Nuclear energy & its role in Europe's future energy mix

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ABOUT FORATOM

Who we are

FORATOM acts as the voice of the European nuclear industry in energy policy discussions with EU Institutions & other key stakeholders.

Membership

The membership of FORATOM is made up of 15 national nuclear associations representing more than 3,000 companies.

Belgium

Bulgaria

Finland

France

Hungary

Italy

Netherlands

Romania

Slovakia

Slovenia

Spain

Sweden

Switzerland

Ukraine

United Kingdom

CEZ (Czech Republic) and PGE EJ 1 (Poland) are Corporate Members

Key topics

EU Energy Policy:

- Economics of nuclear
- EU energy mix
- Environment
- Euratom Treaty
- Security of energy supply
- Special projects - Brexit

Nuclear technology:

- Nuclear safety
- Nuclear transport
- R&D
- Supply chain
- Waste disposal

Communication:

- Nuclear advocacy
- Perception of nuclear energy
- Promotion of nuclear energy
- Public opinion
- Young generations in nuclear

Nuclear energy’s contribution to Europe's economy

126

NUCLEAR REACTORS
IN OPERATION IN THE EU

70

€ BILLION/YEAR

800,000

JOBS

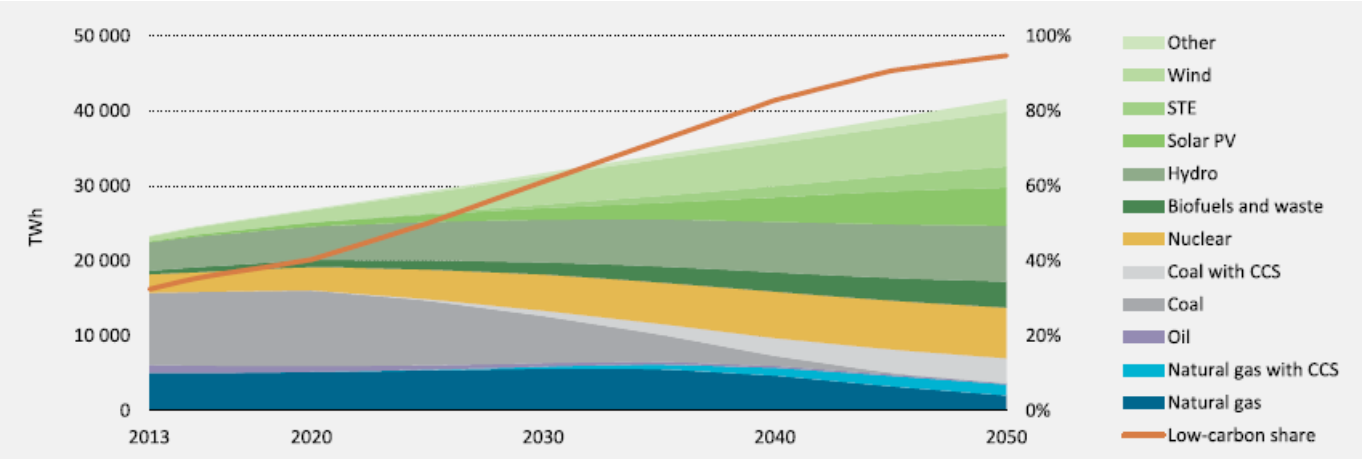
26%

ELECTRICITY PRODUCTION

ROLE FOR NUCLEAR IN FIGHTING CLIMATE CHANGE

What the World has to achieve to save the climate…

Global electricity production and technology shares in the IEA 2DS



533 gCO_2/kWh

68% fossil fuels
22% renewables
11% nuclear

40 gCO_2/kWh

17% fossil fuels
67% renewables
16% nuclear

Source: IEA, ETP2016, OECD/NEA 2018

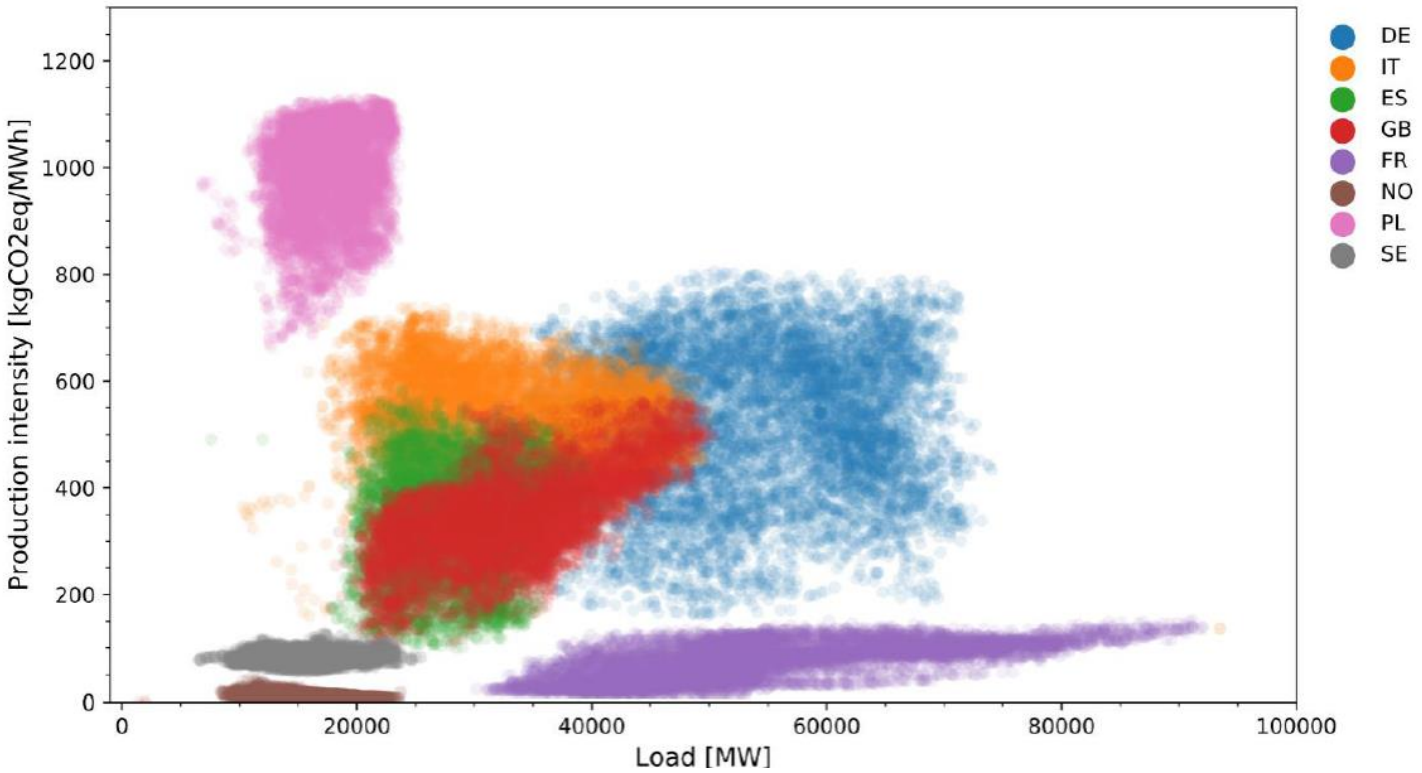
- A **complete reconfiguration** of the electricity generation system is needed by 2050.
- Rise of nuclear is accompanied by a *complete phase-out* of coal and oil, a drastic decrease of gas, development of CCS and a massive increase of renewable energies.
- Colossal investments for the energy sector: 40 trillion USD + 35 trillion USD in energy efficiency.

Paris Agreement

196 states adopted in 2015 the **Paris Agreement** and made a commitment to the common objective of limiting greenhouse gas emissions.

The agreement provides for keeping the increase in global average temperatures well **below 2°C**, and continuing efforts to limit the temperature rise to **1.5°C**.

CO2 emissions by selected EU Member States



Source: Tranberg, B., Corradi, O., Lajoie, B., Gibon, T., Staffell, I., & Andresen, G. B. (2018). Real-Time Carbon Accounting

