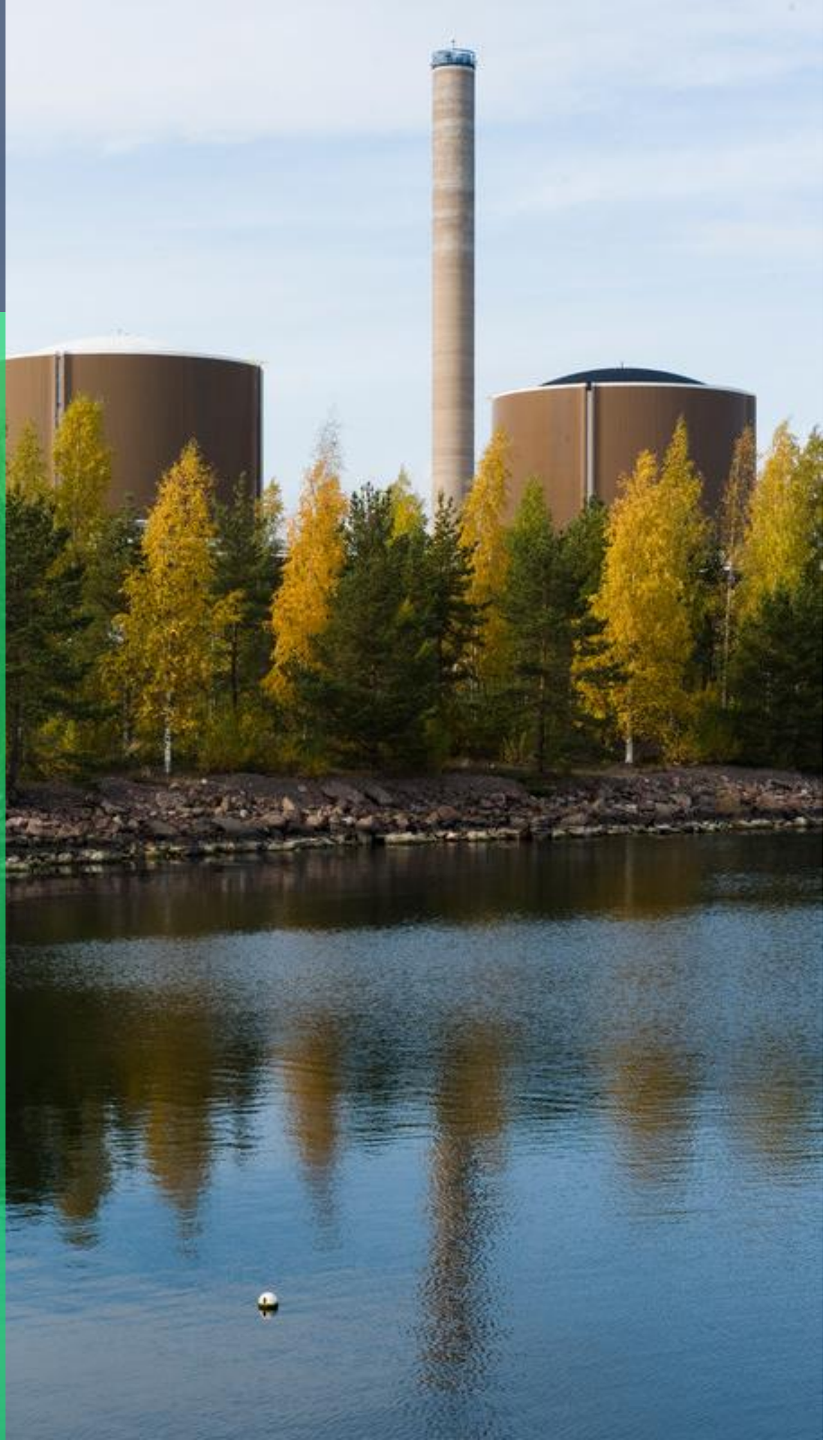

The issues that were the most important to study/ lessons learned

- Feasibility study from technical and safety perspective needed
- But also financial feasibility study and public and political acceptance are a must
- If plant lifetime management, equipment reliability and maintenance processes are well established already (=knowledge/understanding of the condition of your plant, systems and equipment), it is possible to make a good assessment of the feasibility from different aspects with moderate costs. If you don´t have these, making good assessment it is extremely difficult.
- Own understanding of plant, requirement level and history required. Not to trust only on external view
- Huge effort. To consider whether to do it with small or large team. Smaller team – higher probability to miss some technical point of view. Bigger team – harder to summarize and find common consensus
- Financial feasibility: sensitivity analysis (base, low, high scenarious) and risk analysis
- Higher requirement level needs to be considered (also ”softer” issues: quality and organizational requirements)
- In Loviisa NPP an organizational change in summer 2023 related especially to investment and project management in order to manage the investment required for the life-time extension
- If there is decision to continue operation, issues identified as critical should be investigated further to mitigate risks and uncertainties

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Loviisa long-term operation Program (LTOP) is strategic growth objective for Fortum

Program objectives ensure the feasibility of implementation

Sub-programs to further detail the objectives

- **Technical feasibility**
- **Financial feasibility**
- **Feasibility from safety perspective**
- **Public and political acceptance**

Program objectives

- Stable, reliable and predictable operation until 2050
- Safety, security and sustainability improvements
- Secondary circuit modernizations to increase production
- Management of productivity over remaining lifetime
- Investments in set frame (schedule, cost and quality)
- Securing competence and capabilities for operations until 2050

Program obejctives fulfilmment tp be ensured through more in detailed planning of portfolios

Strategy cornerstones / boundary conditions

Profitability

Safe
On par with best available technologies in terms of health impact on people and the environment

Societal acceptance

CO2-free
Lowest emissions per GWh over plant lifecycle for any major technology

Market environment

Stable & predictable
Dispatchable power on demand

Competence

Solid basis of our nuclear operations

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Loviisa Long-term operation program aimed at implementing the needed investments

9 portfolios	~200 single projects

All actions aim to improve nuclear safety

Safety classified Mechanical Components and Readiness for Repairs	Turbine Island modernization	Buildings, Structures and Infra
I&C modernization	Emergency Diesel Generators and Electrical equipment modernization	Ventilation and Air conditioning systems Modernization
Safety Improvements	Nuclear fuel and waste	Security

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What inputs trigger the renewal of system, structure or component

- Technological obsolescence and lack of spare parts in stock
- End of qualification
- Reduced performance in system health
- High maintenance and/or operation costs
- Physical aging
- Authority requirements
- Improving nuclear or personal safety
- Geopolitical situation
- Internal and external operation experiences
- Functional failure

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Status of Loviisa Main Components

No significant actions foreseen

Investments prepared for long term ooeration

Containments and reactor buildings

No lifetime limiting degradation mechanisms identified.

Moisture separator reheaters

Replaced 2015-2017.

Turbines

HP turbines replaced 2016-2018.
Replacement/modernization of LP turbines foreseen
Potential for extra production

Generators, Switchgears,

Rotors replaced 2012-16
Four stators have been replaced 2018–2020
6 kV breakers 2008-2013
0,4 kV breakers 2016

Reactor pressure vessels

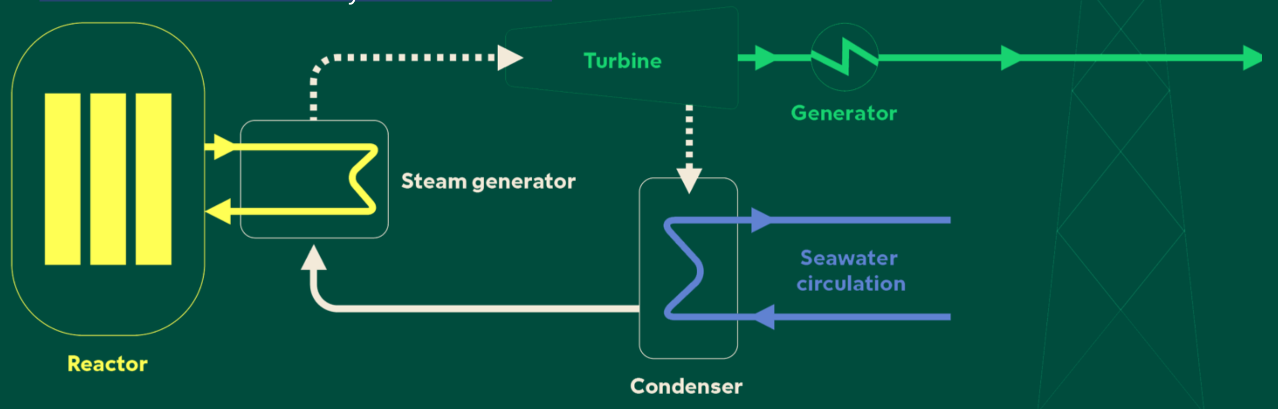
Analyses ongoing.
Reactor pressure vessel irradiation embrittlement is assessed as manageable.

Automation

Replacement of plant protection-, Severe accident management-, Normal operation-, Turbine protection and control- and ventilation systems

Emergency core cooling systems

No actions identified.



Emergency diesels

Ensuring strategic spare parts

Main transformers

Replaced 2014-16.

Primary coolant pumps, loops and pressurizers

No lifetime limiting degradation mechanisms identified.

Steam generators

Degradation of tubes is currently manageable (lifetime limiting phenomenon).

Preheaters

Replacements foreseen.

Potential for extra production

Seawater pumps

Replacement foreseen.

Potential for extra production

Condensers, and Feedwater pumps

Potential for extra production.

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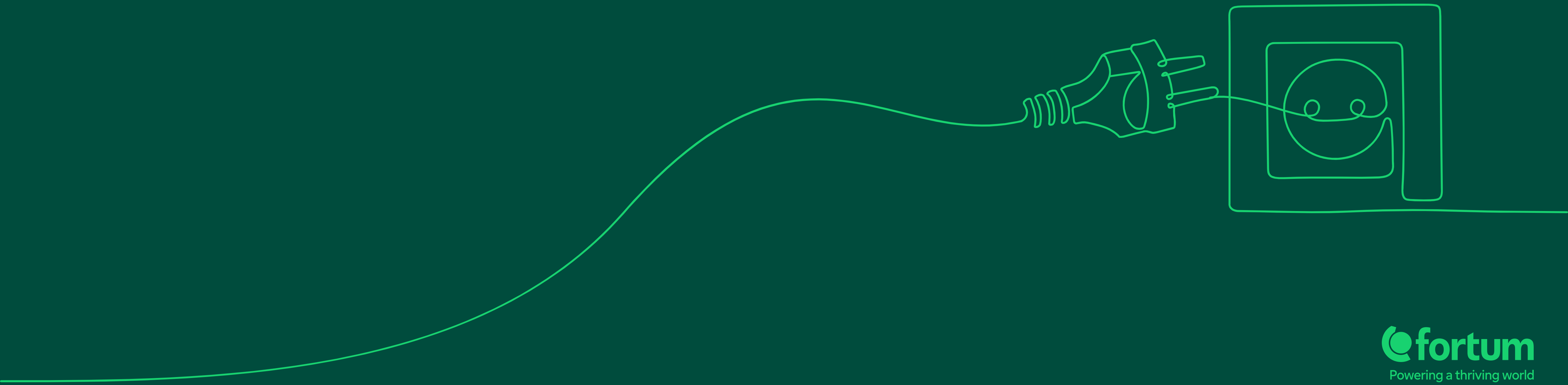
Thank you!



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Making emerging technology a lifeline instead of a threat

Vattenfall R&D

Anders Wik

2025-01-22

Energiforsk

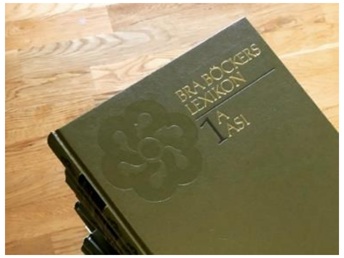
1980

2025

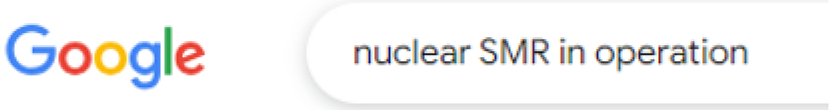
Communication

Computer power

1980 | 2025



Information search

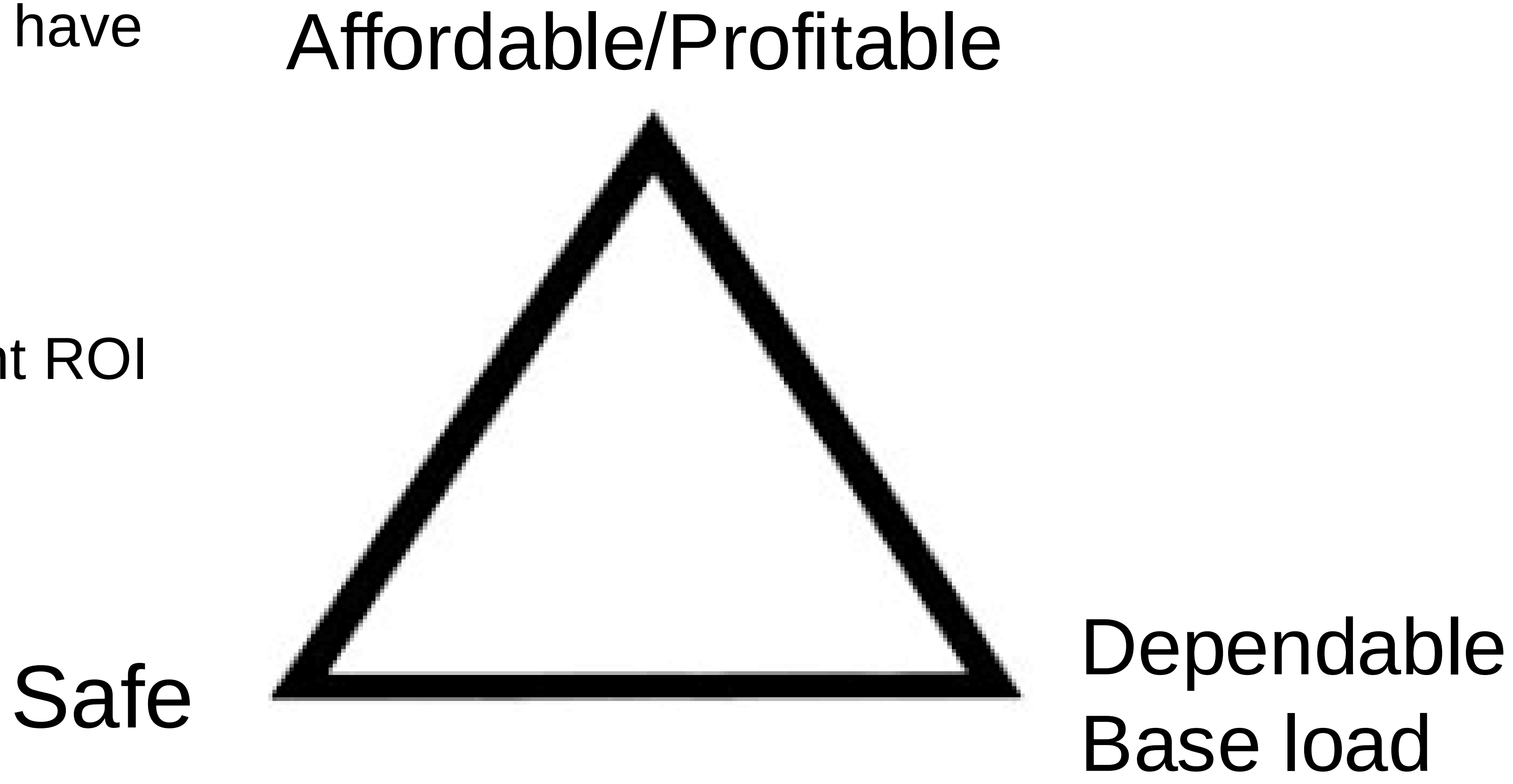


Services/Transactions

LTO Trilemma for existing NPP´s

- The existing NPP´s will have to fulfill the following:

