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Nuclear extension scenarios

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Executive summary

This study is a complement to the PATHS2050 study which came out end of 2022 [1]. In all scenarios of the PATHS2050 study, it was assumed that the Doel 4 and Tihange 3 nuclear power plants had 10-year extension of the operational lifetime between 2025 and 2035. This study analyses the impact of increasing the extension of the lifetime of the nuclear power plants in two ways:

- What if Doel 4 and Tihange 3 nuclear power plants would be operational until 2045 instead of 2035?
- What if the lifetime of two additional nuclear power plants is extended?

The model setup and parameters are identical to the PATHS2050 study, where the parameters related to nuclear power plants are updated. The new sensitivity runs are based on the 'Electrification scenario' of the PATHS2050 study, where we allowed investments in 16 GW additional offshore wind imported from the far North Sea from 2030 on to Belgium and Small Nuclear Reactors operational from 2045 onwards.

Important to note is that this study looks at the potential economic benefits and costs of nuclear extension from the energy system point of view. In other words, the study sheds light on what investment and operational costs could make a lifetime extension cost-effective in the energy system. This study does not assess the investment business case for a nuclear extension.

The conclusions of the study are the following:

The extension of Doel 4/Tihange 3 for 20 years at a total cost of 65€/MWh would be cost-effective.
A scenario considering 65€/MWh for the total cost of the extension of nuclear power for 20 years was explored. As mentioned in the previous paragraph, there is no information on how this cost would be distributed among the different cost factors, e.g. technical investment costs, financing costs, waste management costs etc. The 65€/MWh is an assumption based on a political statement that it will be between 65 and 75€/MWh for a 10 years extension, and was not calculated by the consortium based on bottom-up information. There is no official confirmation of that price by the operator, which hence could be higher than 75€/MWh. The results revealed that if the total costs for the extension of 20 years are below 65€/MWh, then this investment is part of a cost-optimal mix.

The restart of additional 2GW of nuclear power plants in 2030 for 20 years, would be cost effective only below a cost of 75€/MWh.
The question investigated was the following; If Doel 4 and Tihange 3 are extended for the period 2025 – 2045, what would be the impact of restarting an additional 2GW of nuclear powerplants in 2030 until 2050? A sensitivity analysis indicated that below 75€/MWh, this investment would be cost effective. This is an upper threshold, meaning that an investment above 75€/MWh would not be cost effective. The cost of the restart of the extra 2 GW will by all means be higher than the value for Doel 4 and Tihange 3.

The cost effectiveness of a restart of additional 2 GW of nuclear power plants decreases with time
Given the many challenges that remain to restart nuclear power plants that are currently prepared for decommissioning, a sensitivity analysis was performed, assuming the technical updates/investments for restart would only be ready in 2035 instead of 2030. In that case, the threshold for a cost effective investment would be at 70€/MWh instead of 75€/MWh. This is because the next decade, there is still quite a lot of gas based electricity production, while in 2050, the majority of the electricity is produced with low cost renewables, decreasing the profitability potential for extending nuclear power plants.

The extension of Doel 4 and Tihange 3 for 20 years would significantly reduce investments in renewables capacity in the second decade, the restart of Doel 3 and Tihange 2 would increase this effect.
Extending the lifetime of D4/T3 for 20 years will negatively impact investments in renewables, mainly in the second decade of operation. The restart of D3/T2 on top of the D4/T3 extension would increase this effect.
In 2030, 1 TWh of electricity from nuclear would replace 0.1 TWh of renewable electricity (a total of 13.5TWh replaces 1.3 TWh). In 2040, 1 TWh of electricity from the first 2 GW would replace 0.6 TWh of renewable electricity, the second 2GW would replace 0.8 TWh of renewable electricity.

Table 1: Renewable electricity replaced by extra nuclear extension/restart in TWh.

Renewables (PV + wind) in comparison with only D4/T3 for 10 years [TWh]	2030	2040
D4/T3 2025 - 2045	-0	-7.5
D4/T3 2025 – 2045 + D3/T2 2030 – 2050	-1.3	-18.1

The restart of additional 2GW of nuclear power plants, as well as the extension of D4/T3 for 20 years have an impact on the energy system, but do not change the emission pathways fundamentally.
The CO_2 emission reduction is 2.1 Mt in 2030 and 1.8Mt in 2040 when 4 GW is extended. The CO_2 emission reduction from adding the first 2 GW (Doel4/Tihange 3) and the last 2 GW (restart) is respectively 1.2 Mt and 0.6 Mt in 2040. Extending 2GW of nuclear until 2050 does not significantly increase the share of nuclear power plants in that year, the model rather keeps the share of nuclear power production constant at 20% of total production, while postponing investments in new nuclear. Extension of nuclear power plants beyond 2045 may hamper the deployment of small modular nuclear reactors.