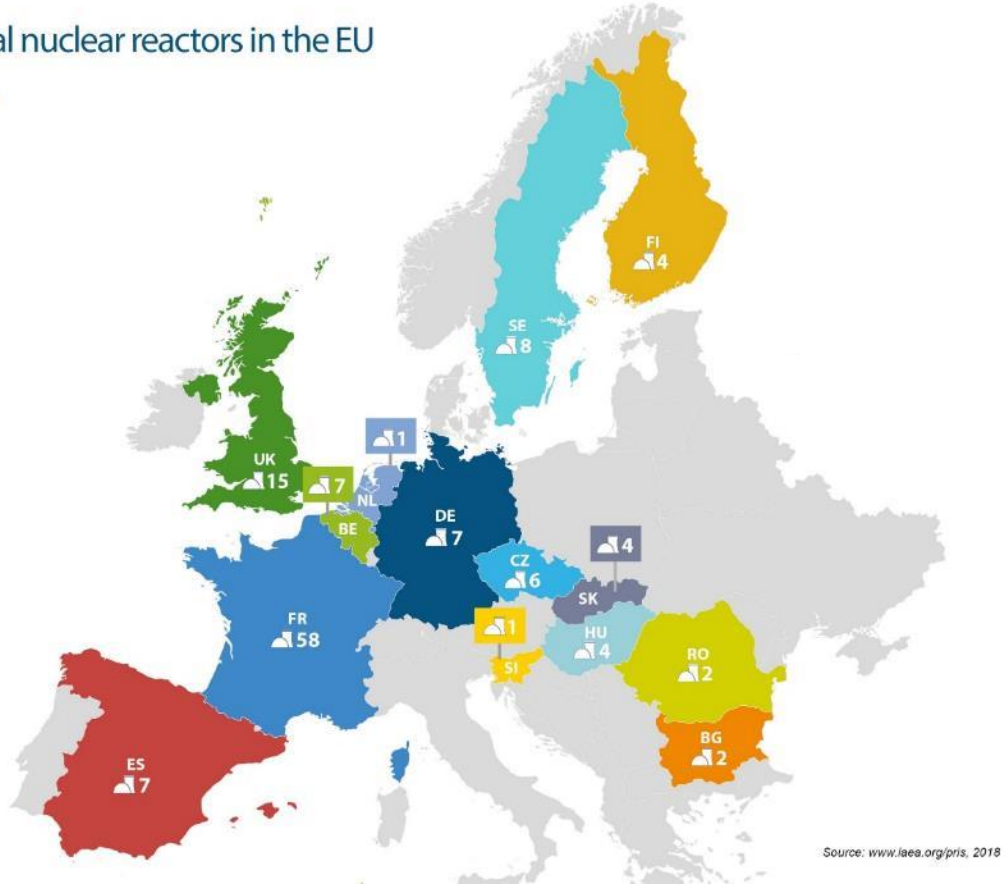
NUCLEAR IN THE EU - CURRENT STATUS & PERSPECTIVES

Nuclear energy in the EU

126 Operational nuclear reactors in the EU

Nuclear share of electricity

- **72% France** 58 reactors - 63 130 MW
- **54% Slovakia** 4 reactors - 1 814 MW
- **50% Belgium** 7 reactors - 5 913 MW
- **50% Hungary** 4 reactors - 1 889 MW
- **40% Sweden** 8 reactors - 8 629 MW
- **39% Slovenia** 1 reactor - 688 MW
- **34% Bulgaria** 2 reactors - 1 926 MW
- **33% Finland** 4 reactors - 2 764 MW
- **33% Czech Republic** 6 reactors - 3 930 MW
- **21% Spain** 7 reactors - 7 121 MW
- **19% UK** 15 reactors - 8 918 MW
- **18% Romania** 2 reactors - 1 300 MW
- **12% Germany** 7 reactors - 9 515 MW
- **3% Netherlands** 1 reactor - 482 MW