- **Safety** Paramount
- **Profit** Meet requirement ROI
- **Availability** ~85-90%



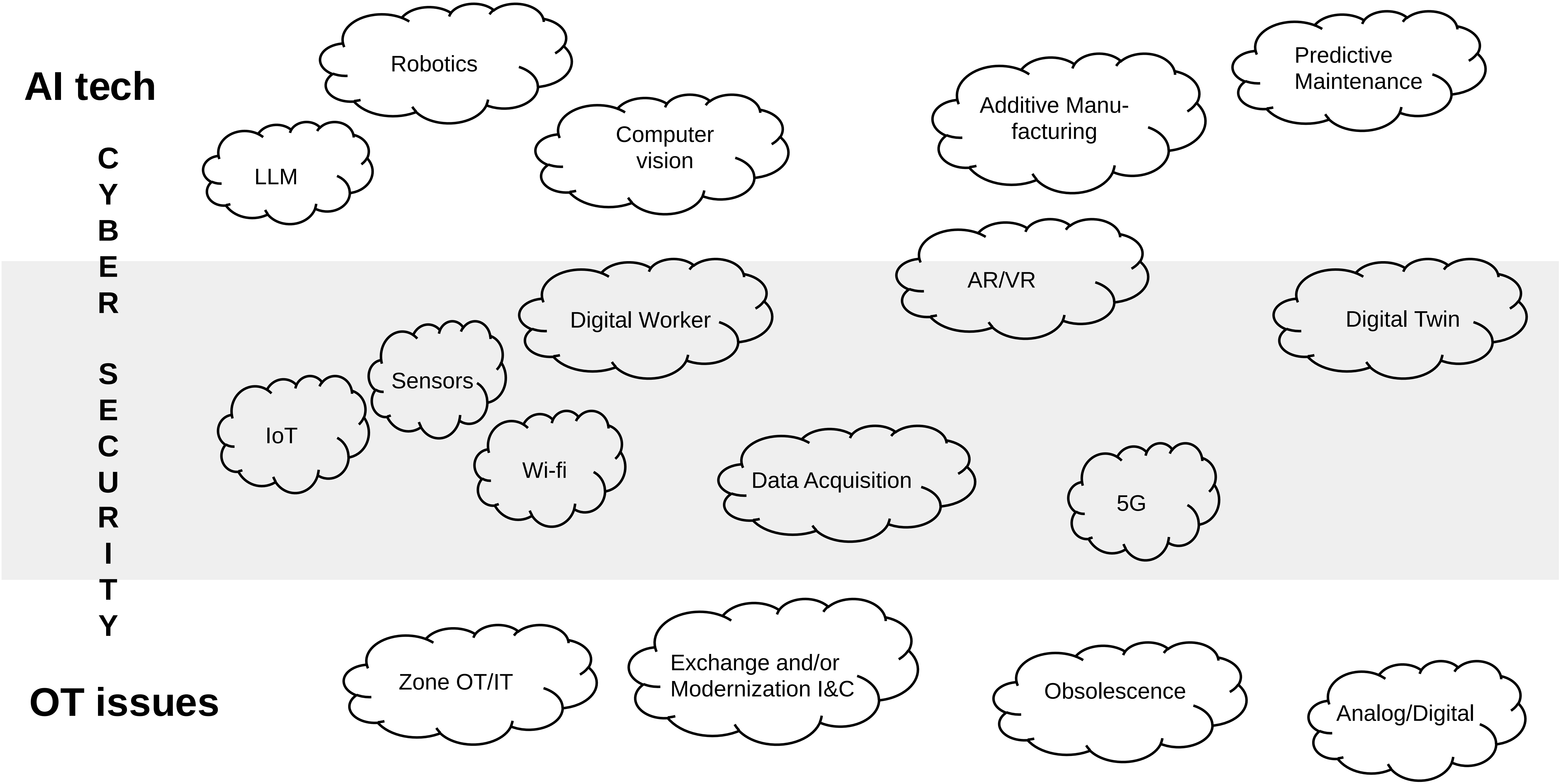
Obsolescence and Competence – two important issues for LTO

- **Obsolescence.** Will we find vendors and equipment to support the power plants in keeping them up and running? There will be exchange and modernisation of structures, systems and components (SSC) for the upcoming 20-40 years. May Additive Manufacturing be one answer?

- **Competence.** Perhaps the most complex issue. What competence will we need in the future? Same as today or something else? How to attract students to work with existing NPP when NNB comes around?

Hurdles for new technology

- **Regulations.** Uncertainty if we are within the existing regulations.
- **Conservative approach.** Not well proven design, ”What if?”.
- **Mindset.** ”Not for us, we are special”.
- **Cyber Security.** Information can leak outside.
- **Time constraints.** Initial increased workload to implement.


AI tech
CYBER SECURITY
Robotics
LLM
Computer vision
Additive Manu-facturing
Predictive Maintenance
AR/VR
Digital Worker
Digital Twin
Sensors
IoT
Wi-fi
Data Acquisition
5G
OT issues
Zone OT/IT
Exchange and/or Modernization I&C
Obsolescence
Analog/Digital

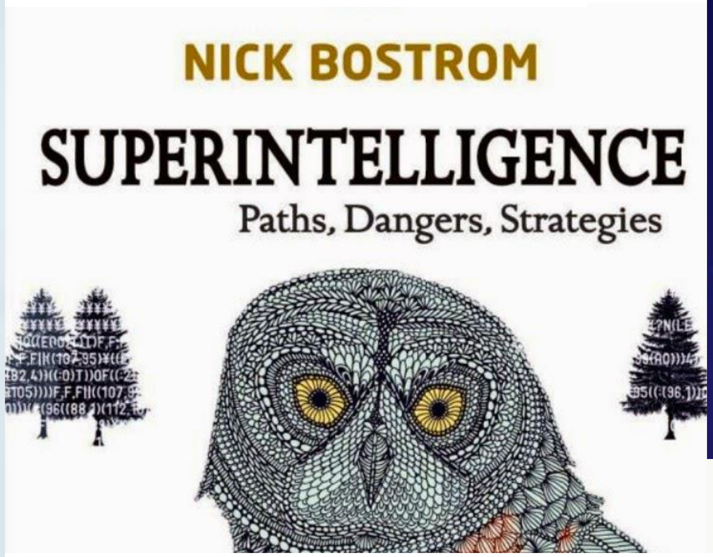
DN DEBATT

DN Debatt. "Farligt att lagstifta mot en AI-teknik vi knappt förstår"

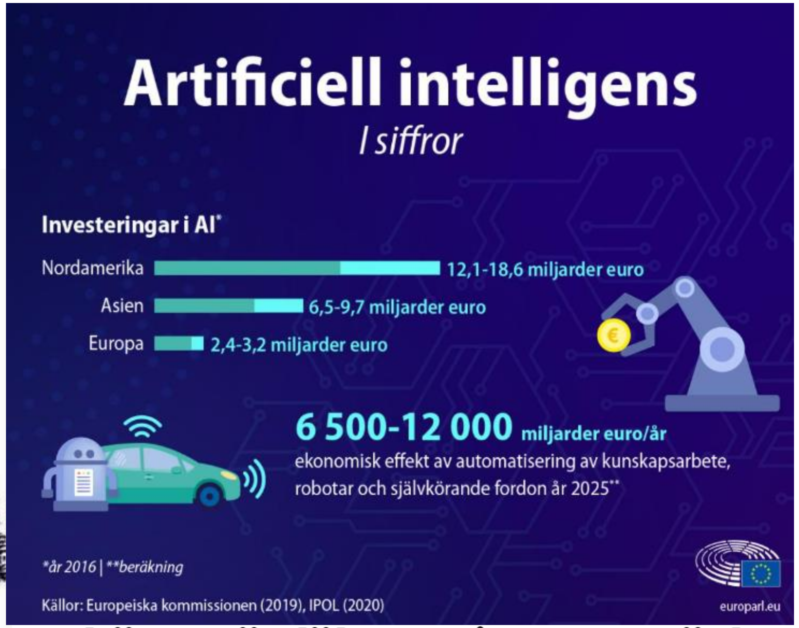
Uppdaterad 2023-04-18 Publicerad 2023-04-17

Elon Musk and Others Call for Pause on A.I., Citing 'Profound Risks to Society'

More than 1,000 tech leaders, researchers and others signed an open letter urging a moratorium on the development of the most powerful artificial intelligence systems.



"Universitetens nonchalans skrämmer mer än AI"



AI bättre än läkare på att upptäcka hudcancer

Is AI dangerous? Answer from ChatGPT.

AI can be dangerous if it's developed, used or controlled improperly. Some risks include: loss of jobs, unintended consequences from AI systems, biased AI systems that perpetuate existing inequalities, and the potential for AI systems to be used for malicious purposes, such as cyberattacks or autonomous weapons. However, if developed with proper safety measures and ethical considerations, AI has the potential to greatly benefit society.

Is AI dangerous? Answer from ChatGPT.

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OpenAI

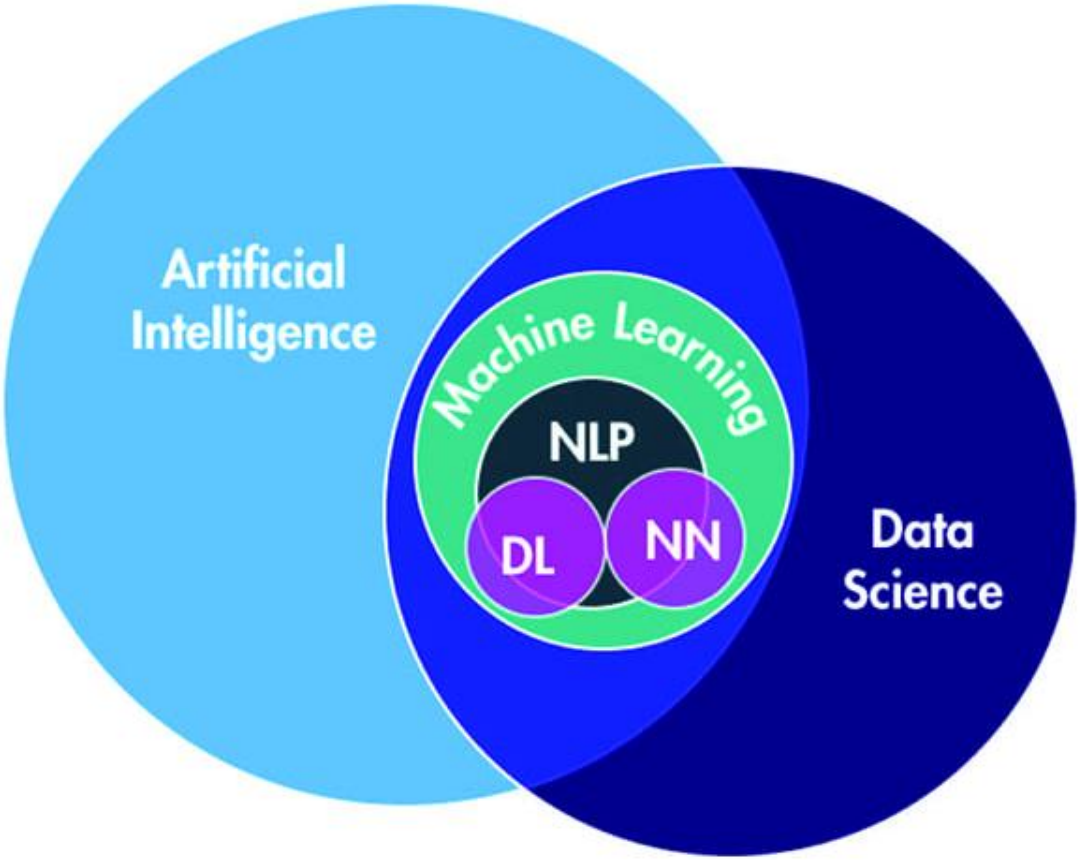
Where does Predictive Maintenance fits in in the digitalization landscape?

Machine learning can be “supervised” or “unsupervised”. The former is more common and is used by training a system with known data.

Predictive maintenance can be regarded as a subcategory of machine learning.

Predictive maintenance relies on data from various sources in the plant.

It is often a “grey zone” between predictive maintenance and operating support.

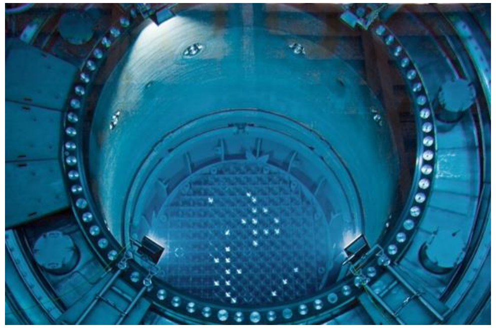


NLP: Natural Language Processing
NN: Neural Networks
DL: Deep Learning

Typical approach for Predictive Maintenance Questions to ask before starting.

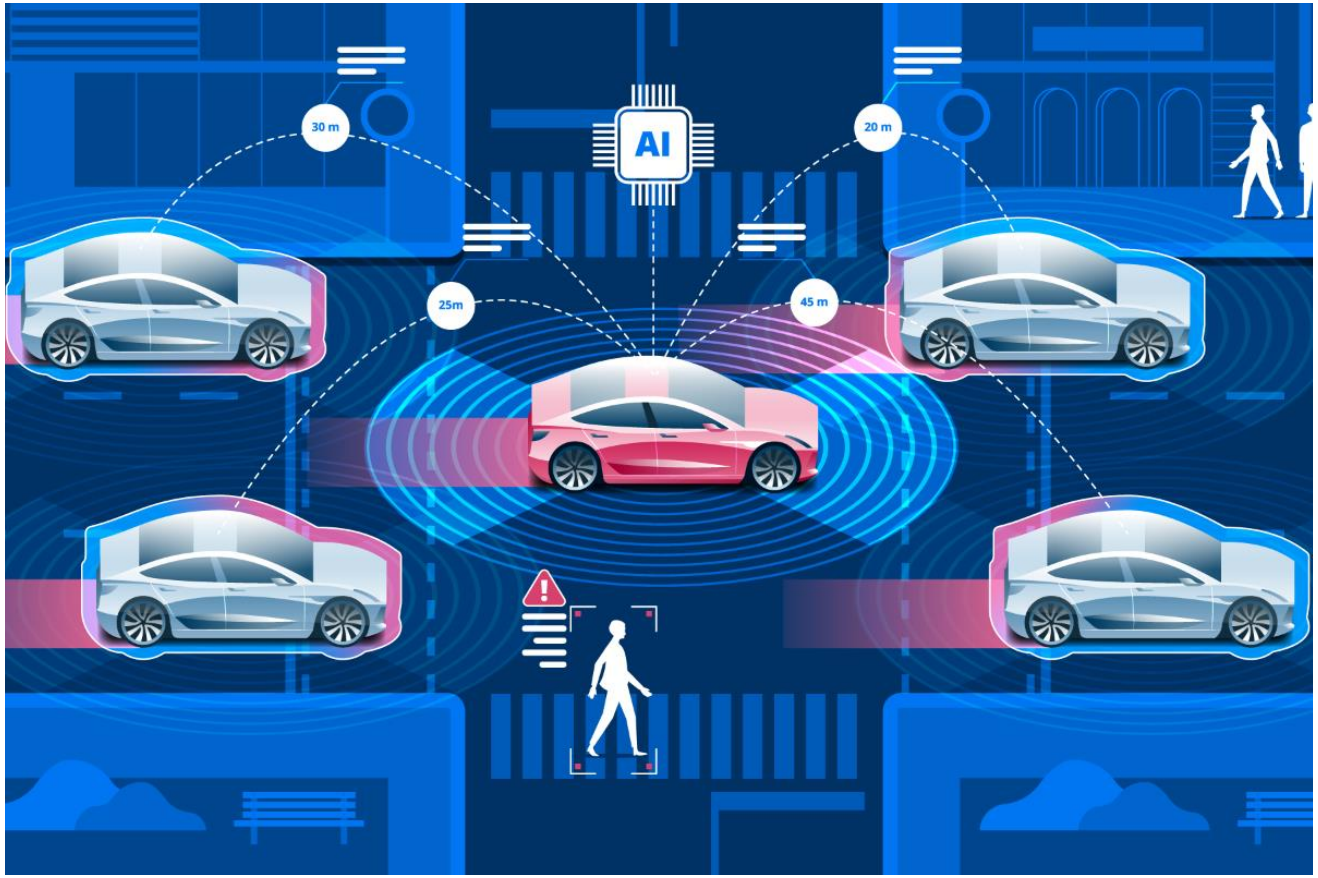
- Is the system or component of great importance for safety or production?
- Is it worth it to go further with predictive maintenance, cost/benefit?
- Do we have enough data to do successful predictive maintenance?
- Is the data reliable?
- Do we have the resouces and skills to implement predictive maintenance in our organization?