Costs of extending nuclear power plants

Projected costs for the nuclear extension projects in D4/T3, and for other Belgian power stations, were not found to be available. This study does not provide any information on the bottom-up costs of extending the operational lifetime or restarting nuclear power plants. In a recent political debate, a strike price for nuclear power of 65 – 75€/MWh was mentioned by minister Van der Straeten [2]. This strike price corresponds to a guaranteed income for the nuclear operator, however the exact parameters are still subject of negotiations between the operator Engie and the Belgian state.
This study assumes that the total cost of extending nuclear power plants is the same value as the strike price. All costs are assumed to be included in this number:

- The capital investment costs (CAPEX) to make the investment possible, including the financing costs.
- Fixed operation and maintenance costs, which are the costs to run and operate the plant, and costs related to the safety of the site,
- Variable operational costs, which include:
  - Acquiring the nuclear fuel,
  - Costs for nuclear waste disposal,
  - The costs related to nuclear safety are assumed to be included in the variable operational cost.
- Any possible risk premium and profit margin charged by the operator is also assumed to be included in this cost.

Not included in the costs are the electricity grid upgrade costs, which would be necessary following a nuclear restart. For instance, restart/extension of in 2 or more nuclear power plants in Tihange, in combination with gas fired power plants already planned in the current CRM mechanism, could require a grid upgrade. This cost is not considered in this study.

The costs for nuclear extension assumed in this study are higher than the ones in the previous study in 2020, where investment costs and operational costs assumed added up to a levelized cost of electricity of 42 – 44€/MWh for 20 and 10 years extension, respectively [3].

1. The current situation of nuclear power plants

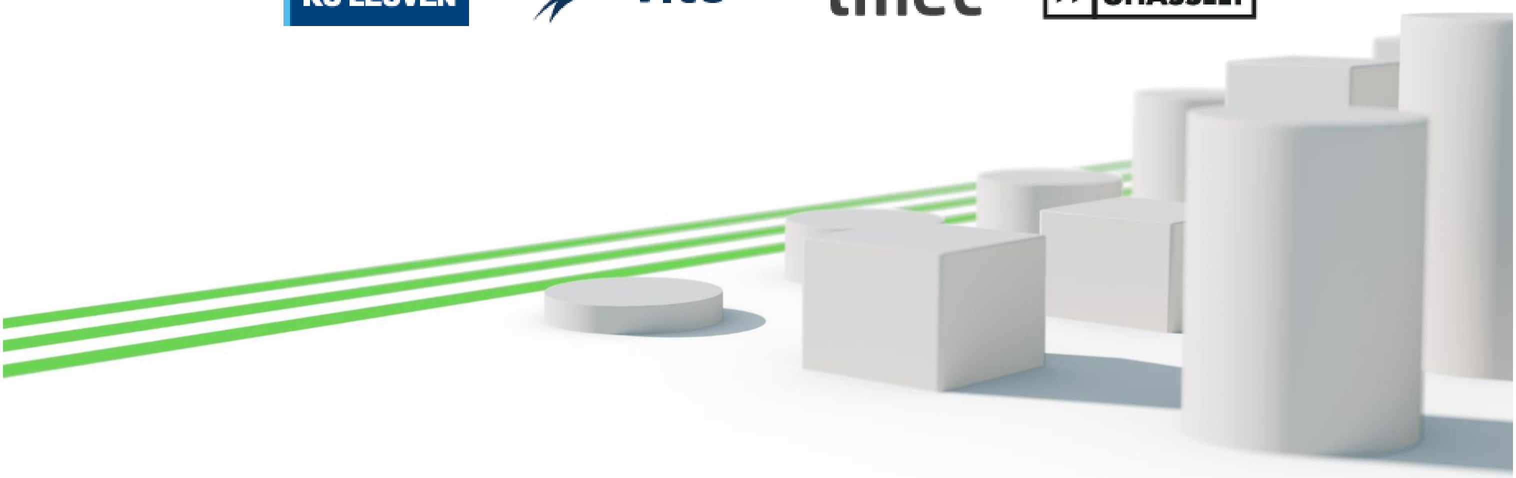
At the time of writing (September 2023), five nuclear power plants are active in Belgium, as indicated in the Table below:

Table 2: Decommissioning status of the nuclear power plants in Belgium

Power plant	Capacity (MW)	Commercial operation start	Decommissioning status
Doel 1 & Doel 2	890	1975	To be closed in 2025
Doel 3	1006	1982	Closed Sept 2022
Doel 4	1039	1985	Extended 2025 – 2035
Tihange 1	962	1975	To be closed 2025
Tihange 2	1008	1983	Closed Jan 2023
Tihange 3	1046	1985	Extended 2025 – 2035

In 1975, the power plants Doel 1 and Doel 2, which are so-called 'twin power plants' and share a cooling circuit, were connected to the grid, as well as Tihange 1. Seven years later, Doel 3 started commercial operation, followed by Tihange 2 and 3, and Doel 4. All of the Belgian nuclear power plants use the technology 'Pressurized Water Reactor (PWR)'.