ELECTRICITY PRODUCTION

26%

LOW-CARBON ELECTRICITY

50%

New build in the EU – construction & plans

Nuclear power plants under construction

Finland
1 reactor - 1 600 MW

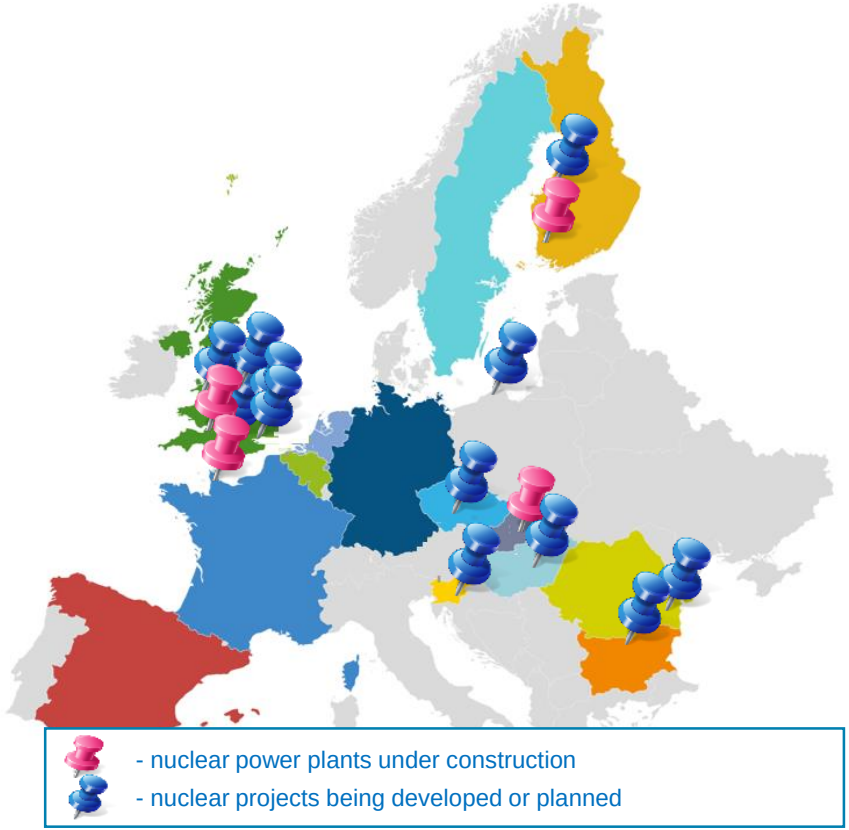
France
1 reactor - 1 630 MW

Slovakia
2 reactors - 880 MW

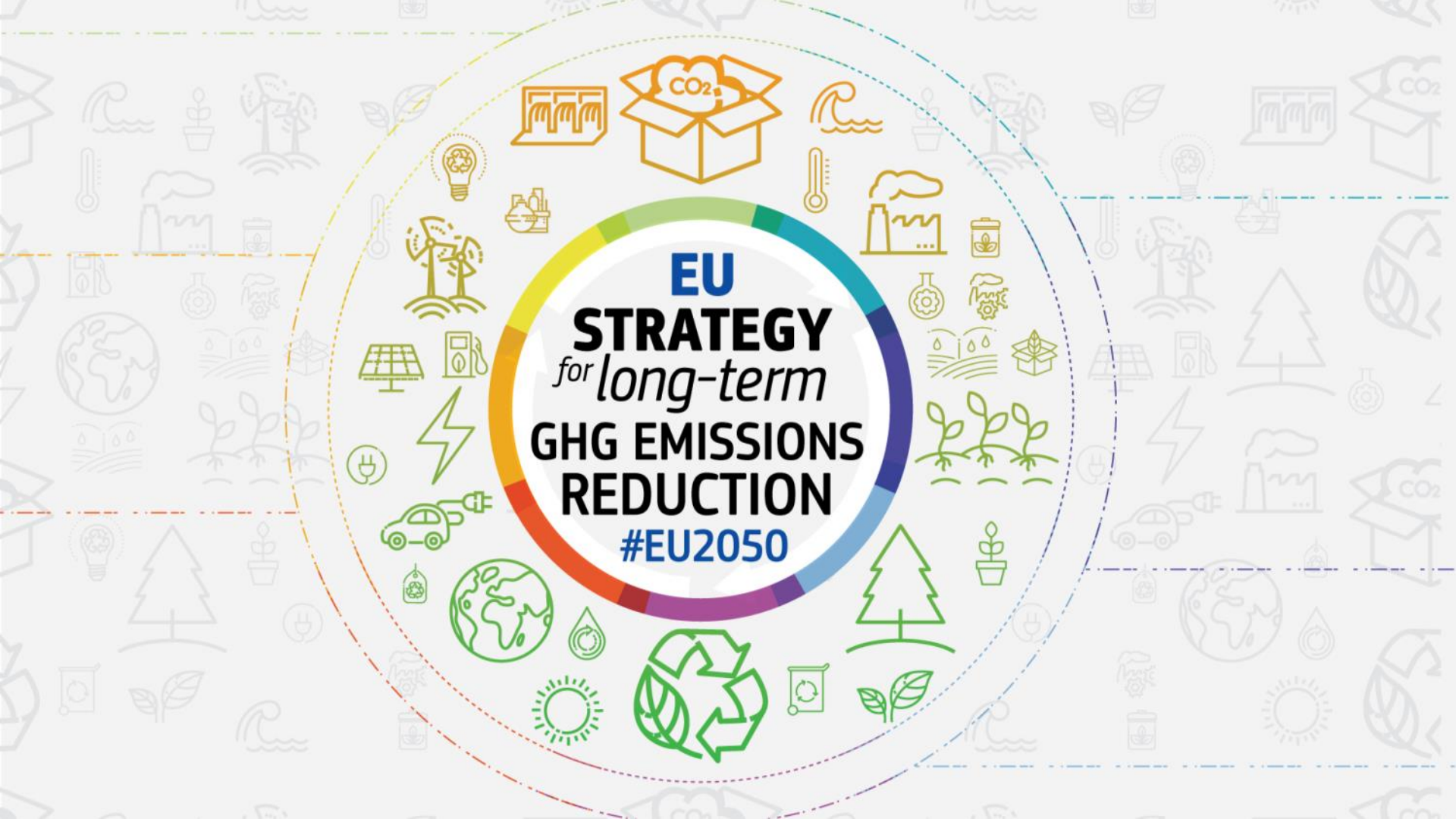
UK
2 reactors - 3 200 MW

Countries preparing or considering new build

- ✓ **Bulgaria**
- ✓ **Czech Republic**
- ✓ **Finland**
- ✓ **France**
- ✓ **Hungary**
- ✓ **Poland**
- ✓ **Romania**
- ✓ **Slovenia**
- ✓ **UK**



Source: European Commission's PINC, May 2017


EU
STRATEGY
for long-term
GHG EMISSIONS
REDUCTION
#EU2050

FTI CL Study (commissioned by FORATOM)

Pathways to 2050: role of nuclear in a low-carbon Europe

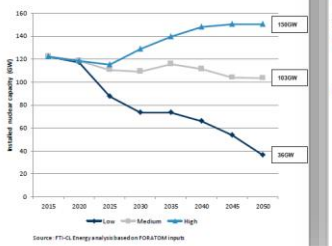
Final report

The nuclear scenarios cover a range of installed capacities reflecting different assumptions for retirements, life extensions and new build

Scenarios design

- Each scenario is based on current nuclear plants and projects under construction as well as planed nuclear phase-down policies. Each scenario then assumes different life extension decisions as well as different commissioning date for future new nuclear plants. As a result:
  - In the **short term**, in all scenarios, nuclear capacity **drops by 5 to 20GW by 2025**.
  - In the **longer-term**, variation of extension and new built decisions lead to the following scenarios:
    - In the **low scenario**, most of the existing plants close without further extensions and new plants projects fail to conclude. The nuclear capacity decreases to **36GW by 2050**.
    - In the **medium scenario**, a number of long term operation (LTO) extensions are awarded and new plants are built, in line with current advanced projects. The nuclear capacity reaches **103GW by 2050**.