Autonomous Cars vs. NPP´s. What is a more complex environment?

- Self-driving cars have a very complex envirionment with unpredictable situations, e.g. people, animals, weather etc.
- What about NPP´s? Mostly physics and predictable phenomena.



© Smart Cities World

Do we want autonomous systems?

Ethics and AI/Robotics

Asimov´s Laws of Robotics (1942)

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.

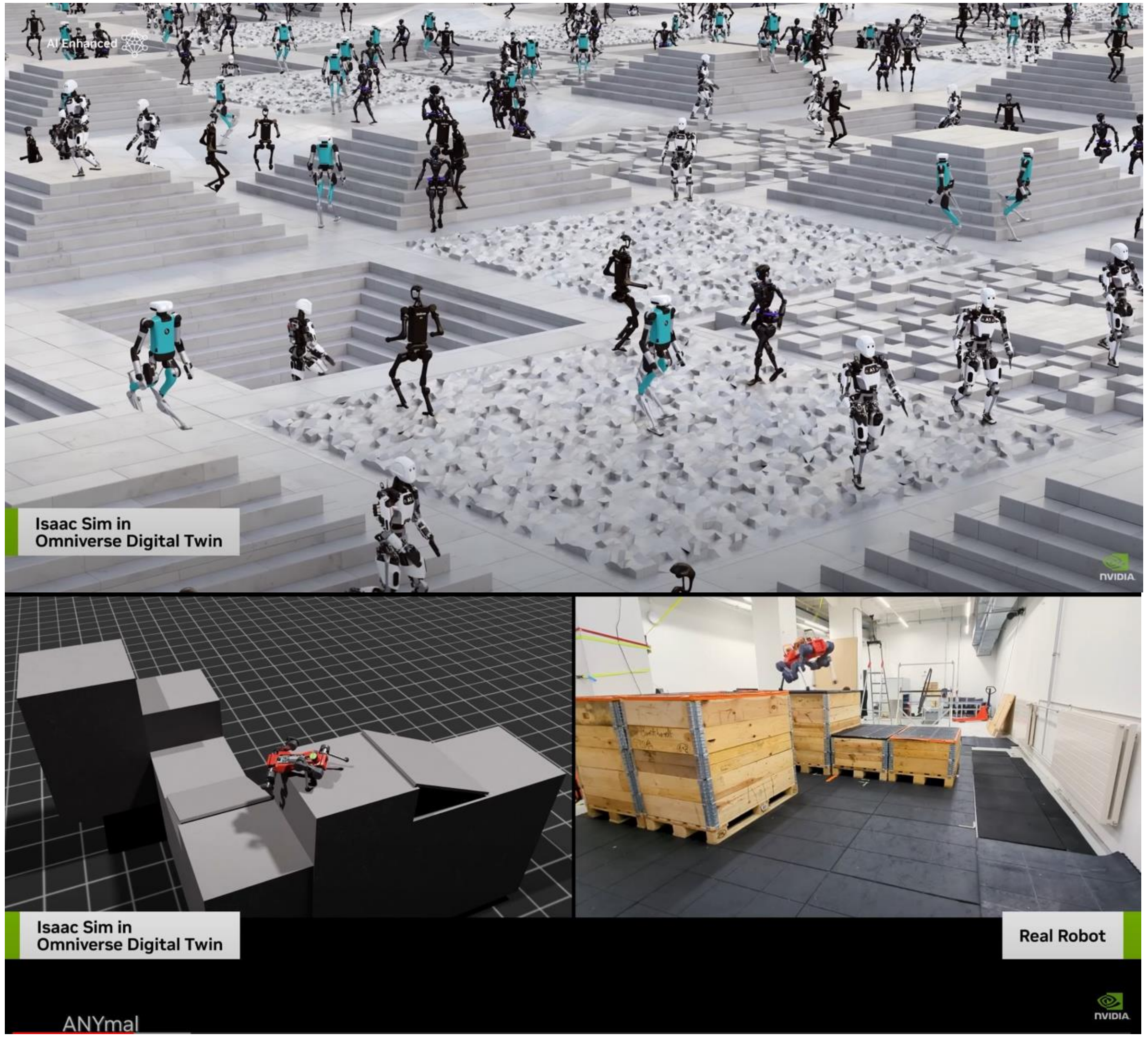
Humanoid robots - explained

World simulation

Robots are trained in virtual environments to be able to perform tasks in the real world

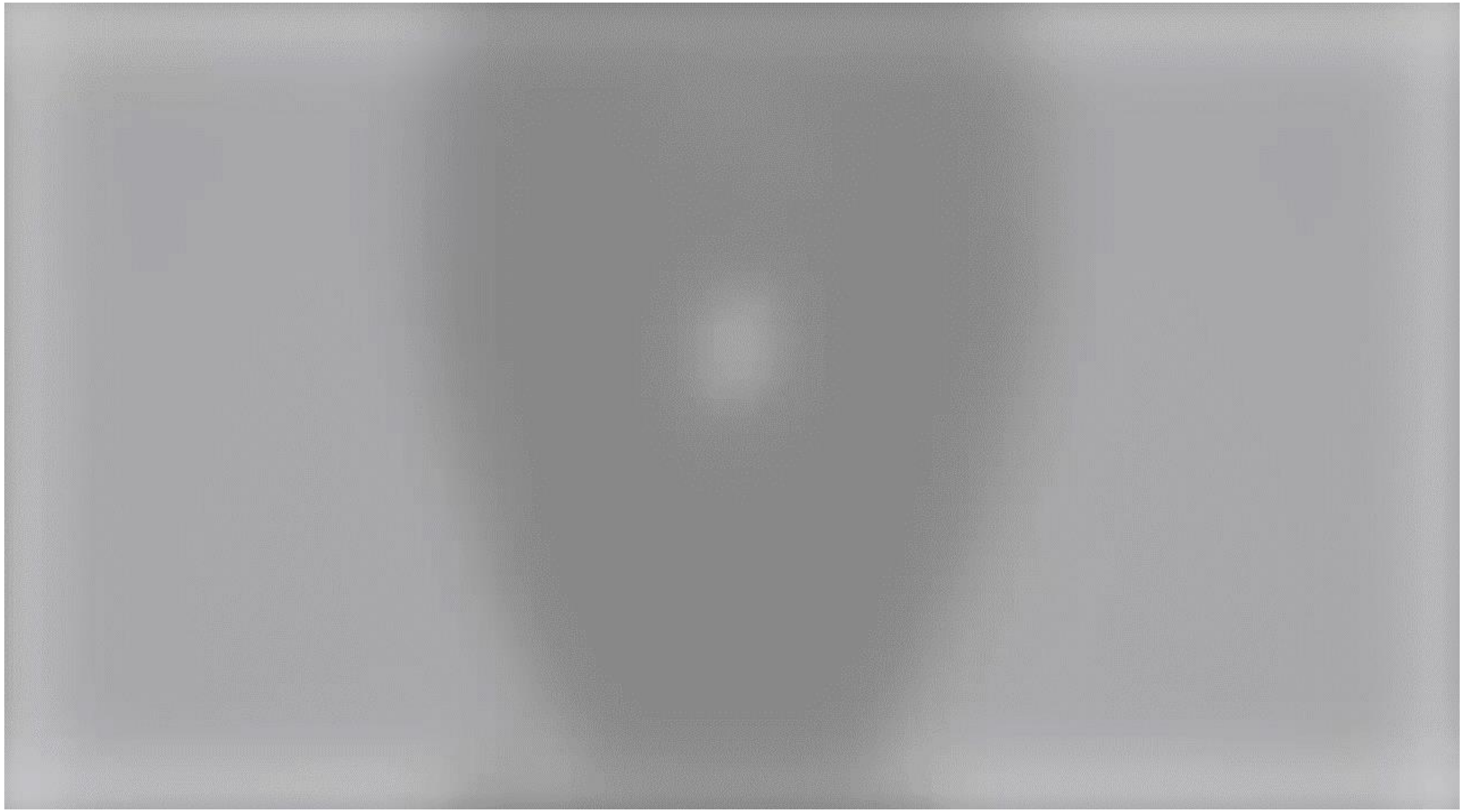
Foundation model for robotics
➔ Understand the environment

Ai agents
➔ Decision on what to do



General purpose robotic platform

We add all things together



Status as we speak

Tesla – Optimus robot

FigureAI – Figure robot

Agility Robotics – Digit

1X – Neo (Norway)

Unitree Robotics – G1 (China...)

Your future workmate?

Is this just a question of *When* rather than *If*?

I think this will happen in the future but I also believe that the humans will still be around.

So, AI in all its beauty, we humans still have a role in our existing NPP´s!

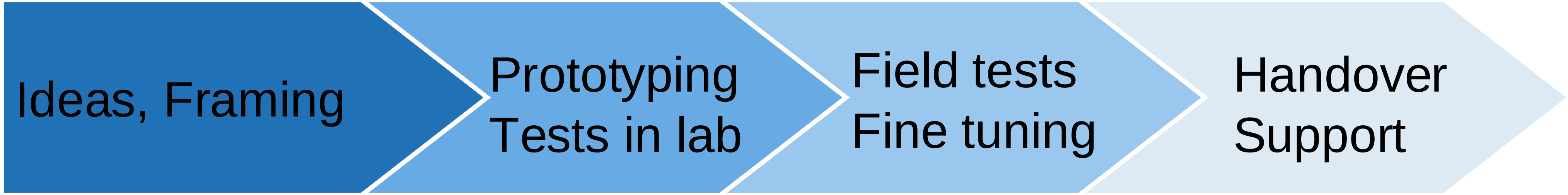
Picture: Business Insider

Thank You for Your Attention

Extra

Workflow R&D towards deployment

- Ideas are framed and goes through a screening process for Go/No Go
- Protypes are produced and tested in lab environment
- Field tests are conducted to see robustness and user friendliness
- Finally product/service is handed over to BA/BU for deployment. Support function remains for a certain time period by R&D



The colours indicate the involvement of R&D. The darker, the more involvement from R&D personnel and laboratory resources.

Enhancing the safety of concrete structures for long term operation

Annual Nuclear Conference: Life After 60 – Long Term Operation of Nuclear Power, Stockholm, 22.1.2025

Miguel Ferreira, ACES Project Coordinator
VTT Technical Research Centre of Finland Ltd.

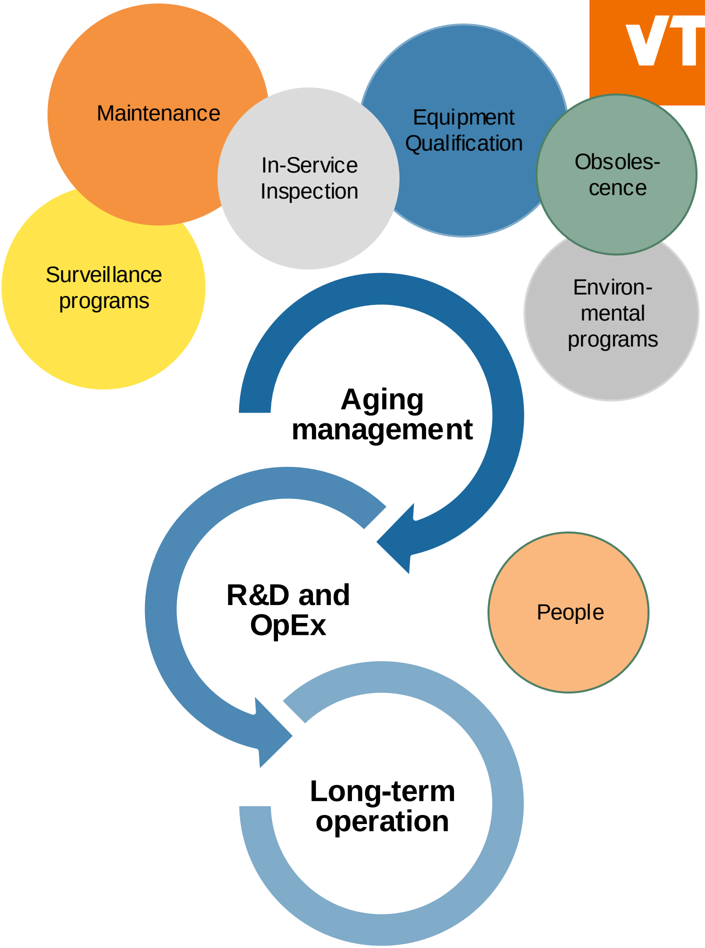
ACES
Towards improved Assessment of Safety Performance for LTO of nuclear Civil Engineering Structures

This project has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 900012

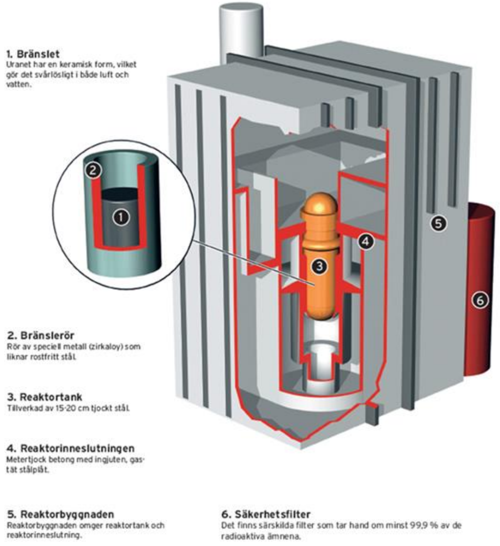
Ensuring the Nordic Material Research Capabilities for Long Term Operation – Focus on RPV and Primary Circuit

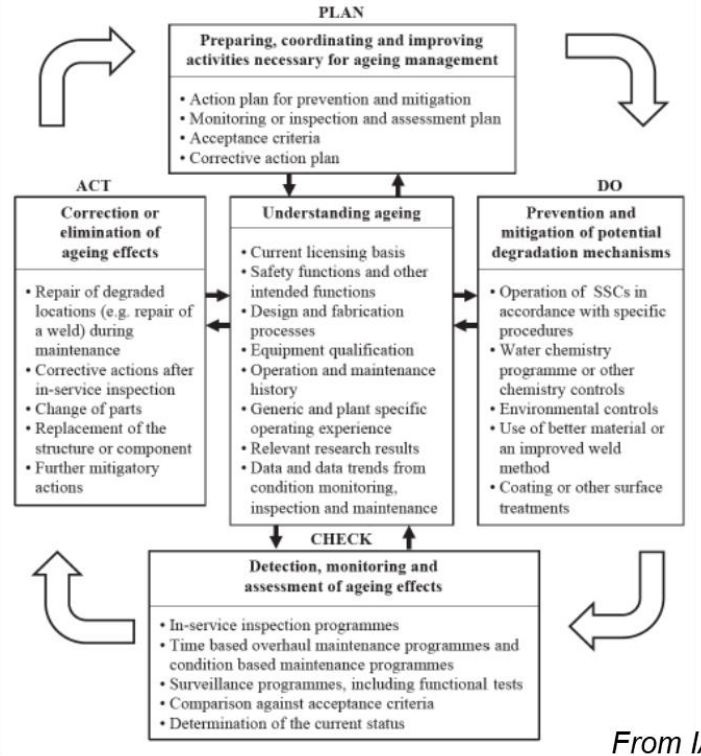
Noora Hytönen, Sebastian Lindqvist VTT
Pål Efsing, Ringhals Ab