Most recently, Doel 3 and Tihange 2 discontinued operations.[1] Doel 3 has undergone chemical decontamination of the pipelines and is being prepared to be decommissioned. Tihange 2 ceased operation in Jan 2023. Recently, an agreement has been reached between the Belgian Ministry of Energy and the operator of the nuclear power plants –Engie– to extend the lifetime of the two most recent reactors Doel 4 and Tihange 3 for ten years. Tihange 1 and Doel 1 & 2 already received a lifetime extension to 50 years of operation and are scheduled to cease power production activities in 2025.



[1] https://nuclear.engie-electrabel.be/en/nuclear-energy/shutdown-our-nuclear-power-plants/shutdown-doel-3-and-tihange-2

2. Scenario assumptions in the study

The questions investigated in this study are to assess the impact of extending the lifetime of Doel 4 and Tihange 3 even more, to 20 years of additional operation. As a second objective, this study investigates the possible impact of extending the lifetime of an additional 2GW of nuclear power plants, in addition to Doel 4/Tihange 3.

2.1. Technical feasibility of additional lifetime extension for nuclear power plants

In all explored scenarios, Doel 4 and Tihange 3 are extended for 10 or 20 years, depending on the scenario.
The model is run with the assumption that the capacities of Doel 3 and Tihange 2 are selected for additional nuclear extension.
The reason behind this assumption is straightforward: Doel 3 and Tihange 2 are the most recent nuclear power plants, other than Doel 4 and Tihange 3 which are already to be extended.

Both Doel 3 and Tihange 2 are detected to have 'laminar flaws' caused by hydrogen flakes. After close inspection and temporary shutdown in 2015, the power plants were cleared for restart. However, extending the operation of these power plants poses a complex challenge. Several essential steps need to be executed, including the following:

- A safety study needs to be made and approved, indicating that the hydrogen-related laminar flaws in the reactors do not compromise nuclear safety.
- For Doel 3 the chemical decontamination needs to be reversed. While this is possible in principle, it is not at all common to reverse such a procedure. The chemical decontamination of Tihange 2 is due to start shortly.
- A new environmental impact report needs to be drafted, submitted and approved, including a public inquiry.
- Other decommissioning activities (e.g. machines which are already decoupled etc.) need to be turned back.
- The necessary investments and components need to be replaced which are end of their lifetime; Instrumentation, pressure transmitters, temperature probes, pumps/valves which need to be revised, and so on. Some of these components need to be custom-made. Pressure tests need to be performed prior to operation.
- Qualified personnel needs to be found for the investments in the power plants, both for the retrofit and the safe operation.

Given the above-mentioned procedures and works, it is assumed in the model that the commercial operation can only start in 2030. As explained in the next chapter, a sensitivity is run if the power plants would only be ready by 2035.

Technically, Tihange 1 could also be extended instead of Tihange 2, however, the costs are expected to be even higher as the power plant is older. Extending multiple power plants in Tihange, in addition to the two planned gas power plants around Liège, may lead to grid congestion. Nevertheless, an electricity network assessment is beyond the scope of this study and the costs involved are not included. For Doel 1&2, compliance with the new WENRA safety standards would be challenging, given the fact that these units share a common cooling circuit. Extending the lifetime of one of these reactors is not investigated in this study.

In summary, this study examines the potential extension of additional 2GW of power plants on top of Doel 4 and Tihange 3, and the commercial operation of these power plants is assumed to start in 2030.

2.2. Costs for a nuclear power plant lifetime extension

One of the key questions is the investment costs associated with nuclear extension. These costs are critically dependent on the nuclear technology, the lifetime of the plant and its components, the regulatory and legal framework, as well as the design of the plant.

These types of costs are typically not available, as they have to be studied in detail and contain commercially sensitive information. In this study, data on a nuclear lifetime extension in a bottom-up way were not found. The study attempted to find data by contacting organizations, however no cost data could be made available. Cost data include a close evaluation of the components which need to be replaced, the personnel which need to be hired etc. is beyond the scope of this study. Clearly, given the extra challenges for extending the lifetime of Doel 3 and Tihange 2 and the decommissioning stepts already taken by the time a potential decision can be made to study this, the costs for those two will be higher.