    - In the **high scenario**, a number of additional new plants (including ≤5GW of SMR and <1GW of Gen-IV) are commissioned replacing thermal baseload and contributing to decarbonisation of the power sector and wider European economy. The nuclear capacity reaches **150GW by 2050**.

EU-28 nuclear installed capacity outlooks (GW)



Source: FTI-CL Energy analysis based on FORATOM inputs

Installed capacity outlook

In the medium scenario, RES capacity reaches 1570 GW (+231%) by 2050, while the flexible capacity hits 500 GW (+695%)

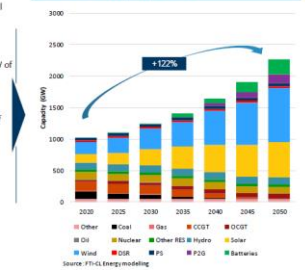
Modelling approach

- The model is set up so that sufficient capacity is operational to ensure security of supply at least cost

Installed capacity outlook:

- **Thermal plant closure:**
  - Between 2020 and 2050, 300GW of the existing 310GW of thermal capacity (97%), would close due to anticipated closure or reaching their end of life.
- **This would be replaced by:**
  - 1100GW of **new RES** over 2020-2050 reaching a total of 1570GW in 2050
    - Wind: 860GW; and
    - Solar: 560GW
  - 445 GW additional **new flexible capacity:**
    - 240GW battery;
    - 5GW DSR*;
    - 55GW thermal peakers; and
    - 145GW Power to Gas**

Medium scenario capacity outlook



Source: FTI-CL Energy modeling

Daily generation outlook

Optimising the use of short term and long term storage will be critical to maintain an efficient and economic operation of nuclear plants

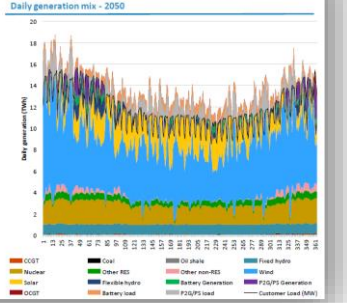
Nuclear contributes to providing flexibility and baseload power to the system by cycling at different times:

- **It can complement solar and wind variability** by providing flexible and dependable carbon free generation.