04/02/2025 VTT – beyond the obvious


Maintenance
In-Service Inspection
Equipment Qualification
Obsoles-cence
Surveillance programs
Environ-mental programs
Aging management
R&D and OpEx
People
Long-term operation

Generating Basis for Continued Operation of the Nordic NPPs



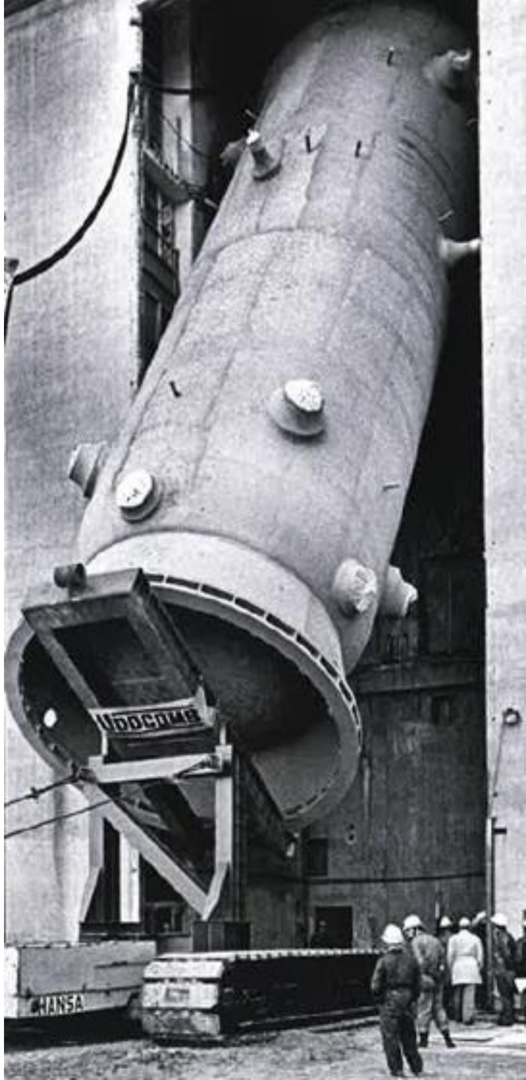


Plan
Do
Check
Act

From IAEA SSG-48

Ensuring Safe LTO: Addressing RPV Material Issues

- RPV irreplaceable component and its durability is a life-time limiting factor in NPP operation
- Thermal and irradiation embrittlement during operation decreases the operation margin
- There are no redundant systems to fulfill the safety functions of the RPV and thus we need to prove its functionality for the entire proposed time of operation



Ageing management of RPV

- 6 BWRs, 2 PWRs, and 2 VVERs are going towards operation beyond the original licensing period in the Nordic
- Necessary to distinguish the operational limiting factors
- There are several knowledge gaps to address:

High-dose mechanical properties

Correctness of the surveillance program vs. actual materials properties

Combined effects of thermal and irradiation induced ageing

Nordic Collaboration in Research

- NKS-BREDA project: Barsebäck Research & Development Arena
- SAFIR2022 BRUTE project: Barsebäck 2 RPV material used for true evaluation of embrittlement
- SAFER2028 BRIGHT project: Barsebäck RPV investigation through thickness
- NKS-RePousses project: Reactor Pressure Vessel LTO Assessment
- FEMMA project: Dissimilar Metal Welds

Nordic Collaboration in Research

- Additional value to the Nordic nuclear community:
  - Improve R&D and Knowledge transfer
  - Workshops, technical meetings
  - Supporting doctoral studies
  - Enabling generational transition

- VTT: Hotcell laboratory at Centre for Nuclear Safety, Mechanical testing on irradiated materials and microstructural investigations
- KTH: Modelling the constrain effect and weakest link probability
- Chalmers: Atom probe tomography for mechanistic understanding of embrittlement
- Ringhals: Operations Experience (OpEx)

Knowledge transfer

SAFIR2018

Reactor pressure vessel embrittlement seminar for the BREDA – BRUTE project

Place: VTT, CNS building, meeting room Einstein / Kivimiehentie 3, Espoo

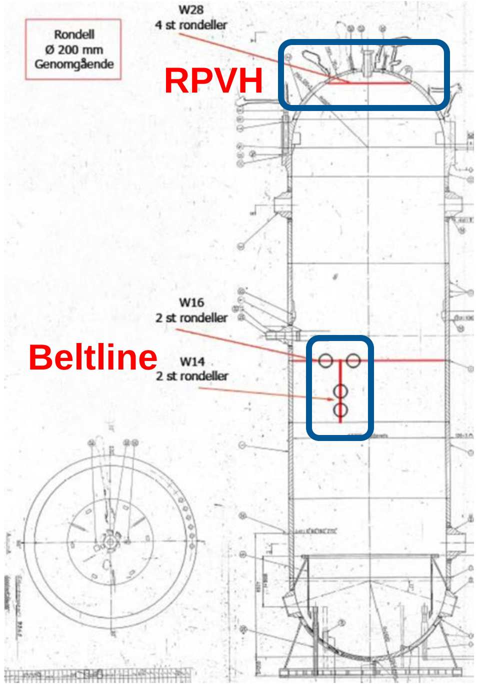
Time: 31 October, 2018

9:00	*Opening and welcome*	*Ulla Ehrnstén, VTT*
9:10	Expectations for the BREDA project	Jenny Rouden, Ringhals
9:40	The Ringhals RPV story	Jenny Rouden, Ringhals
10:10	Aging and constraint effects of low alloy steels – Magnus Ph.D. Project	Magnus Boåsen, KTH
10:40 – 11:00	*break*	
11:00	Clustering processes during ageing of reactor pressure vessel steels – an atom probe tomography study	Kristina Lindgren, Chalmers
11:30	Review of constraint effect (size effect)	Sebastian Lindqvist, VTT
12:00-13:00	*LUNCH*	
13:00	Life time assessment of OL1/Ol2 RPV´s	Antti Kallio, TVO
13:30	Microstructural investigations, possibilities and objectives	Ulla Ehrnsten, VTT
14:00	*break*	
14:30	Surveillance testing procedures	Petteri Lappalainen VTT
15:00	Multi-scale modelling of microstructural evolution in Ringhals RPV welds	Pär Olsson, KTH
15:30	Discussion	
16:00	Adjourn	

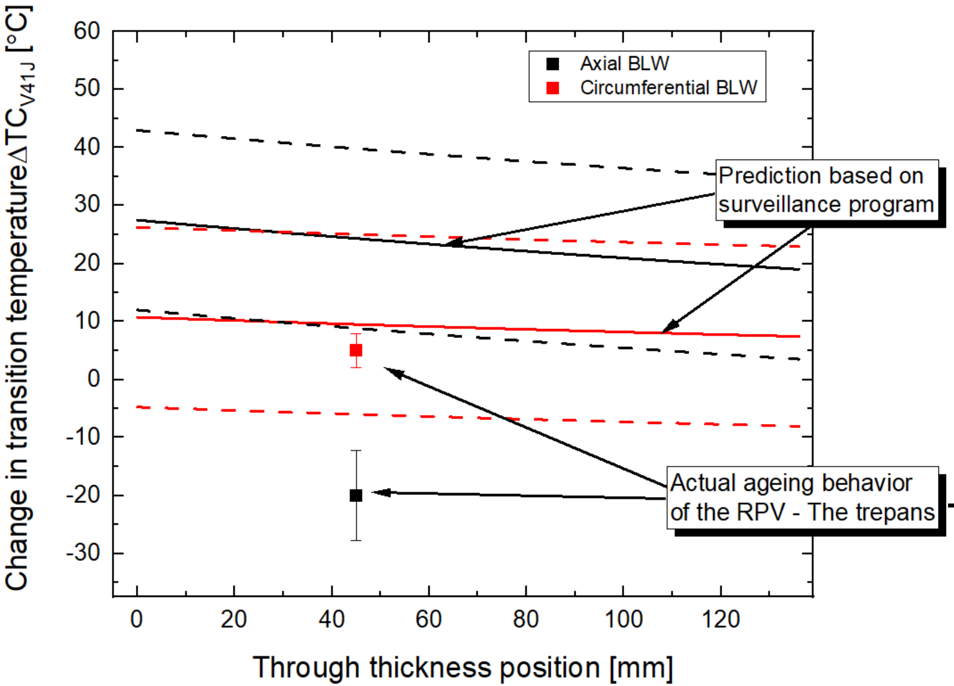
BREDA–BRUTE–BRIGHT

- A unique possibility was created through the decommissioning of the Barsebäck 2 NPP → Use of harvesting to enable knowledge building
- BREDA (2016-2022) launched in Sweden
- SAFIR2022 BRUTE (2018-2022) and SAFER2028 BRIGHT (2023-2025) on performing the mechanical testing and microstructural characterisation at VTT, Finland
- Objectives the three knowledge gaps mentions earlier
  - Comparison between results from the plant and from the surveillance program
  - Effect of thermal aging on low alloy steels at BWR operating temperatures
  - High-dose surveillance material evaluations
  - \+ The use of miniature mechanical test samples to allow for update of the surveillance programs for LTO

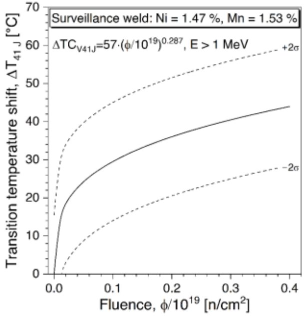
Extraction of trepans from B2

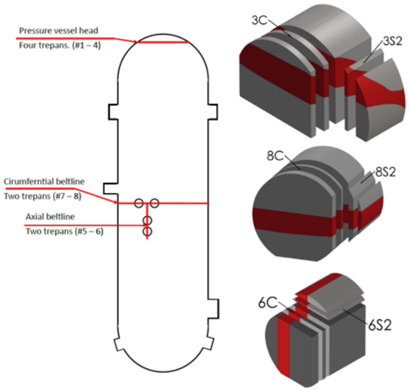


The surveillance program describes the ageing of the RPV operated for 28 years

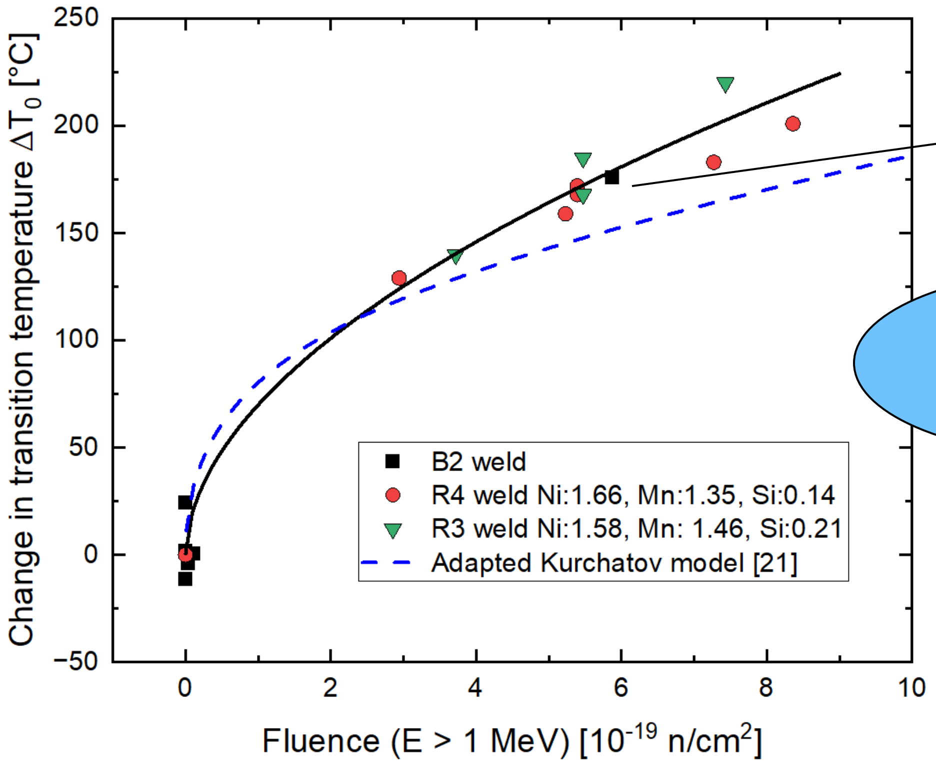


Surveillance





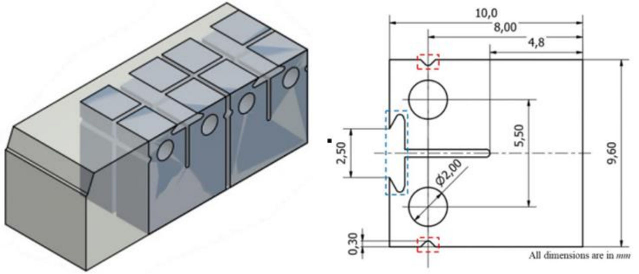
In the high-fluence region, the Barsebäck 2 weld embrittlement is similar to Ringhals 3 and 4



The fluence is equivalent to approximately 300 years of BWR operation and 60-80 years of PWR operation

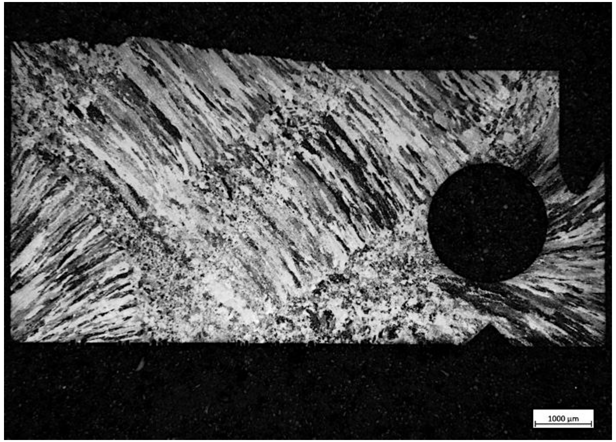
Surveillance weld located in a high flux position in the core region

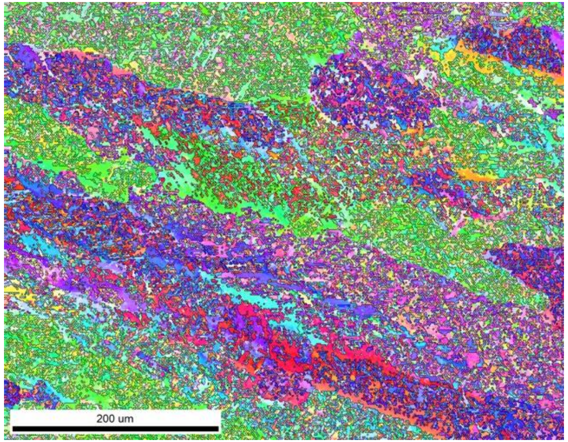
Based on fracture toughness measurements

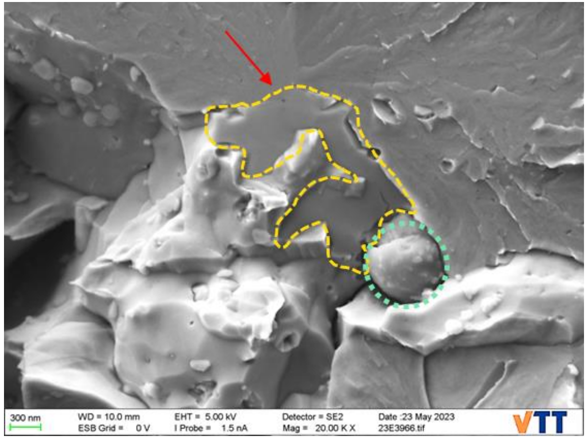


Finding weakest links in the material – Understanding ageing

- Increasing the mechanistic understanding of brittle fracture initiation and microstructure after thermal ageing and neutron irradiation
  - Fracture surface analysis
  - Microstructural evolution through thermal ageing and irradiation
  - Identifying microstructural features that initiate a brittle fracture
  - Differentiating welding metallurgical effects from operation ageing effects