Instead, the researched question is the following: '*Which levelized costs of electricity production over the lifetime of a nuclear extension would make the investment part of a cost-effective energy mix*?'

Recently, however, Belgian energy minister Tinne Van der Straeten mentioned a range between 65 €/MWh and 75€/MWh[2] for the strike price of the contract-for-difference (CfD) which is still being negotiated. Such a contract-for-difference would mean that if the electricity price is lower than the strike price, the Belgian state compensates the operator for the difference between the strike price and the electricity price. In a so-called 'double-sided CfD', the operator pays back the state when the electricity price is above a certain amount. As the negotiations are ongoing, the parameters are not yet known. As will be explained later, this study takes these parameters as a starting point for the analysis and then performs a sensitivity to gain more insights.

Another reference is the French regulator CRE, who estimated the costs of nuclear power production for the entire French nuclear fleet in combination with a lifetime extension of 60 years. The resulting cost was 60.7€/MWh for the period 2026-2030, 59,1€/MWh for the period 2031-2035, and 57,3€/MWh for the period 2036-2040 [2]. In this value, the costs for exploitation (fuel included), investments in the existing fleet, the management of nuclear materials and waste, and costs related to the construction project of Flamanville nuclear power plant are included.

These numbers cannot one-to-one be translated into a similar cost for Belgian nuclear power plants, as the design, lifetime, possible learning effects, and wholesale market regulation are different in France.

It is important to note that, if in the following results, a value in €/MWh levelized costs of electricity production is mentioned, the following cost parameters of nuclear are included in those costs:

- The capital investment costs (CAPEX) to make the investment possible, including the financing costs. Model results are usually expressed in €2019. This includes the interest cost during the construction time and the cost of deferred income due to the construction time, all expressed in one "overnight investment cost" CAPEX figure.Fixed operation and maintenance costs, which are the costs to run and operate the plant, and costs related to the safety of the site,
- Variable operational costs, which include:
  - Acquiring the nuclear fuel,
  - Costs for nuclear waste disposal,
  - The costs related to nuclear safety are assumed to be included in the variable operational cost.
- A risk premium and profit margin charged by the operator can also be included in this cost,

The abovementioned costs lead to the 'levelized cost of electricity': which represents the per-kWh cost of building and operating a generating plant over an assumed financial lifecycle. The definition is the following:

$$LCoE = \frac{sum\ of\ costs\ over\ lifetime}{sum\ of\ electrical\ energy\ produced\ over\ lifetime} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

With I_t the investment costs in the start year, M_t the operations and maintenance costs, F_t the fuel costs, E_t the electricity generated in the year *t*, *n* the expected lifetime, and *r* the discount rate of the investment.

In this study, we take the 65-75€/MWh which was mentioned as a possible range for the strike price and take it as the starting value, assuming that this value is the total value for the levelized costs for electricity production. For the extension of D3/T2, we perform a sensitivity analysis to assess the costs below which the investment is part of the most cost-effective energy transition.

All model results assume a societal discount rate of 3% for the entire energy system, consistent over all sectors and technologies. This means that, when making an investment, a 3% financial return is expected. This is usually a realistic return for residential investors, however, industrial investors typically require a higher return on investments.

[2] https://www.dekamer.be/doc/CCRI/pdf/55/ic1143.pdf

2.3. Scenario overview

For the 2022 PATHS2050 study, three main and several sensitivity scenarios were published. The assumptions for this study build further on the 'Electrification' scenario, as this scenario assumes the availability of new nuclear power plants operational from 2045 onwards and with this study the interplay between the extension of existing power plants and newly built can be analyzed. All parameters and assumptions of the model are identical to the Electrification scenario, for which the parameters are described in detail in [1]. The economic parameters of existing nuclear power plants are however changed depending on the scenario, as outlined in Table 3.

