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

19 November 2018

1 Context and objectives of the study: the role of nuclear in ambitious decarbonisation pathways for Europe

1.1 Following the European Parliament ratification of the Paris agreement on 5 October 2016, the **European Union reaffirmed its commitment to decarbonise its energy mix** while going beyond what was originally pledged corresponding to 85-90% GHG emission reduction by 2050 (European Council, October 2009). The IPCC Special Report on 1.5C released in early October suggests global emissions in 2030 would need to be 45% below 2010 levels, and net zero by 2050.

1.2 A series of energy roadmaps and scenario studies from the European Commission[1] and other international organisations[2] have shown that embarking on such an ambitious decarbonisation pathway would require a **growing role of electricity**, from c20% of the European final energy consumption in 2015 to more than 40% by 2050. In such scenarios, total electricity consumption is expected to increase by more than 1% per year on average through the electrification of transport, heating and cooling and industrial processes, more than offsetting the significant energy efficiency gain achieved on current electricity end-usages.

1.3 The power system will therefore play a key role in the decarbonisation of the European economy, and policy makers need **to design a set of policies that will ensure meeting the objectives** of **decarbonising the power generation mix at the lowest cost for consumers while ensuring security of supply**.

1.4 To provide fact-based evidence to the policy debate, FORATOM mandated FTI-CL Energy to analyse **the potential contribution of nuclear generation towards a low-carbon European economy based on three different scenarios**.

a. The study **models the impact and costs associated to different nuclear scenarios** in the European Union**,** including new build, long-term operation (LTO) and phase-out to varying degrees.

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1 2050 EU Energy roadmap (2010), EU Reference scenario 2013, 2016, PINC

2 World Energy Outlook (IEA, 2018) / IPCC 1.5°C report

b. The study assumes across all scenarios a **95% decarbonisation of the energy mix in 2050**, compared to 1990; together with **further electrification of the European economy**: 2050 demand forecast is projected to reach c4100TWh, compared to c3100 TWh today.

c. The study also assumes **technology improvements based on the European Commission reference assumptions** on electricity technology costs and performances[3], together with nuclear construction cost reductions opportunities that could be achieved.

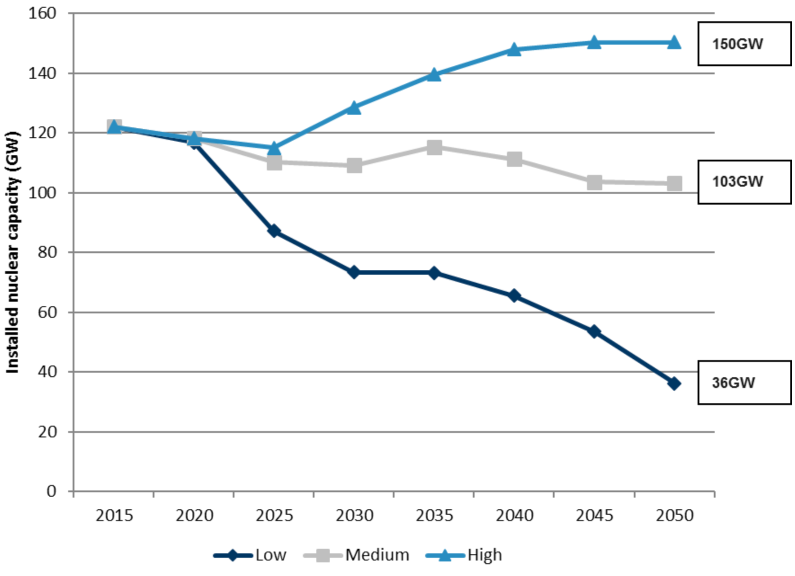
d. The study **leverages FTI-CL Energy's European power market model** to dynamically simulate the impact and costs of the three different scenarios, based on a two-step optimisation process:

- Dynamic optimisation of the generation mix based on the economics of RES, thermal plants and storage, to ensure security of supply and meet EC objectives at the least cost; and
- Short term optimisation of dispatch of the different units on an hourly basis.

2 A multi-criteria analysis of the contribution of nuclear to decarbonising Europe

2.1 The three nuclear scenarios have been designed to cover a range of possible future developments for nuclear in Europe. In the near future, the scenarios are based on the life expectation of the current nuclear plants, planed nuclear phase-down policies and projects under construction. Each scenario then assumes different life extension decisions as well as different commissioning date for future new nuclear plants. The resulting capacity outlook of the three scenarios is presented in the Figure 1 below.

Figure 1: EU-28 nuclear installed capacity outlooks in the 3 scenarios (GW)



Source: *FTI-CL Energy analysis including FORATOM inputs*

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3 Technology pathways in decarbonisation scenarios, Advanced System Studies for Energy Transition (ASSET), July 2018.