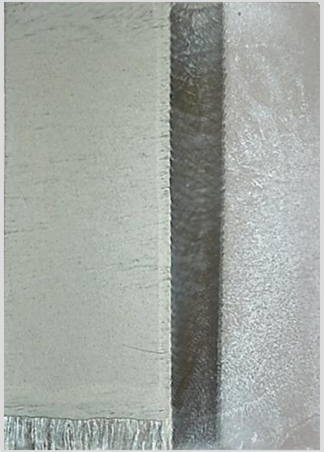
Barsebäck RPV investigations activities

Activities	Number of items
Impact toughness test	88
Fracture toughness test	120
Fractography samples	132
Research reports	40
Scientific publications	11
Seminars and technical meetings	13
Conference presentations	10
Doctoral theses	6

Nordic Collaboration on Dissimilar Metal Welds (DMWs)

- FEMMA (2020-2022) and FEMMA+ (2023-2027) projects coordinated by VTT
- Involvement of Finnish and Swedish utilities and authorities
  - TVO, STUK
  - Ringhals, OKG, Chalmers, SSM
- Main challenge in DMWs is the mismatch between two dissimilar metals; crystallographic mismatch, welding induced residual stresses, and susceptibility to stress corrosion cracking

Narrow-gap weld



Double-buttering repair weld

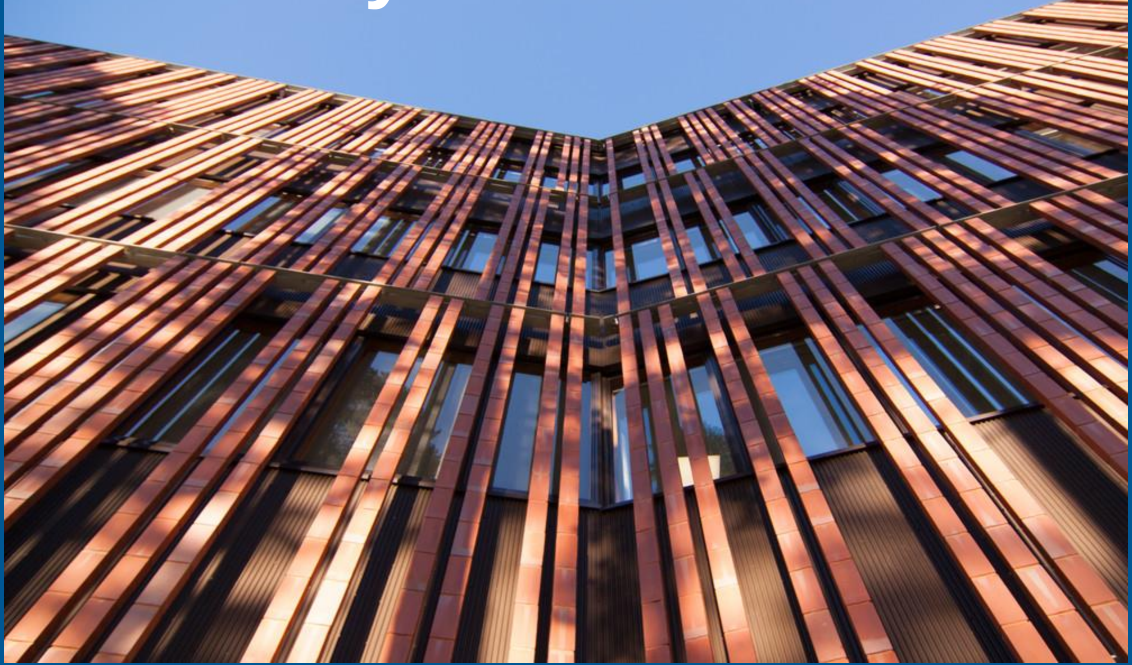
Collaborative Innovations and Knowledge Build-up for Life After 60

Potential to further enhance RPV life-time evaluations

- Solutions for diminishing volume of representative materials
- Focus on fine-tuning the evaluation procedures accounting for transferability, to have a more precise estimate on operation margin and remaining life-time
- Improved mechanistic understanding of material behaviour at high doses
- Competence build-up and knowledge management together on all levels: Research institutions, Authorities, and Utilities

Thank you! Kiitos! Tack!

Pål Efsing
Senior Specialist
Ringhals
pal.efsing@vattenfall.se



Noora Hytönen
Research Scientist
VTT
noora.hytonen@vtt.fi

Mentimeter

WHICH REGULATORY, SYSTEM OR POLITICS RELATED ISSUE IS THE MOST IMPORTANT TO MAKE SECOND LIFE-TIME EXTENSIONS HAPPEN?

74 responses

74

WHICH TECHNICAL ISSUE IS THE MOST IMPORTANT TO MAKE SECOND LIFE-TIME EXTENSIONS HAPPEN?

75 responses

75

WHICH ISSUE WAS LESS IMPORTANT FOR THE FIRST LIFE-TIME EXTENSIONS, BUT IS CRUCIAL TO THE SECOND LIFE-TIME EXTENSIONS?

74 responses

concrete swelling
deregulated market
aging
know how
change of generation
energy market
resources and competences
technology
newbuild
civil structures
profitability
supply chain
economics
ressources
sequrity
knowledge transfer
competense
competence
supply
ssm
requalification
obsolescence
generation change
generation shift
cables
real life end
ageing
i and c
concrete
subsidies
stick to the decision
civil ageing
true end of life
digitalization
computer development
civil aging
digitalizatin
research and competence
resources
conpetence
cyber war
supply demand
degradation mechanism

74

Mentimeter

WHAT IS, IN YOUR OPINION, THE MAIN "MAKE-OR-BREAK" ISSUE FOR SECOND LIFE-TIME EXTENSIONS?

71 responses

71

IAEA

Safety Aspects of Long Term Operation

SALTO

Life After 60 – Long Term Operation of Nuclear Power

IAEA support to Member States with respect to safe long term operation beyond 60 years

Gabor Petofi - g.peofi@iaea.org

LTO Project Manager

IAEA Nuclear Installation Safety Division

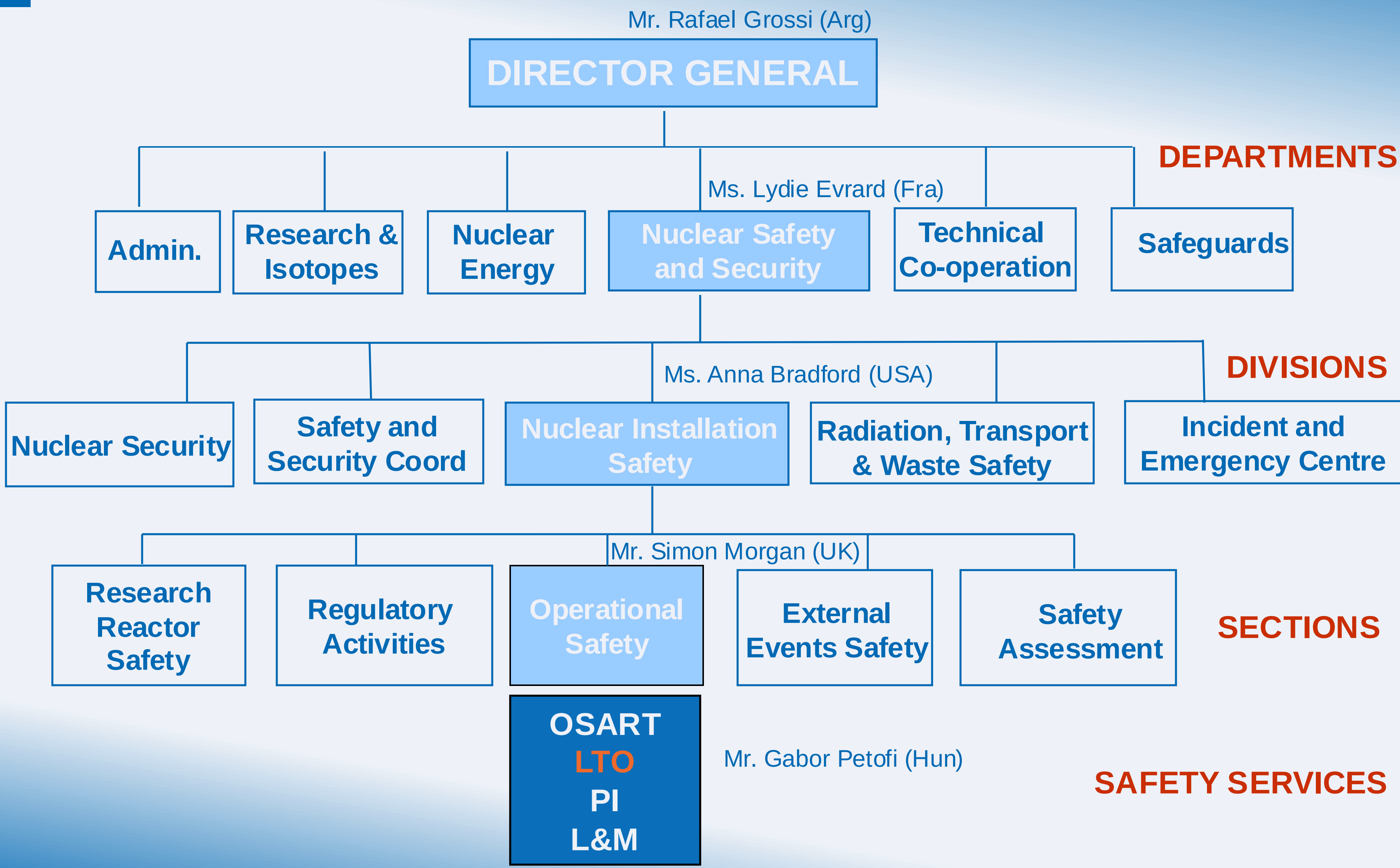
Introduction

- Name: Gábor Petőfi
- Position in IAEA
  - Senior Nuclear Safety Officer
  - Operational Safety Section
  - Division of Nuclear Installation Safety

- Current Main Activities in IAEA
  - LTO project leader
  - Team leader for SALTO Peer Review Services missions
  - IGALL Steering Committee and WGs 2, 4 scientific secretary
  - Since February 2018 with IAEA

- Originally: Hungarian, worked 18 years at regulator (HAEA)

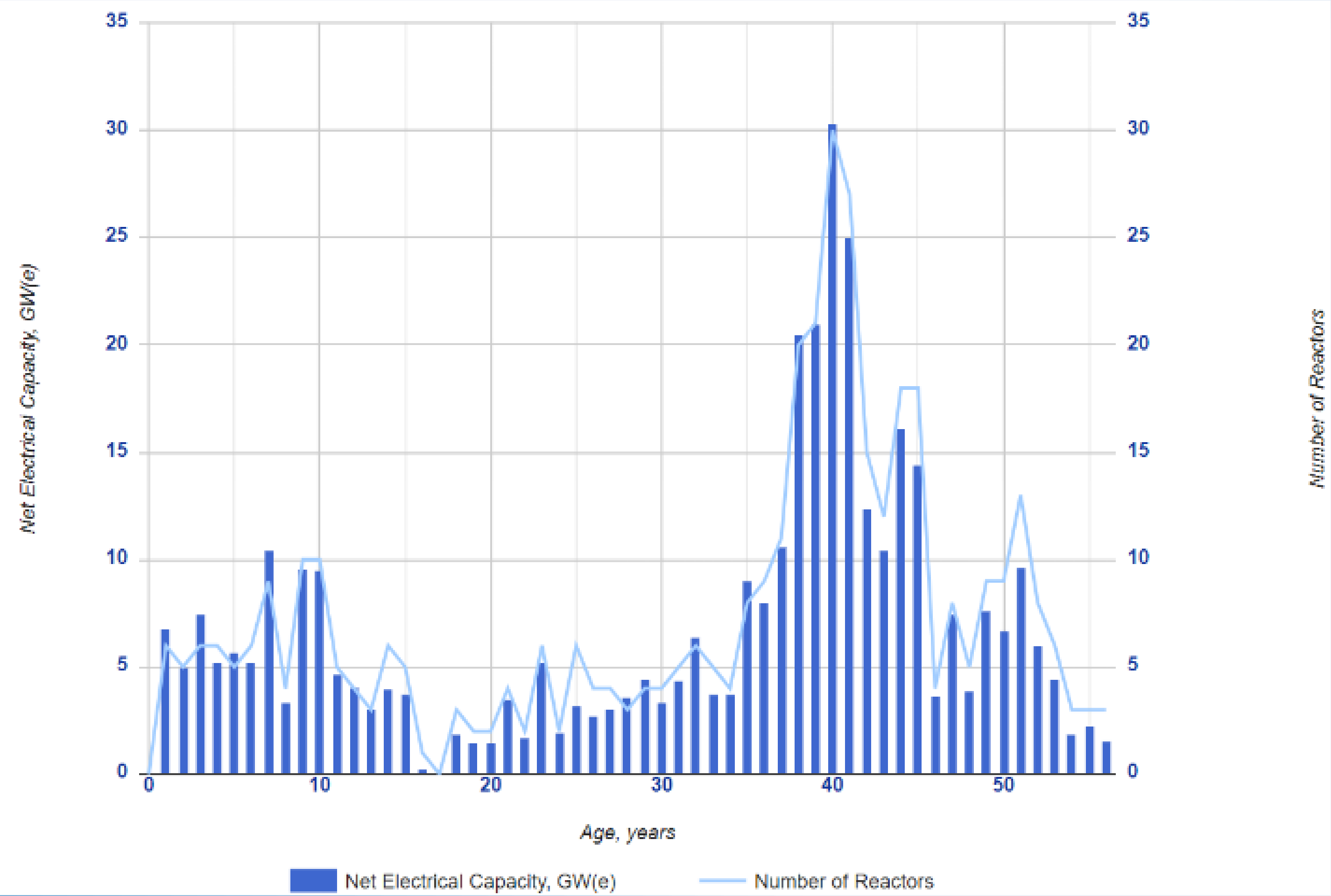
IAEA Organizational Chart



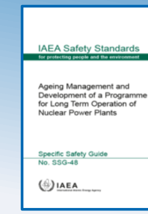
Global ageing situation of NPP reactors

(https://pris.iaea.org, 02-12-2024)

417 reactors 284 above 30y 191 above 40y



How does IAEA support AM and safe LTO of NPPs?