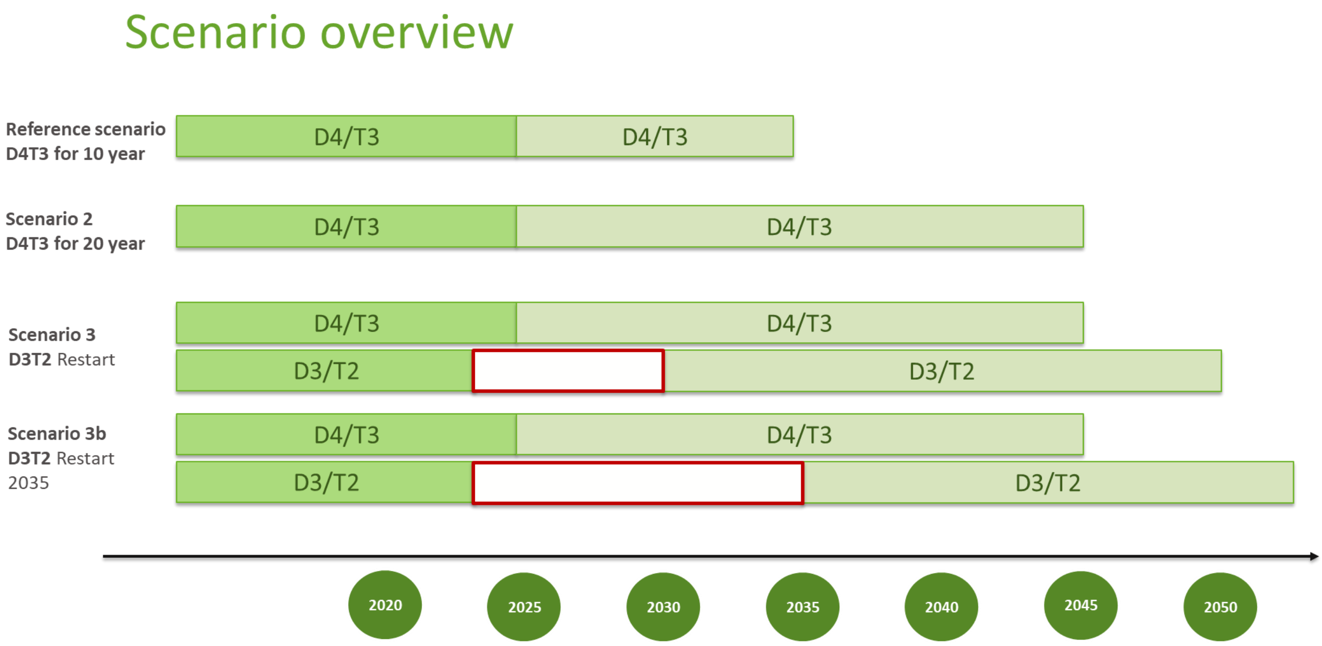


Figure 1: Scenario overview

Table 3: Scenario assumptions in this study. LCOE is the levelized cost of electricity production, as explained in section 3.2.

Scenario	Assumption D4/T3	Assumption D3/T2
D4/T3 10	Extension D4/T3 2025 - 2035 Total LCOE: 75€/MWh	No extension
D4/T3 20	Extension D4/T3 2025 - 2045 Total LCOE: 65€/MWh	No extension
D4/T3 + D3/T2 2030	Extension D4/T3 2025 - 2045 Total LCOE: 65€/MWh	Extension D3/T2 2030 - 2050 Total LCOE: Sensitivity analysis
D4/T3 + D3/T2 2035	Extension D4/T3 2025 - 2045 Total LCOE: 65€/MWh	Extension D3/T2 2035 - 2055 Total LCOE: Sensitivity analysis

The first scenario assumes the extension of the lifetime of Doel 4 and Tihange 3 nuclear power plants for ten years, in line with what is on the table today. The most optimistic case is assumed, that the power plants are available throughout the winters of 2025 – 2026. In this case, the levelized cost of electricity production is assumed to be 75€/MWh. Important to note that this is an assumption only, and no details are available on how the technical investment costs, financing costs, operation and maintenance costs, waste treatment costs and other factors add up to the 75€/MWh. The scenario results show if a 10-year extension at this LCOE is cost-effective from a societal point of view.

The second scenario assumes a 20-year lifetime extension at an LCOE of 65€/MWh. Although the investment cost is assumed to be higher for a 20-year extension, the LCOE, in €/MWh, over the entire period is lower.

A third scenario assumes that in addition to Doel 4 and Tihange 3, Doel 3 and Tihange 2 are extended for 20 years. For these scenario runs, we test at what LCOE the additional D3/T2 extension would appear in the cost-optimal solution of the model. Due to the many retrofit actions which are currently not yet in the stage of being prepared, there is a fourth scenario where the operation of D3/T2 starts only in 2035.

The annual availability factor of all nuclear power plants is assumed to be 80%. The power plants undergo a fixed maintenance schedule, mostly in the summer period. Unplanned outages are not foreseen in the model.

3. Results

3.1. Extension of D4/T3 to 20 years

First, we discuss the impact of a lifetime extension of Doel 4 and Tihange 3 to 20 years instead of 10 years. The impact on the energy system can be seen below. For the 20-year lifetime extension, at an assumed LCOE of 65€/MWh, the investment in a 20-year lifetime extension of Doel4/Tihange3 was found to be part of a cost-effective energy system.