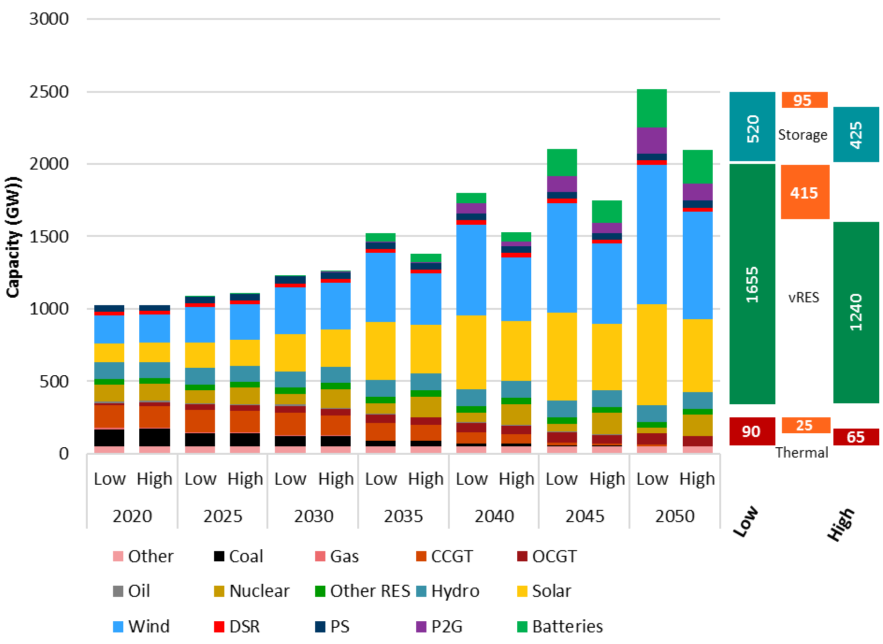
2.2 The study analyses the different scenarios using **a multi-criteria analysis framework** to capture their impact on the main dimensions of Europe's energy policy: security of supply, emissions and environmental impact, consumer costs and wider economic and competitiveness issues.

2.1 Security of supply

2.3 Decarbonising the European power mix by 2050 while maintaining security of supply will require the mobilisation of all low-carbon, secure and cost-efficient power generation sources. In a low nuclear scenario, the European power sector will face several additional challenges, such as:

a. **Need for additional capacity**: in the low nuclear scenario, to compensate for a 114GW reduction in nuclear power capacity in 2050 (compared to the high nuclear scenarios installed capacity in 2050) an additional investment in 535 GW - representing around half of the current total installed capacity - will need to be available in 2050 (415GW of RES comprising 190GW of solar and 225GW of wind, 95GW of new storage and around 25GW of new thermal power).

Figure 2: Low and High nuclear scenario capacity outlook to 2050



Source: FTI-CL Energy modelling

b. **Reliance on yet immature storage technologies:** A low share of nuclear in the energy mix will significantly increase the power system's reliance on large scale yet immature storage technologies (reaching around 440 GW of batteries and seasonal storage such as Power2X in 2050 in the Low scenario). In contrast in the high nuclear scenario, the nuclear load-following capability would play an increasing role in supporting the integration of variable renewables, and therefore reduce the need for additional storage technologies.

c. **Increased reliance on thermal generation**. A low nuclear generation scenario would rely more heavily on fossil fuel based thermal generation in the short to medium term. By closing nuclear capacity instead of investing in its long-term operation, **2790TWh of additional fossil fuel based thermal generation will be needed** in the short to medium term, representing a **+20% increase** or the equivalent of 4 years of the EU's projected thermal power generation.

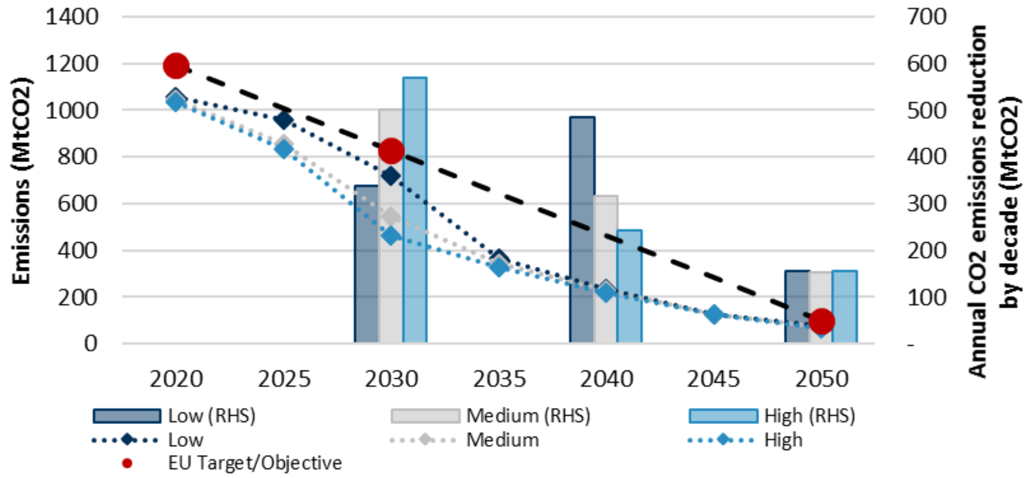
d. **Increased dependency on imported fuel**: The low nuclear scenario would increase fossil fuel consumption (gas and coal) by 6500TWh, pushing up Europe's dependence on fossil fuels to an equivalent of +36% in gas consumption and +18% in coal consumption between 2020 and 2050.