1. Establishment of related IAEA Safety Standards

2. Fostering information exchange and establishing databases
   1) IGALL Programme
   2) AM and LTO workshops
   3) SALTO methodology and experience transfer workshops

3. Provision of peer review service to assist Member States in application of related Safety Standards

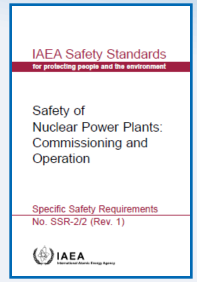
   Safety **A**spect of **L**ong **T**erm **O**peration (SALTO)

1. LTO and AM related IAEA guidance

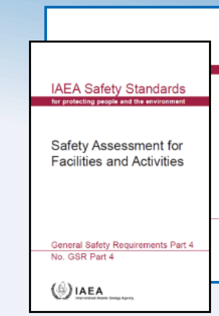
SAFETY REQUIREMENTS


IAEA Safety Standards
for protecting people and the environment
Safety of Nuclear Power Plants: Design
Specific Safety Requirements
No. SSR-2/1 (Rev. 1)
IAEA

SSR-2/1
Safety of NPPs: Design

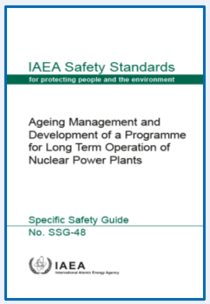

IAEA Safety Standards
for protecting people and the environment
Safety of Nuclear Power Plants: Commissioning and Operation
Specific Safety Requirements
No. SSR-2/2 (Rev. 1)
IAEA

SSR-2/2
Safety of NPPs: Commissioning and Operation

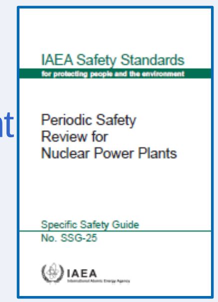

IAEA Safety Standards
for protecting people and the environment
Safety Assessment for Facilities and Activities
General Safety Requirements Part 4
No. GSR Part 4
IAEA

GSR part 2
Leadership and Management for Safety
GSR part 4
Safety assessment for facilities and activities

SAFETY GUIDES

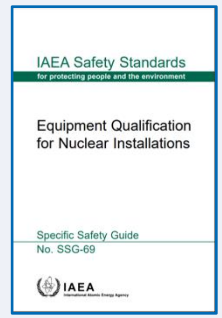

IAEA Safety Standards
for protecting people and the environment
Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants
Specific Safety Guide
No. SSG-48
IAEA

SSG-48
Ageing Management and LTO


IAEA Safety Standards
for protecting people and the environment
Periodic Safety Review for Nuclear Power Plants
Specific Safety Guide
No. SSG-25
IAEA

SSG-25
PSR

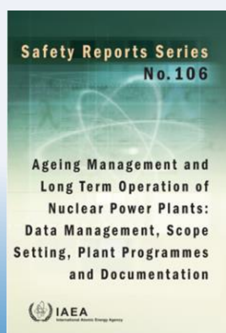
SSG-69
EQ


IAEA Safety Standards
for protecting people and the environment
Equipment Qualification for Nuclear Installations
Specific Safety Guide
No. SSG-69
IAEA

Other important Safety Guides:
GS-G-3.1 Management System…
SSG-71 Modifications
SSG-72 Operating Organization
SSG-74 Maintenance, Testing, Etc.
SSG-13 Chemistry Programme…

SAFETY REPORTS

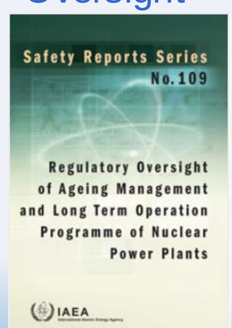
SRS 106
Scoping


Safety Reports Series
No.106
Ageing Management and Long Term Operation of Nuclear Power Plants: Data Management, Scope Setting, Plant Programmes and Documentation
IAEA

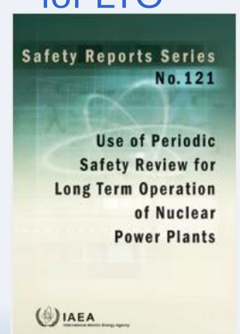
SRS 82
IGALL, Rev.2


IAEA
SAFETY REPORTS SERIES
No. 82 (Rev. 2)
Ageing Management for Nuclear Power Plants: International Generic Ageing Lessons Learned (IGALL)

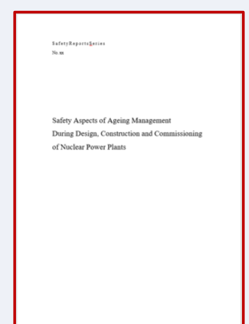
SRS 109
Regulatory Oversight


Safety Reports Series
No.109
Regulatory Oversight of Ageing Management and Long Term Operation Programme of Nuclear Power Plants
IAEA

SRS 121
PSR support for LTO


Safety Reports Series
No.121
Use of Periodic Safety Review for Long Term Operation of Nuclear Power Plants
IAEA

SRS XXX
Design, construction, commissioning


Safety Reports Series
No. xx
Safety Aspects of Ageing Management During Design, Construction and Commissioning of Nuclear Power Plants

LTO and AM related IAEA documents

Available online

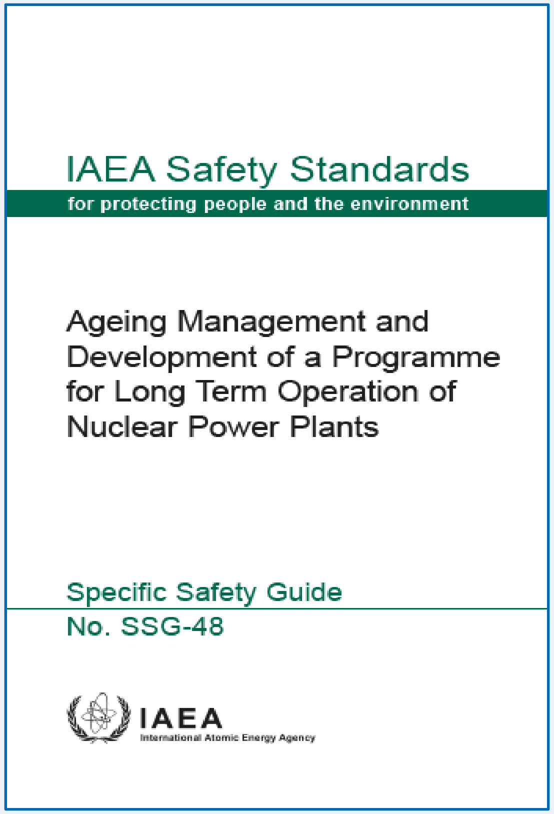
IAEA requirements on 60+

IAEA SSR-2/2 (Rev. 1)

Requirement 16: Programme for long term operation

Where applicable, the operating organization shall establish and implement a comprehensive programme for ensuring the long term safe operation of the plant **beyond a time-frame established in the licence conditions, design limits, safety standards and/or regulations**.

Specific Safety Guide on AM and LTO SSG-48


IAEA Safety Standards
for protecting people and the environment

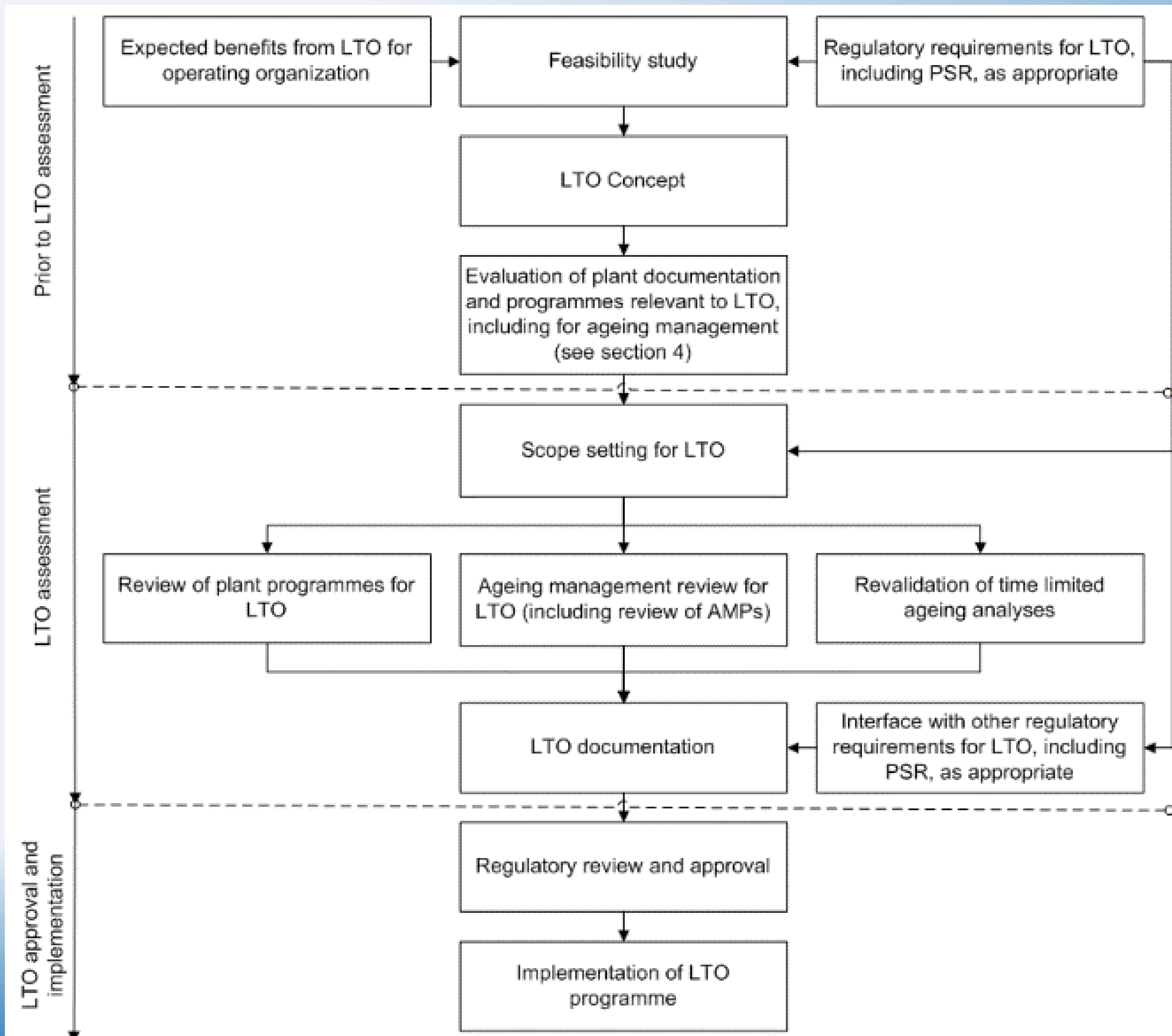
Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants

Specific Safety Guide
No. SSG-48

IAEA
International Atomic Energy Agency

- Comprehensive and systematic guidance on ageing management
  - Focused on physical ageing and management of technological obsolescence
- Provides methodology for LTO independently of age and period
- Issued in 2018
- **Revision starts in 2025**

Need for change due to 60+?



No major gaps or need for change identified for 60+

Planned revision of SSG-48

- General review timeline: 2025-2028
- Technical Meeting: 28-30 October 2025
  - Collect MS experience on using SSG-48
  - Finalize development goals, schedule and contents
- Technical aspects (proposed)
  - Experience from subsequent LTO preparations
  - Extend guidance on early life cycle phases
    - design, construction, commissioning and decommissioning
  - Better integration of HR and knowledge management
  - Concept of plant level ageing management and effectiveness assessment
  - SALTO experience
  - Advanced data analysis (AI)
  - Periodic Safety Review synergies

2. International Generic Ageing Lessons learned programme - IGALL

- Collect proven ageing management practices
- Establish a repository of ageing management techniques
- Support the systematic approach described in SSG-48
- Fully extrabudgetary progamme
- Member States are encouraged to contribute!

IGALL Participation as of 2024 (Phase 7)

- Argentina
- Armenia
- Belarus
- Belgium
- Brazil
- Bulgaria
- Canada
- China
- Czechia
- Finland
- France
- Germany
- Hungary
- India
- Iran
- Japan
- Korea
- Mexico
- Netherlands
- Pakistan
- Romania
- Russia
- Slovakia
- Slovenia
- South Africa
- Spain
- Sweden
- Switzerland
- Türkiye
- Ukraine
- UAE
- UK
- USA
- EU JRC
- OECD/NEA
- EPRI
- WANO

IGALL information share

Public website

- 119 Ageing Management Programmes
- 33 Time Limited Ageing Analysis
- 4 other programmes
- 5 regulatory documents
- IGALL AMR table
- IGALL Safety Report and IGALL TECDOC
- IGALL Dynamic Register
- Calendar of IGALL meetings

IGALL support to 60+

- IGALL Phase 4 to 6
  - Systematic review and comparison if IGALL documents with GALL-SLR report and collection of other Member States experience
  - Outcomes are incorporated in IGALL AMPs/TLAAs
- No specific document developed for SLR in IGALL
  - No SLR specific degradation mechanism or ageing effect was identified
  - Known mechanisms: more severe and/or new locations
  - New phenomena: due to increased exposure levels
  - LTO guidance document can be effectively used

Technical/safety issues for 60+ in IGALL

- RPV neutron embrittlement
  - high fluence trends, surveillance programmes
- RPV internals – high fluence effects
  - irradiation-assisted stress corrosion cracking
  - loss of fracture toughness
  - swelling of reactor internals
- Concrete and containment performance
  - long-term radiation, high temperature exposure
  - wooden piles in structures
- Electrical cables
  - environmental qualification
  - in-service cable testing
  - long-term cable submersion
- Buried piping
- High Density Polyethylene (HDPE) and Carbon Fiber Reinforced Polymer (CFRP) piping

Safety Aspects of Long Term Operation (SALTO) missions - Objectives

- Objective assessment of preparedness for LTO with respect to IAEA Safety Standards
- Recommendations and suggestions for improvement where performance falls short of IAEA Safety Standards
- Opportunity for the plant to discuss practices with experienced experts
- Experience exchange and sharing of lessons learned

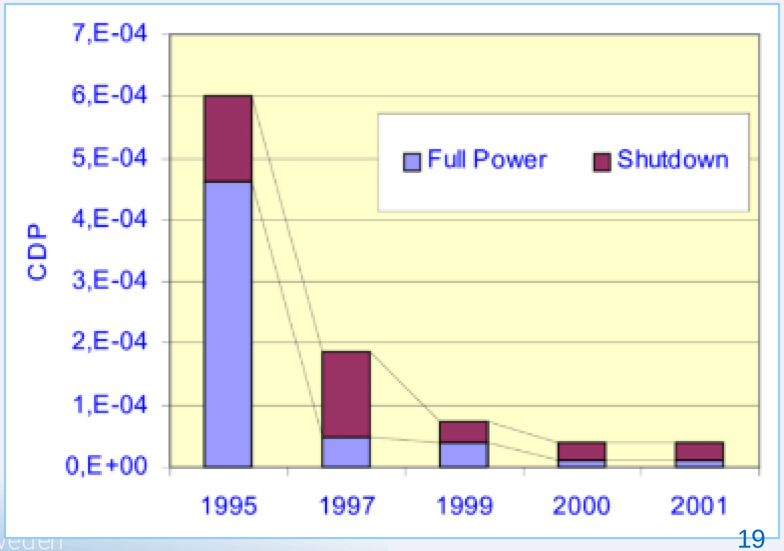
SALTO Mission Scope

Scope of the **standard SALTO Peer Review service**, divided to areas according IAEA SALTO Guidelines is as follows:

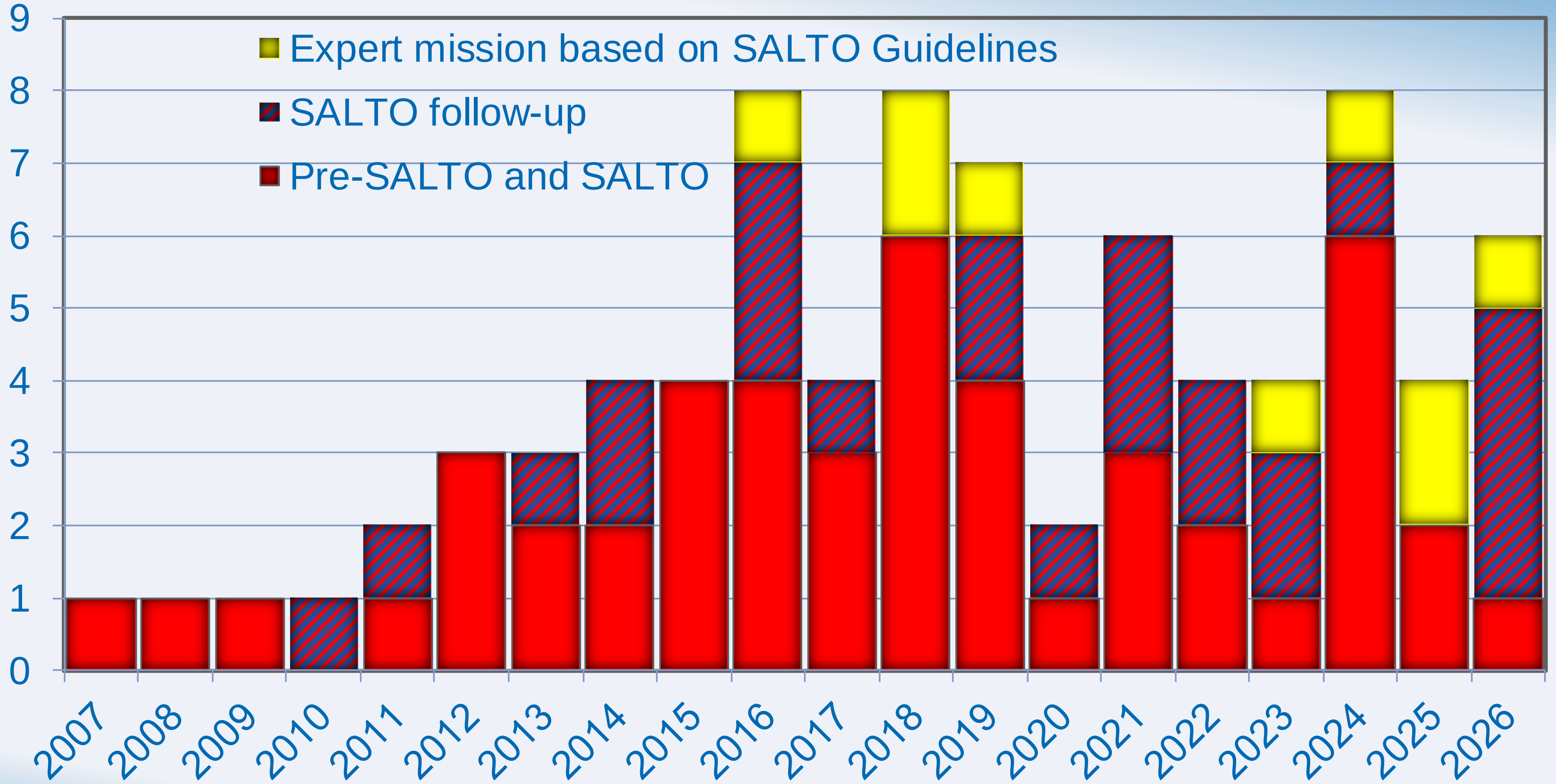
Area A	Organization of ageing management and LTO activities
Area B	Scope setting, plant programmes and corrective action programme
Area C	Ageing management of mechanical SSCs
Area D	Ageing management of electrical and I&C SSCs
Area E	Ageing management of civil SSCs
Area F	Human resources, competence and knowledge management for LTO

Standard SALTO Peer Review scope

- The scope of the SALTO peer review does **NOT** include:
  - Assessment or review of the plant **design**
  - Assessment of the **environmental impact** of LTO
  - **Economic assessment** and LTO investment strategies
- Review scope does include activities for **design improvements**
  - Periodic Safety Review are meant to identify potential safety improvements



SALTO missions 2007 – 2026 (partially plan)



SALTO mission to prepare for subsequent LTO

- NPPs for 2nd SALTO peer review service cycle
  - Borssele, the Netherlands (license: 2034): pre-SALTO in 2024
  - Armenian NPP, Armenia (2026): SALTO in 2025
  - Paks NPP, Hungary (2032): pre-SALTO in 2026/27

- Issues to focus for 60+
  - Maintained effectiveness of existing activities?
  - Plant changes addressed by/in ageing management?
  - Further modernization project?
    - What is safe enough? Do we need more for 60+?
  - Loss of knowledge is significant in 20 years
  - Clear regulatory expectations
  - Timely decision making (for safety and investments)


IAEA
Safety Aspects
of Long Term
Operation
SALTO


Questions? I’m all eaers?
Until the clock says othewiere
QUESTIONS?
QUSTON
EARS?
Inoud
Quest
smiling

Thank you!

Overview of nuclear in EU with 2050 perspective

Yves Desbazeille – Director General

Energiforsk Annual Nuclear Seminar – 22 January 2025

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About nucleareurope

We act as the voice of the European nuclear industry in energy policy discussions with EU Institutions and other key stakeholders

Membership: nucleareurope represents 15 national nuclear associations

Corporate Members:

CEZ (Czech Republic)
Fermi Energia (Estonia)
Nuvia (France)
PEJ (Poland)
Rolls-Royce SMR (UK)
Urenco (Global)
KGHM (Poland)
NAAREA (France)

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What does nuclear contribute to the EU's economy?

100 Nuclear reactors in operation in the EU

1 million jobs

€ 100 billion/year

24% of the electricity Production (2024)

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The EU's needs to decarbonize are massive…across all sectors

Electricity

1600 TWh/y
EU Low carbon electricity production to be deployed by 2040

80GW
European Nuclear capacity to be replaced by 2050 (end of life)

Hydrogen

>20 Mt H_2/y
REPowerEU Market Estimate for 2030

1000 TWh/y
Equivalent additional clean electricity demand

Industrial heat

~1250 TWh_{th}/y*
Iron – Steel, Non-metallic minerals and chemicals heat demand in EU

> 45% market
Heat < 400°C

District heat

~500 TWh_{th}/y**
Current district heat demand in EU

> 2/3 fossil-fueled
Assets to be retired and replaced in the coming two decades

European SMR pre-Partnership-WS1 Market Analysis Final Report-3 July 2023

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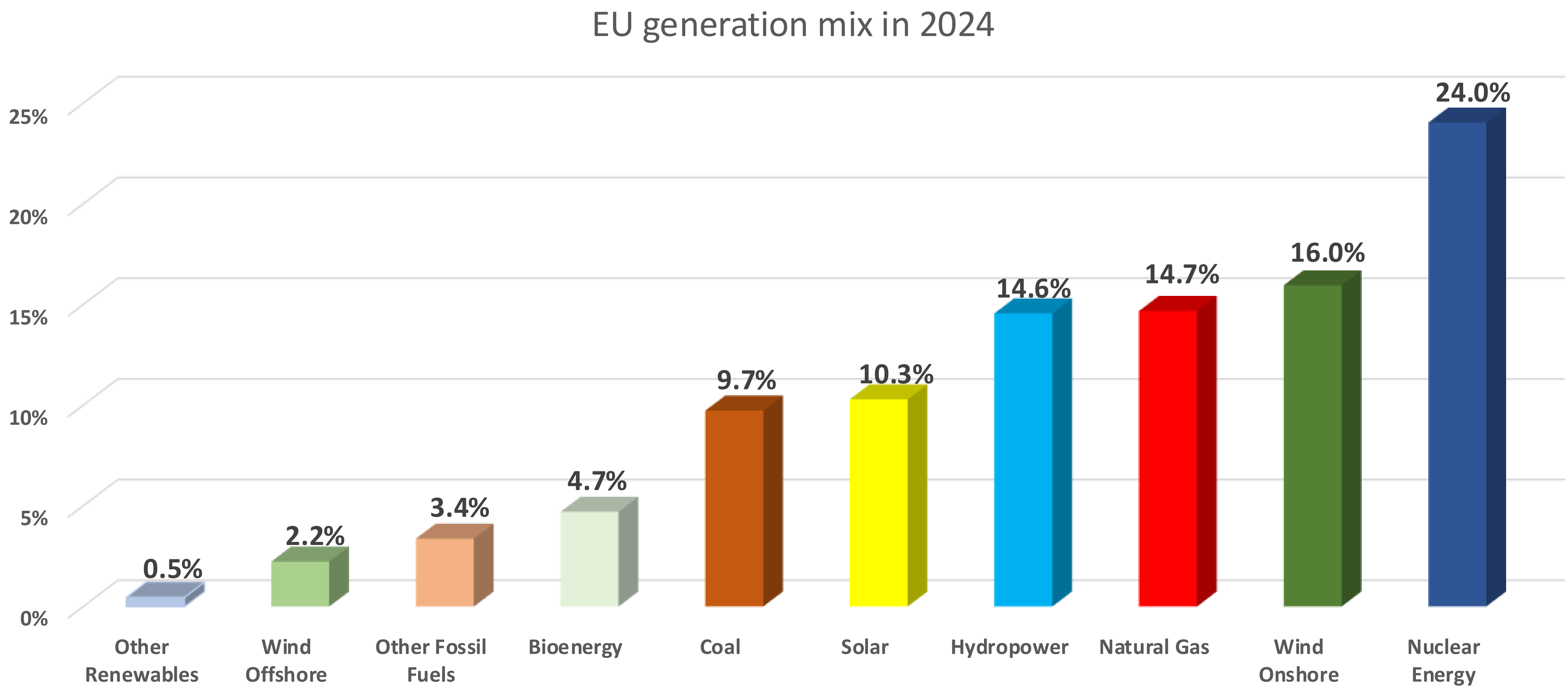
Status of EU's power sector



Source: nucleareurope calculations based on eurelectric ELDA

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Political commitment and what it entails for LTO

Meeting of the Nuclear Alliance in Paris on 16 May

- Member states participating: France, Belgium, Bulgaria, Croatia, Estonia, Finland, Hungary, Netherlands, Poland, Czech Republic, Romania, Slovenia, Slovakia and Sweden.
- Italy participated as observer and UK as invited country.
- During the meeting, a statement has been released.
- *Ministers discussed the positive impact of nuclear energy on the European economy: they acknowledged that nuclear power may provide up to 150 GW of electricity capacity by 2050 to the European Union (vs roughly 100 GW today)*

Photo by @Paul_Messad @EURACTIV_FR

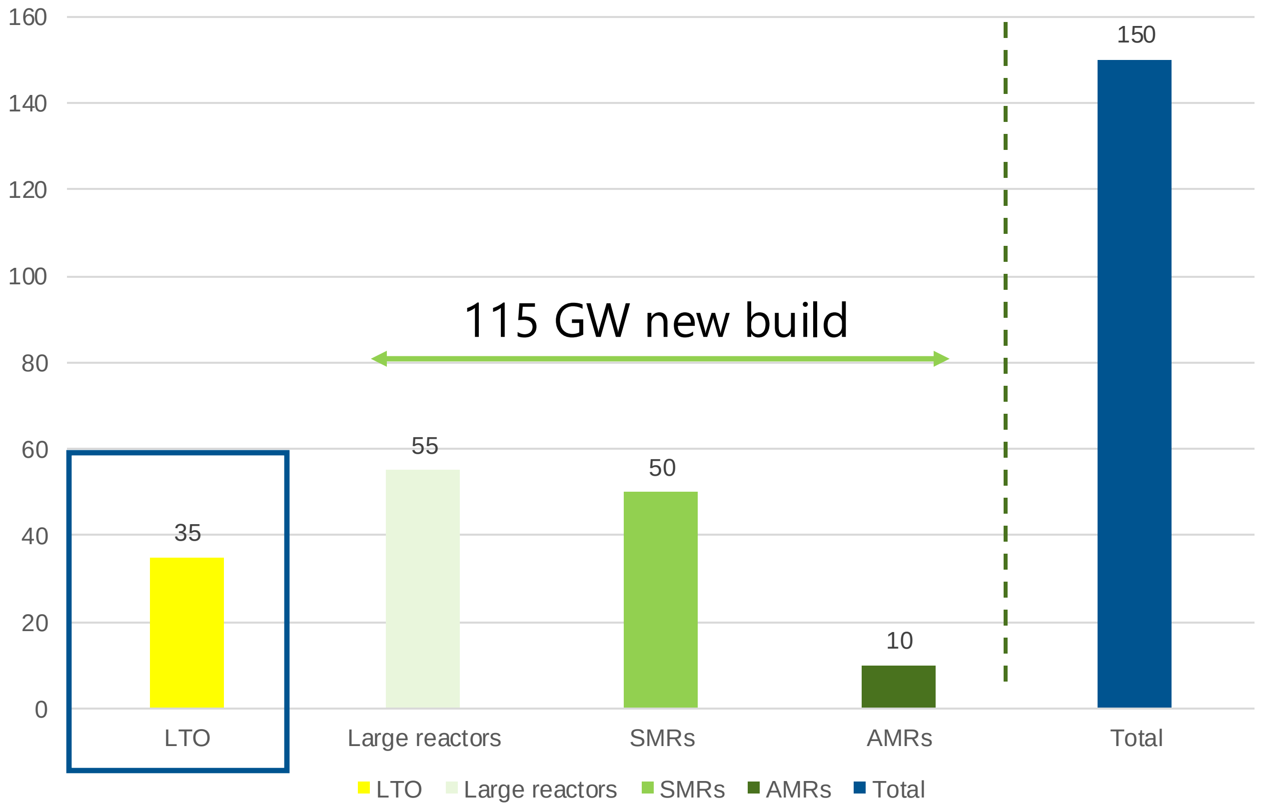
An increased ambition for a European nuclear future

The latest EC scenarios updates from the projected share of nuclear show a steady decrease despite the obvious benefits that a significantly higher scenario provides to the EU system in a deep decarbonization scenario.

Based on this, nucleareurope promotes an upscaled scenario of at least 150 GW* capacity in 2050

This scenario requires:

- The current share of 25% electricity production to be maintained in the EU.
- Part of the needs from hard-to-abate heavy industries in terms of decarbonized heat, hydrogen, etc. to be covered by SMRs (from early 2030s) and AMRs later on (from 2040s).
- Mobilization of industry and decisionmakers both at EU & national levels