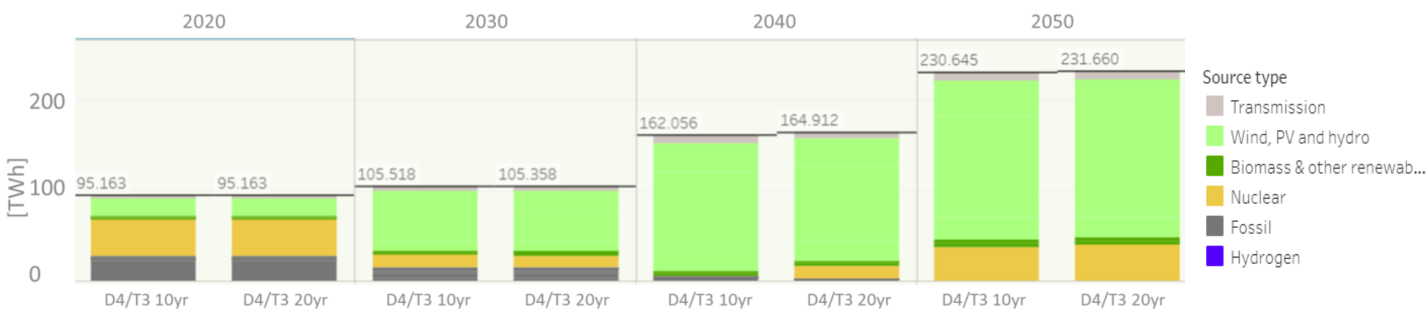


Figure 2: Impact of a lifetime extension of 20 years for D4/T3 on electricity generation.

The impact on the CO_2 emissions is given in Figure 3. The effect is maximal in 2040, with a difference of 1.3Mt CO_{2eq} per year. The first ten years are most important to reduce emissions, as renewables penetration in the electricity system is not yet at its maximum potential. Beyond 2040, renewables penetration in the system is so high that the emission reductions due to nuclear extension decrease.

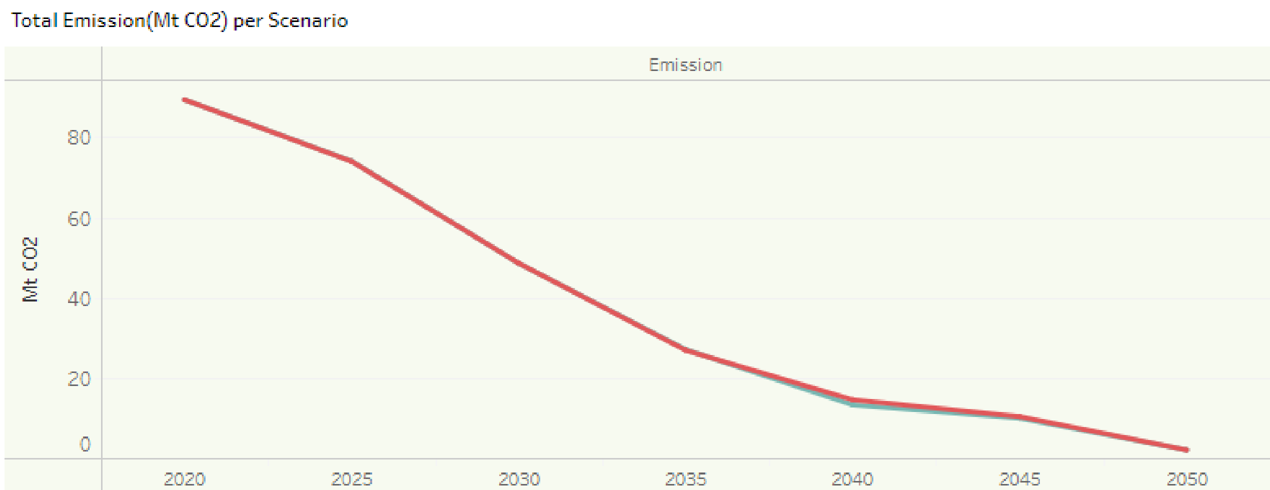


Figure 3: Emissions in the PATHS2050 electrification scenario with a 10-year extension of nuclear power plants D4/T3 (red line), and a 20-year extension of the nuclear power plants D4/T3 (blue line). The difference is mainly visible around 2040, with a maximal effect of 1.3MtCO_2/year.

The impact on renewables of a longer lifetime extension is limited. In 2040, a 20-year extension, compared with 10 years, is given in the Table below.

Table 4: Impact of 20 years lifetime extension of D4/T3 with the reference of only 10 years lifetime extension. of Doel 4/Tihange 3.