Seasonal utilisation of storage and P2G:

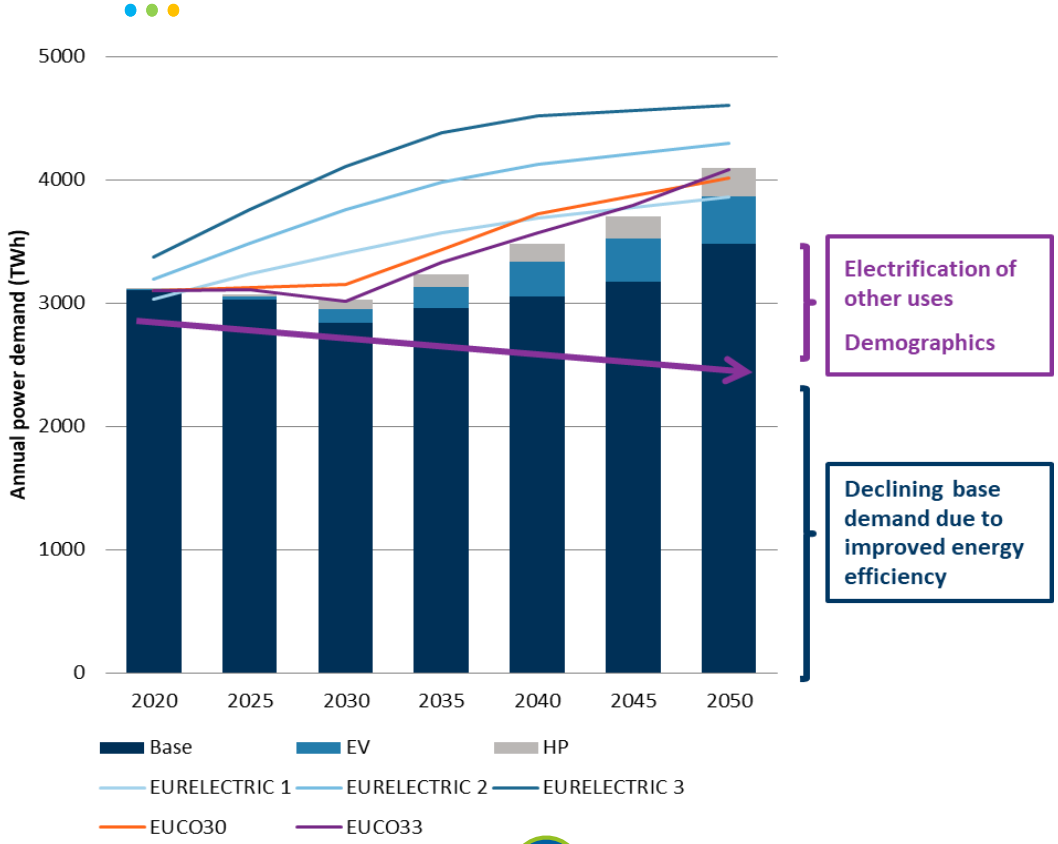
- **Storage capacities** are essential to stabilise the power system by capturing excessive production and generating in scarcity situations.
- **In summer**, beyond batteries transferring solar power from day to night, P2G enables solar power to be transferred from one day to the next. It can represent up to 10% of the customer load.
- **In winter**, P2G enables to offset low wind days and weeks, transferring power on a seasonal timeframe. P2G can represent up to 20% of the customer load.

Daily generation mix - 2050

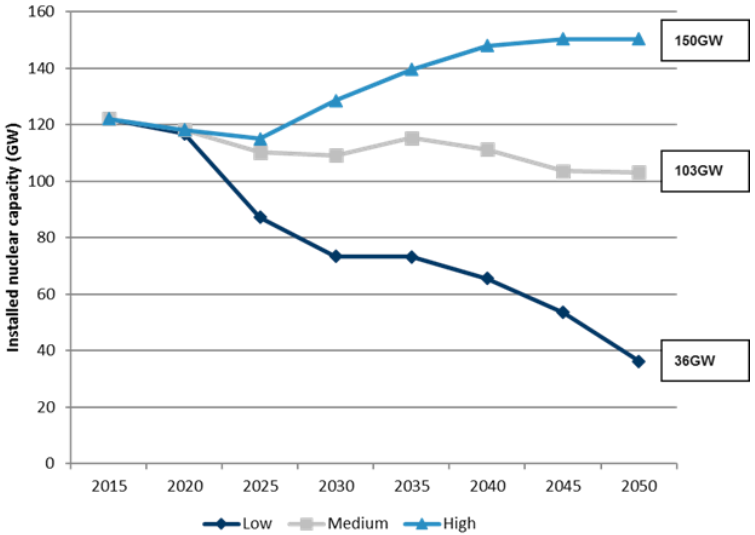


The main assumptions of the study

- **95% decarbonisation** of the energy mix in 2050, compared to 1990;