*Aggregated figure based on recent national intentions / declarations

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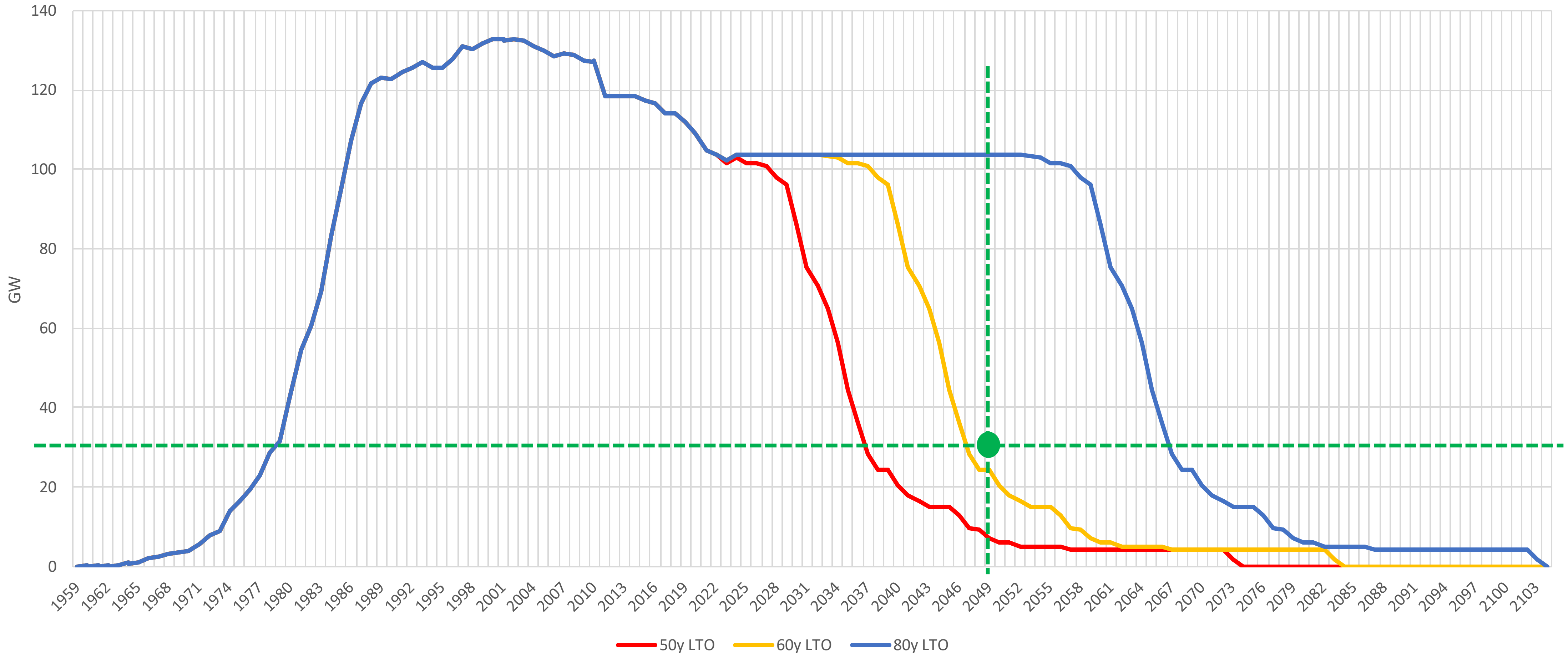
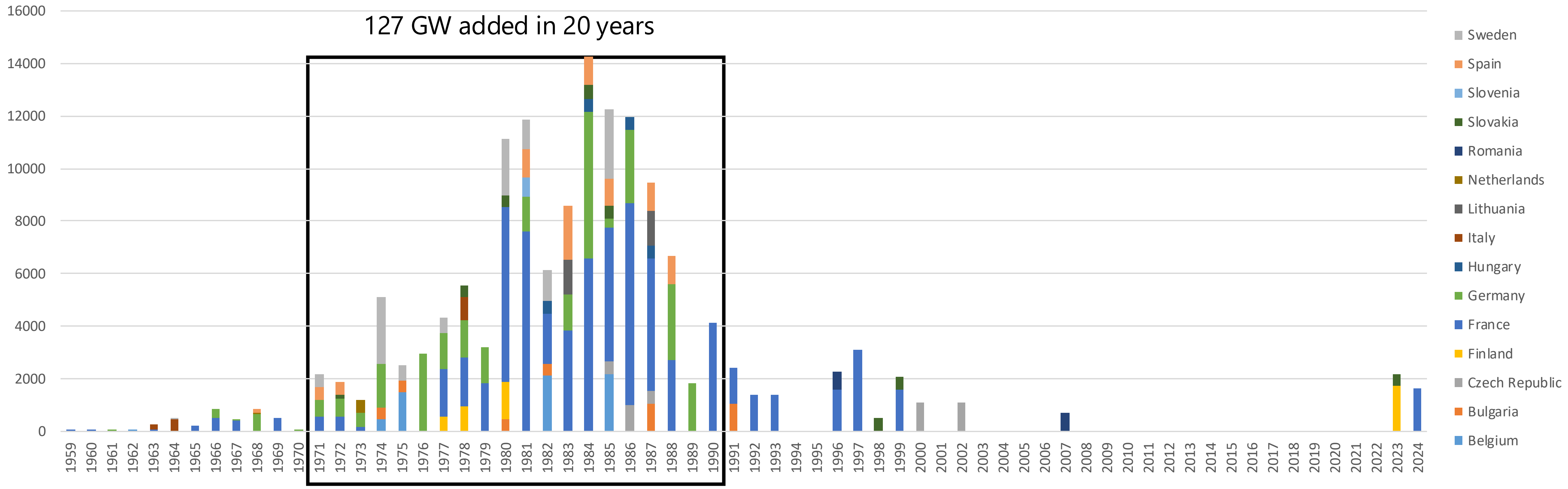
Lifetime extension scenarios of the existing fleet



nucleareurope chart based on [IAEA PRIS database]

History of EU's nuclear fleet deployment



nucleareurope chart based on [IAEA PRIS database]

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The main challenges of LTO in Europe

LTO of NPP: an important topic for nucleareurope for a long time

- ➢ Position paper released in July 2019
- ➢ All the points made in the position paper are still valid:
- *LTO is unarguably economically advantageous compared to other power sources. It requires a much lower capital investment cost, leading to low investment risks for investors and capital markets, and lower consumer costs.*
- *From a technical point of view, the LTO of nuclear reactors provides a great advantage thanks to the "…timely implementation of reasonably practicable safety improvements to existing nuclear installations" which brings older generation reactors to a level of nuclear safety standards in compliance with the amended Nuclear Safety Directive.*
- *LTO reduces the EU's energy import dependency – mainly fossil fuels – and provides reliability to the grid.*

Challenges for the lifetime extension of the existing reactors

Challange	Example of challenge	Mitigation
Aging Infrastructure	Many components of nuclear power plants, such as reactors and cooling systems, degrade over time. Ensuring these components can continue to operate safely and efficiently requires extensive maintenance and upgrades	Good opportunity on research on aging materials
Regulatory Compliance	Extending the life of a nuclear plant often requires approval from regulatory bodies, which involves rigorous safety assessments and compliance with updated safety standards	Brings older generation reactors to a level of nuclear safety standards in compliance with NSD
Technological Upgrades	As technology advances, older plants may need to be retrofitted with modern systems to improve safety, efficiency, and reliability. This can be both technically challenging and costly	Same as above
Economic Viability	The cost of extending the life of a nuclear power plant can be substantial. Operators must weigh these costs against the potential benefits, such as continued energy production and reduced carbon emissions	With the initial capital investments costs amortised, the investments for lifetime extension are much lower
Supply Chain Issues	Procuring replacement parts for older plants can be difficult, especially if the original manufacturers are no longer in business	3D printing, digital twins, reverse engineering among other possibilities
Knowledge Transfer	As the workforce ages, there is a risk of losing valuable expertise. Ensuring that knowledge is transferred to newer generations of engineers and technicians is crucial for the continued safe operation of extended-life plants	Competences assessed under Euratom funded projects as ENEN+, ANNETT, ENEN++,Skills for Nuclear

LTO of NPP: Espoo convention and Impact assessment

IAEA definition on LTO *"Operation beyond an established time frame defined by the licence term, the original plant design, relevant standards or national regulations." (IAEA, 2018).*

- With the adoption and entering into force of the Convention on Environmental Impact Assessment in a Transboundary Context ("Espoo Convention"-All EU Member States are contracting parties of), it must be determined whether the LTO of NPP falls under its scope of application, rising international obligations.
- Appendix I of the Espoo Convention includes nuclear activities in their scope of application, but **no direct mention to LTO** as part of the proposed activities. Therefore, a **legal determination must be made**.
- At the beginning no Environmental Impact Assessments (EIA) for the LTO of NPP was foreseen but it changed following the discussions/conclusions of UNECE guidance in 2020.

Article 41 of the Euratom Treaty and LTO of NPP

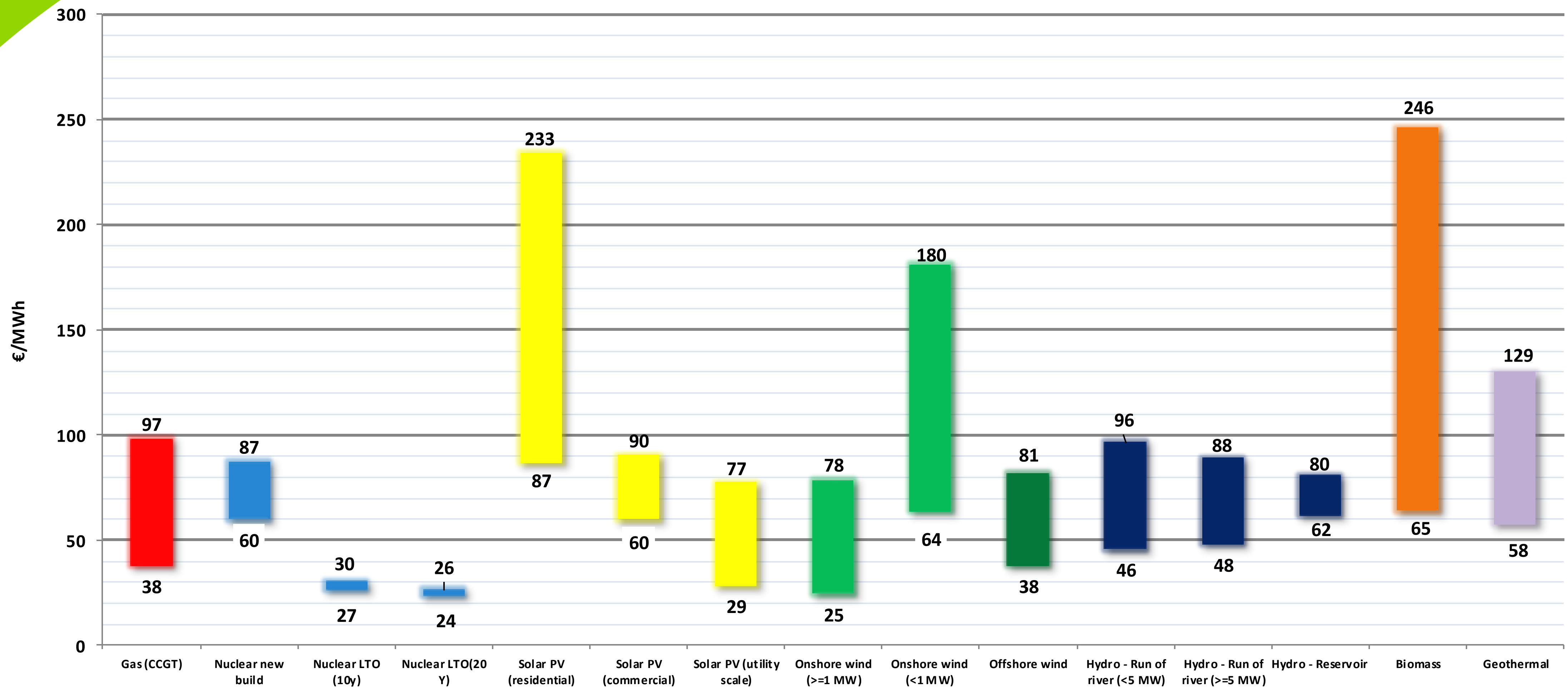
Art 41 of the Euratom Treaty requires nuclear undertakings to notify the European Commission about investment projects. This covers new investments and significant modifications to nuclear installations, **including projects related to the LTO of NPP.**

Article 41

"Persons and undertakings engaged in the industrial activities (...) shall communicate to the Commission investment projects relating to new installations and also to replacements or conversions which fulfil the criteria (...)"

The goal of this notification is to provide visibility and ensure full transparency in nuclear investment projects, uphold regulatory compliance, and verify that the notified projects adhere to safety standards, all while reinforcing energy security across the EU.

LCOE for LTO is very competitive



Comparison of LCOE (levelized cost of electricity) for different technologies in Europe (7% discount rate)
Source: IEA report on "Projected Costs of Generating Electricity 2020"

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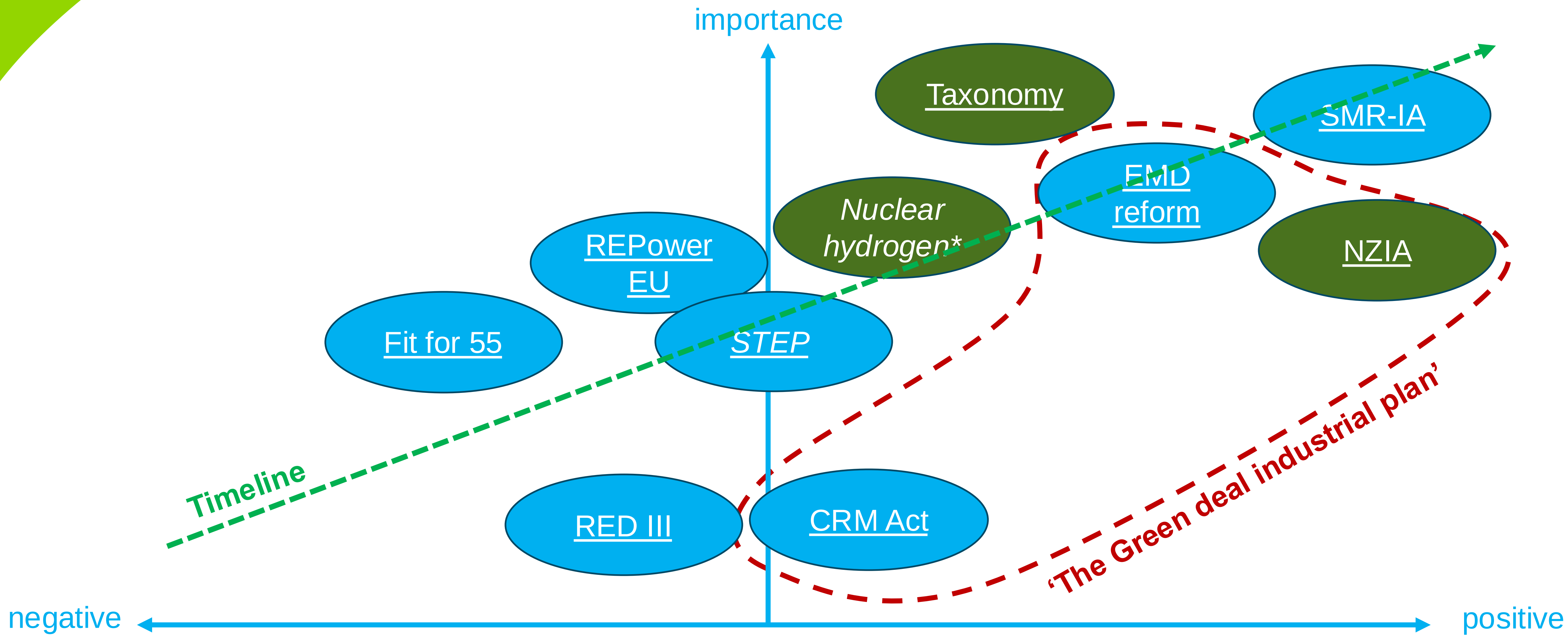
EU policies and initiatives: state of play for nuclear



Files with impact on nuclear sector

Files with impact on nuclear sector and LTO in particular

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*Ongoing file

Transformation challenges of EU nuclear Supply chain

	Long term operation	New large reactors	SMR	Gen IV / AMR
Main challenges	• Component availability • Knowledge management • On site constraints (RP, Sched., co-interv.)	• Big components manufacturing • On site constraints (co-interv., interfaces,…) • Civil works complexity • Project management	• Engineering • Licensing • Modularity management • Manufacturing engineering & implem. • Serial production & standardization	• Engineering • Licensing • Hi degree of components / material / system innovation needs • Manufacturing for dedicated components / needs
SC structure adaptation	Good	Fair (depends on countries)	Mild	Poor
Digital challenges	• 3D modelling • Digital twins • Augmented reality • 3D printing	• 3D modelling • Collaborative platforms • Dynamic construction simulation tools • Additive Manufacturing	• Ditto Gen III+ • 'Industry 5.0' incl. robotics, prod. Management	• Ditto SMR • TBD
Other challenges	• Commercial grade items • SC capacities / availability in some MSs • Fuel supply: enrichmt/ conversion capacities • R&D on component aging	• Serial effect on construction • Component production capacity ramping up • Fuel supply: ditto	• SC Standardization at EU level • Utilization of C&Ss • Manufactory capacity ramping up • Fuel supply: ditto	• TBD • Fuel supply: potential availability issue of new / "exotic" fuel needs
HR	• Adapted but aging	• New staff needed (replact & reinforcemt) • Specific issues (welders…)	• Ditto Gen III+ • Reskilling / upskilling for manufacturing	• High level of dedicated expertise • Skills scarcity (Research…)

Conclusions

Despite all the identified challenges, many Member States considered lifetime extension of the existing nuclear reactors as an opportunity as it can:

- Provide electricity produced at very competitive prices
- Help to preserve the supply chain knowledge and capabilities
- Maintain and prepare the workforce for the expected new nuclear build campaign

This can materialized if the technical and economical challenges are properly addressed by the industry and policy makers

Thank you!

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