Technology – D4/T3 20 years extension instead of 10 years extension	Impact in 2040 on capacity (GW)	Impact in 2040 on generation (TWh)
PV	- 2.6 (-8%)	- 2.6 (-8%)
Wind onshore	- 1.8 (-15%)	-3.5 (-15%)
Wind offshore	- 0.4 (-2%)	-1.3 (-2%)
Fossil based electricity	- 1.6 (-32%)	-1.2 (-22%)

There is an effect on renewable investment, which decreases due to the extension of the D4/T3 power plants. Gas savings are around 2.2TWh in 2040. As the two scenarios compared above are extensions for 10 years between 2025 and 2035, and for 20 years between 2025 and 2045, the differences outside the period 2035 – 2045 are very small.

3.2. Extension of D4/T3 and D3/T2 to 20 years lifetime extension

In a second analysis, the impact of extending the lifetime of an additional 2GW of nuclear power plants, Doel 3 and Tihange 2, is investigated. For these investments, there is no reference value to the cost of extending the lifetime. The costs will most probably be significantly higher than those for D4/T3, given the current state of the power plants which are being decommissioned. Additionally, given the fact that a lot of regulatory, technical and workforce-related steps need to be taken prior to restart, the assumption is that 2030 is the earliest restart.

As there is no relevant data available on the costs associated with a restart of these power plants, the approach is to calculate the threshold value at which these investments could still be cost-effective in the energy system. This threshold was calculated to be 75€/MWh, meaning that above this cost, the extension of D3/T2 is not found to be part of a cost-effective energy system. Given the many regulatory and technical challenges that need to be overcome to prepare 2GW of nuclear power to be extended, a sensitivity assessment was performed where the restart could only take place in 2035 instead of 2030. In that case, the threshold for a cost-effective extension of D3/T2 was found to be at 70€/MWh. The major revenues and emission savings occur in the next decade (2025-2035) when there are still significant amounts of natural gas-based electricity production that can be replaced by nuclear. Towards 2050, the benefits of additional nuclear power decrease as the power production mix evolves to be more competitive due to larger shares of solar and wind energy.

The impact on the power sector is given in Figure 4 and

Table 5. There is an impact on the renewable energy uptake mainly in 2040, however, it is not a key determining factor for the development of renewables. There are some natural gas savings, however, the major savings in gas are in the next five years, when gas-based power plants still have a lot of operational hours. Beyond 2030, as the penetration of renewables in the electricity mix increases over time, the emission and gas savings are more limited.

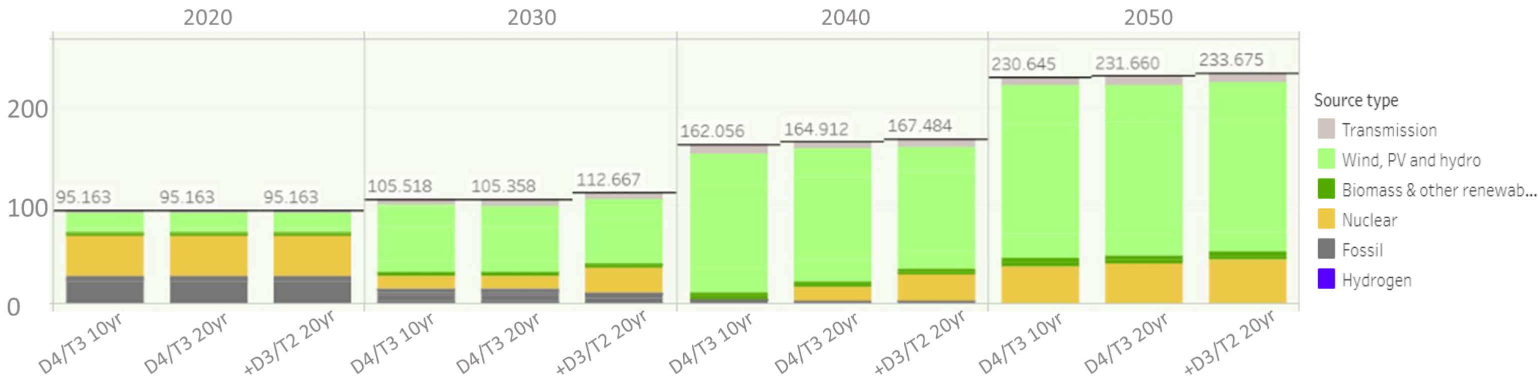


Figure 4: Impact on the energy system of extending D4/T3 for 10 years (left), 20 years (middle) and in addition to D4/T3 extension restarting D3/T2 in 2030 (right).