3 nuclear scenarios



3 nuclear scenarios:

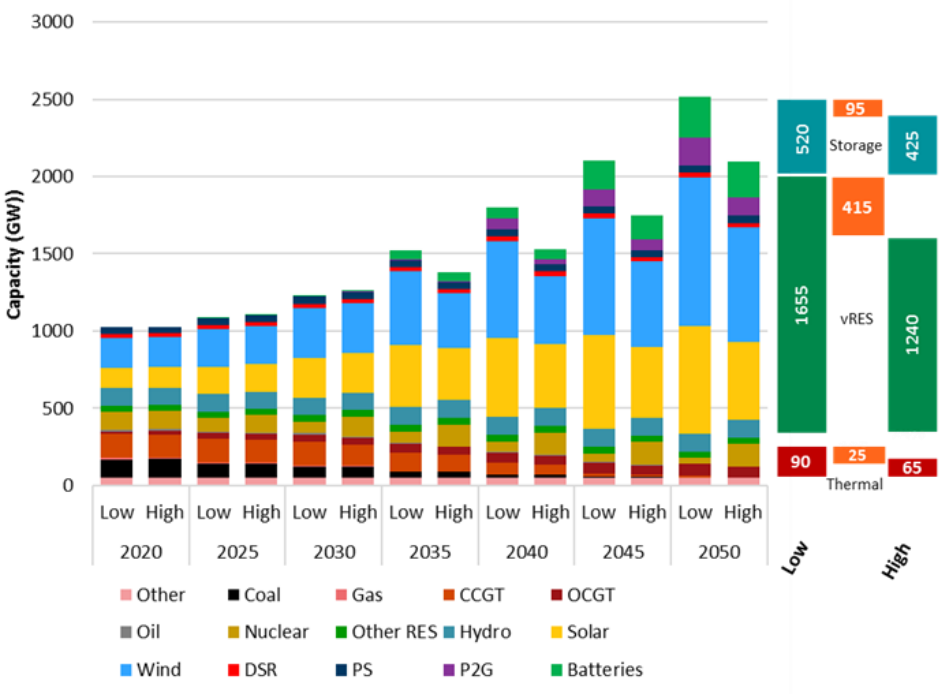
1. **High** – 150 GW, share ~25% (maintaining the current share)
2. **Medium** – 103 GW, share ~15% (in line with the EC strategy)
3. **Low** – 36 GW, share ~4%

The study assesses the impact of each scenario on the key dimensions of Europe's energy policy:

1. security of supply
2. sustainability
3. economics

Key conclusions

Need for additional capacity



The high nuclear scenario provides significant "net" installed capacity savings:

- +114 GW nuclear capacity

against:

- +95 GW storage
- +415 GW vRES
- +25 GW thermal

Key conclusions - Security of energy supply

By 2035, the lack of commercial maturity of storage technologies implies the need for dispatchable sources

- Anticipated nuclear closure (low-nuclear scenario) would lead to **20 GW/7 GW** of new thermal/extension which would become lock-in in the LT

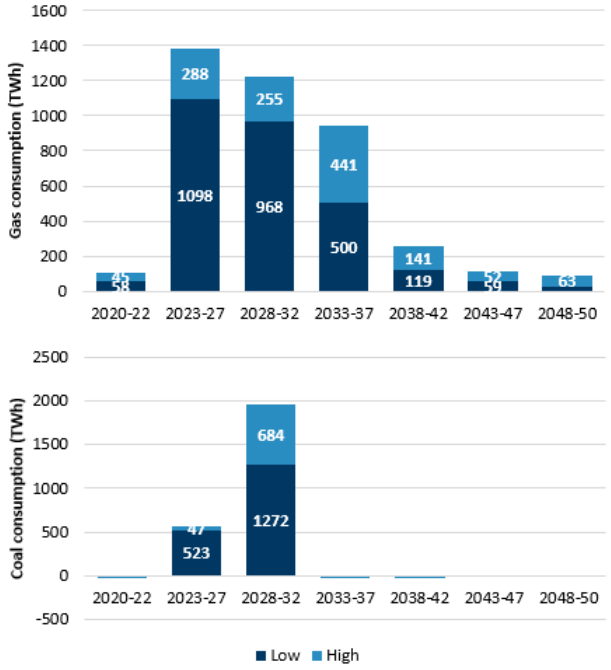
With increasing vRES, the EU power system will face a growing need for flexibility both in ST (balancing) & LT (weekly/seasonal)

- Nuclear can already provide flexibility (e.g. France) & this capability can increase over the time
- In the low-nuclear scenario, significant additional yet-to-be-proven flexible storage capacity would be needed to ensure security of energy supply (**40 GW Battery & 61 GW PT-X**)

Energy dependency on imports

- Anticipated nuclear closures (low-nuclear scenario) would increase fossil fuel consumption by **6500 TWh** increasing EU dependency equivalent to **+36% gas** / **+18% coal** for power consumption over 2020-2050.

Fossil fuel consumption difference from the power sector



Key conclusions - Climate & Sustainability

2050 climate objectives

- Whilst all scenarios meet the 2050 objective, the **probability to reach it is higher** in the high-nuclear scenario with less cliff-edge effects.