2.2 Sustainability

2.4 An efficient power sector transition towards low-carbon technologies will need to account for both **carbon emissions and other environmental impacts, including air pollution, impact on land use and resource use**.

a. **EU decarbonisation targets**. While all scenarios considered theoretically meet the 2030 and 2050 decarbonisation targets, **the probability of reaching the objective is higher in the scenarios which feature at least a stable share of nuclear**, as these show fewer cliff-edge effects in the long run and reduce emissions in the short to medium term. Anticipated nuclear closures in the nuclear low scenario would increase CO_2 emissions from the power sector by 2270Mt or +c17% between 2020 and 2050.

Figure 3: CO_2 emission outlooks from the EU power sector and annual CO_2 emission reduction by decade in the Low/Medium /high nuclear scenarios



Source: FTI-CL Energy modelling

b. **Curtailed energy**. In the longer term, the closure of nuclear power plants in the low nuclear scenario with no life time extensions and limited new nuclear investments would induce about **66TWh of additional curtailed energy in 2050** compared to the high nuclear scenario (a **+160% increase**).

c. **Environmental footprint**. As well as reducing the CO_2 emissions of the power sector, **nuclear energy also limits the environmental footprint of the power sector.** In the high nuclear scenario which includes life time extensions and new investments in nuclear power:

- Air and water pollution would be reduced by c14%, including a 15% reduction in SO_2 emissions, 9% in NOx and 18% in PM; and
- The amount of land needed for power generation would be about 15800km2 lower by 2050 – equivalent to half the size of Belgium – because nuclear generation requires less land than variable RES and fossil fuels to produce the same amount of energy.

2.3 Economics

2.5 The third dimension that the study investigates is the **impact on the cost for consumers and the macro-economic impacts** of the power sector decarbonisation scenarios with different shares of nuclear power. The study **quantifies the impact on the wholesale power prices of different scenarios** with a greater or lower share of nuclear:

a. **Potential cost reductions of different technologies.** The cost associated with power sector decarbonisation will depend significantly on the future possible cost reductions of different technologies, as a result of **learning by doing and technology innovations.** We assume that the nuclear CAPEX will reduce by 37% over 2020-2050, thanks to technological improvements and economies of scale. This compares with an assumed 31% (resp. 50%, 59%, 72% and 77%) of CAPEX reduction over 2020-2050 for onshore wind (resp. offshore wind, solar PV, Power-to-X and Battery).

b. **Impact of anticipated closures and life extensions on costs.** Over the modelling horizon, nuclear life time extension and new build in the high scenario would mitigate the impact of the low carbon transition on consumer costs, by saving a total of 350bn€ (real 2017) compared to the low nuclear scenario over 2020-2050 thanks to lower total generation costs. This represents a saving of c5% of total EU consumer costs over 2020-2050.

   - In the short term, anticipated nuclear closures (in the Low scenario) would increase EU consumer costs by 315bn€ (real 2017) between 2020-35 compared to the high nuclear scenario.
   - In the long term, further nuclear development through life time extension and new builds (High scenario) would further reduce EU consumer costs by 35bn€ (real 2017) between 2035-50 compared to the low nuclear scenario.

c. **Residual value of investments.** Given the long lifetime of nuclear assets (60 years of Gen-III nuclear power plants) the Low scenario would reduce the residual value[4] of investments by €960 billion in 2050 compared to the high scenario. This represents 29% of total annualised new CAPEX investment over 2020-2050.

d. **Network and balancing costs.** Compared to anticipated nuclear closures in the Low scenario, further nuclear development in the High scenario would reduce network and balancing costs by 160bn€ (real 2017) by 2050.

e. **Maintaining nuclear capacity and making further new investments could also provide additional benefits to the European economy:** for instance, this would support about 1 million highly skilled direct job-years in Europe, from conception and construction to the operational phase.

4 The residual value is calculated as the sum of the CAPEX annuities of operational new investments on their remaining economic lifetime after 2051.

3 Conclusions

3.1 **Overall the study demonstrates the important contribution of nuclear to the transition towards a decarbonized European power system:**

a. **In the short to medium term**: The continuation of the operation of the European nuclear fleet will help ensure compliance with the European emission targets and would avoid the temporary increase of the emissions that could risk locking in fossil fuel investments;

b. **In the longer term**: nuclear can support variable renewable sources of energy by providing proven, carbon free dependable power and flexibility to the system and reducing the system's reliance on yet unproven storage technologies.

3.2 **The study also identifies several key enablers for the sustainable role of nuclear power in the European power system:**

a. Whilst the life time extension of existing nuclear plants is generally more competitive against other low carbon resources, new nuclear power will need to **demonstrate significant cost reductions** to succeed in liberalised European power markets.

b. **The timely development of storage technologies including the reduction of their cost** and/or **flexible operation of nuclear** will be critical to ensure the complementarity of nuclear and variable renewables**.**

c. **A market design that rewards the system value of dependable and flexible resources and provides stable long-term investment signals** is necessary to address the challenges the power system would face in a high variable RES environment**.**