In terms of environmental impact, the high-nuclear scenario means

- Decreased CO_2 emissions by **2270 Mt** or c. **17%** of CO_2 emissions over 2020-50 (especially in ST/MT)
- Decreased air/water pollution by c. **14%**
- Decreased land use by c **15,800 km²** (~1/2 Belgium)
- Decreased curtailment (**+66 TWh**)

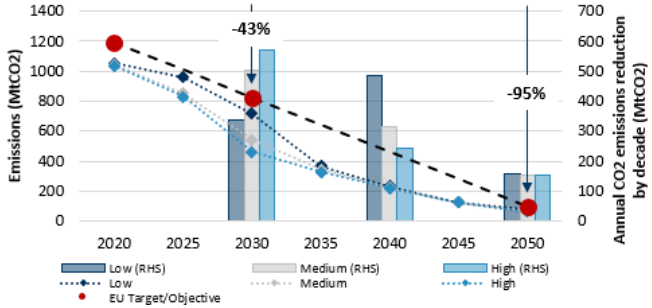
Nuclear is the only large-scale technology that takes full responsibility for all of its waste & fully integrates these costs.

- The **amount of waste generated by nuclear power is very small** compared to other energy sources.
- The quantity of raw materials by unit of energy **is up to x20 smaller** than for solar power.

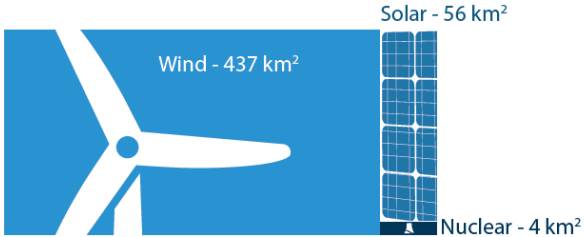
The long lifespan of reactors

- Reactors (60y+ - Gen III) provide high residual asset value after 20y – not tackled by LCOEs – **making nuclear a highly sustainable infrastructure**

CO2 emissions outlook from the power sector



Land required by different energy sources to match the amount of electricity produced by a 1,800 MW nuclear power plant



Key conclusions - Affordability & Competitiveness

Consumers will benefit from the future cost reductions of different technologies, incl. nuclear (learning by doing & innovation):

- Nuclear CAPEX can **decrease by 37%** over 2020- 2050, leveraging technological improvements, further cost reduction for wind onshore (31%), offshore (50%), solar (59%) over 2020-2050

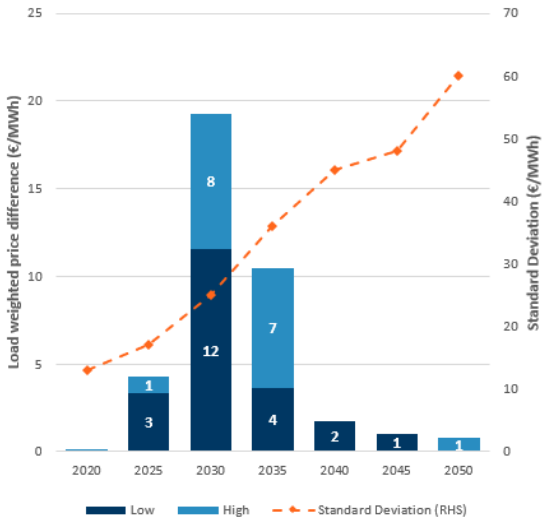
Customers costs

- Further nuclear development (high-nuclear scenario) would **mitigate the impact of low-carbon transition** on customer cost by €350bn via lower total generation costs (up to €20/MWh in 2030)

Network & balancing

- A high-nuclear scenario would mitigate network (c. **€160bn**) & balancing cost (c. **€13bn**)

Power price difference outlook across scenarios (real 2017)



Sourc: FTI-CL Energy modelling

PUBLICATION OF THE STRATEGY – 28 NOV 2018

Nuclear energy in the EC strategy (Nov 2018)

EC Communication*:

"Renewables together with nuclear energy will be the backbone of a carbon-free European power system"

EC in-depth analysis:**

- Nuclear will **remain an important component** in the EU 2050 energy mix
- Capacity of nuclear in 2050 – **between 99-121 GW**
- Share of nuclear in the electricity mix in 2050 – **ca. 15%**
- The consumption of **natural gas** is expected to be severely reduced by 2050 in all scenarios
- In the Baseline, **hydrogen** use develops only as a niche application for road transport and industry

Strategy refers directly to the study commissioned by FORATOM

** https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_en.pdf*
*** https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf*

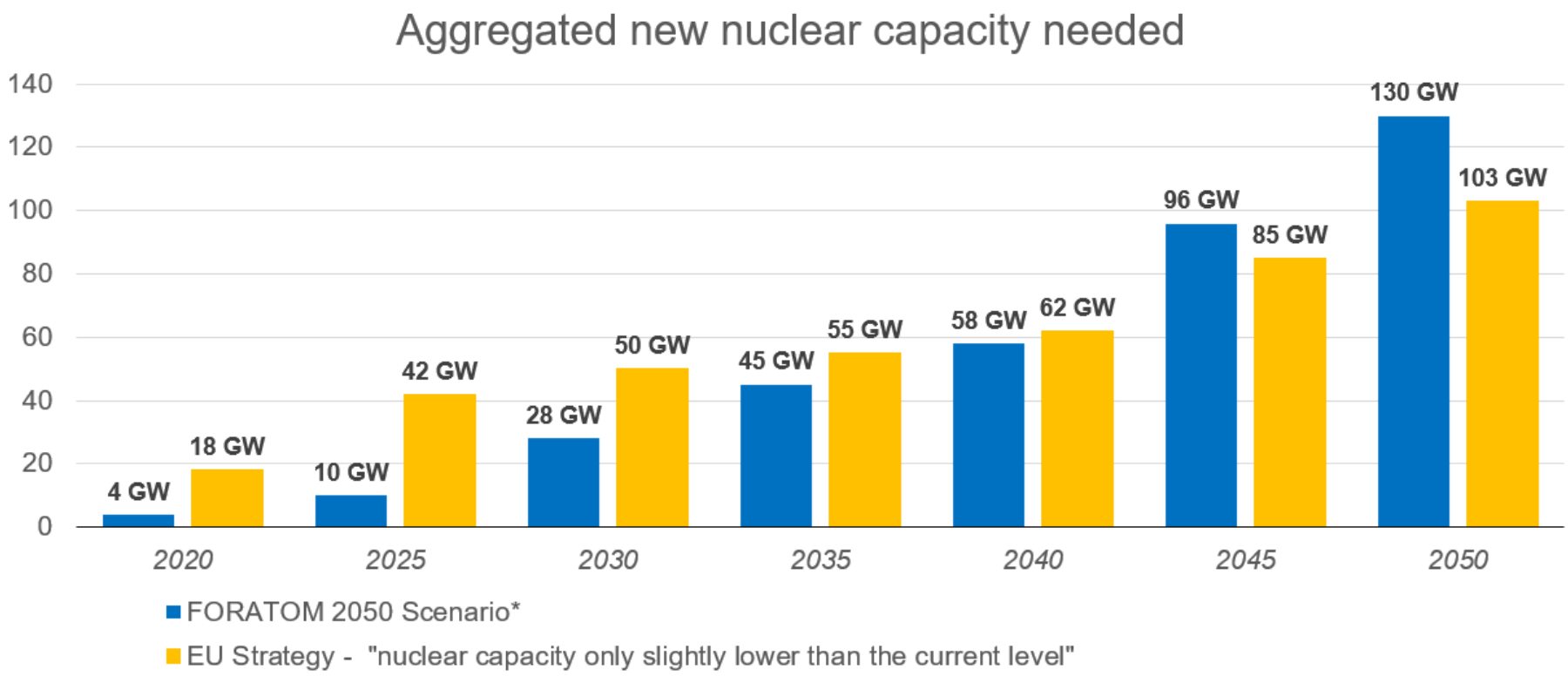
Analysed scenarios

Long Term Strategy Options

	Electrification (ELEC)	Hydrogen (H2)	Power-to-X (P2X)	Energy Efficiency (EE)	Circular Economy (CIRC)	Combination (COMBO)	1.5°C Technical (1.5TECH)	1.5°C Sustainable Lifestyles (1.5LIFE)
Main Drivers	Electrification in all sectors	Hydrogen in industry, transport and buildings	E-fuels in industry, transport and buildings	Pursuing deep energy efficiency in all sectors	Increased resource and material efficiency	Cost-efficient combination of options from 2°C scenarios	Based on COMBO with more BECCS, CCS	Based on COMBO and CIRC with lifestyle changes
GHG target in 2050	-80% GHG (excluding sinks) ["well below 2°C" ambition]					-90% GHG (incl. sinks)	-100% GHG (incl. sinks) ["1.5°C" ambition]	
Power sector	Power is nearly decarbonised by 2050. Strong penetration of RES facilitated by system optimization (demand-side response, storage, interconnections, role of prosumers). Nuclear still plays a role in the power sector and CCS deployment faces limitations.							
Industry	Electrification of processes	Use of H2 in targeted applications	Use of e-gas in targeted applications	Reducing energy demand via Energy Efficiency	rates, material substitution, circular measures	Combination of most Cost-efficient options from "well below 2°C" scenarios with targeted application (excluding CIRC)	COMBO but stronger	CIRC+COMBO but stronger
Buildings	Increased deployment of heat pumps	Deployment of H2 for heating	Deployment of e-gas for heating	Increased renovation rates and depth	Sustainable buildings			CIRC+COMBO but stronger
Transport sector	Faster electrification for all transport modes	H2 deployment for HDVs and some for LDVs	E-fuels deployment for all modes	• Increased modal shift • Electrification as in ELEC	Mobility as a service			• CIRC+COMBO but stronger • Alternatives to air travel
Other Drivers		H2 in gas distribution grid	E-gas in gas distribution grid				Limited enhancement natural sink	• Dietary changes • Enhancement natural sink

CONCLUSIONS

Future of nuclear in EU



*Scenario based on FTI-CL Energy Consulting study "Pathways to 2050: role of nuclear in a low-carbon Europe" (commissioned by FORATOM)

What has to be done?

AT EU LEVEL:

- ✓ Nuclear to be part of the conversation on all policies dealing with climate change
- ✓ Nuclear industry policy
- ✓ Address market failures
- ✓ Increase R&D budgets

AT INDUSTRY LEVEL:

- ✓ Improve competitiveness
- ✓ Work on standardization / harmonization
- ✓ Modernize the sector
- ✓ Develop projects / programmes
- ✓ Improve attractiveness for young talents

Thank you

Your voice in Europe

Join FORATOM & let's work together for a

SUSTAINABLE, RELIABLE & INNOVATIVE FUTURE!

For more information, please contact:

membership@foratom.org