Table 5: Impact on the energy system if D3/T2 could be restarted 2030-2050, compared to a situation where only D4/T3 would be extended for 20 years 2025 - 2045. (energy differences below 0.2TWh are rounded to zero)

D3/T2 Restart + D4/T3 extension, vs only D4/T3 extension	Impact in 2030 on capacity (GW)	Impact in 2030 on generation (TWh)	Impact in 2040 on capacity (GW)	Impact in 2040 on generation (TWh)	Impact in 2050 on capacity (GW)	Impact in 2050 on generation (TWh)
PV	-1.3 (-6%)	- 1.2 (-6%)	-5.1 (-17%)	-4.8 (-17%)	0	0
Wind onshore	0.0 (0%)	0.0 (0%)	-1.4 (-14%)	-2.9 (-14%)	-0.7 (6%)	-1.3 (6%)
Wind offshore	0.0 (0%)	0.0 (0%)	-0.8 (-3%)	-2.8 (-3%)	0	0
Fossil based electricity	-0.5 (-8%)	-3.9 (-25%)	-0.6 (-26%)	-0.8 (-24%)	0	0
New nuclear	N/A	N/A	N/A	N/A	- 1.2 (30%)	-9.7 (-37%)

The emission savings are visible, however, the overall emission pathway is very similar for all scenarios. The major emission savings occur in the period 2025 – 2030, when there is still a lot of natural gas-fired electricity production.

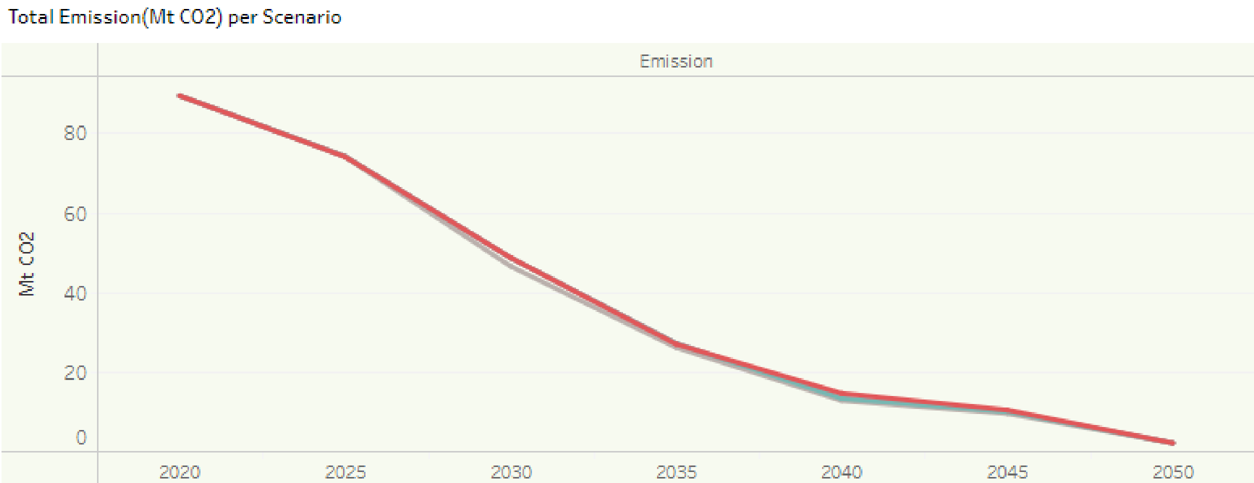


Figure 5: Emission savings of the defined scenarios, total emission of the system, not only electricity production. Emissions of the scenario with both D4/T3 extendended as D3/T2 restarted (brown line) has slightly lower emissions than the lifetime extension of D4/T3 for 20 years (blue line) and for 10 years (red line). The maximum difference is 2.1 Mt in 2030, (only the effect of restarting D3/T2). In 2040, extending D4/T3 and D3/T2 for 20 years has 1.8Mt less emissions than the base scenario where only D4/T3 is extended for 10 years.

4. Bibliography

[1] EnergyVille, PATHS2050 study, www.perspective2050.energyville.be, 2022.

[2] Parliamentary debate 04-07-2023, p45, https://www.dekamer.be/doc/CCRI/pdf/55/ic1143.pdf .

[3] EnergyVille, Aanvullende systeemscenario's voor eletriciteitsvoorziening in België in 2030, https://www.energyville.be/pers/energyville-lanceert-aanvullende-systeemscenarios-voor-elektriciteitsvoorziening-belgie-2030, 2020.

[4] CRE, https://www.connaissancedesenergies.org/parc-nucleaire-la-cre-actualise-son-estimation-du-cout-de-production-pour-les-annees-venir-230922#:~:text=Le%20co%C3%BBt%20complet%20de%20production,ann%C3%A9e%202022)(1, 2023.

5. Annex

Electrical installed capacities for the different technologies

Electrical capacity installed (MWe)	2020 D4/T3 10yr	2020 D4/T3 20yr	2020 D4/T3 20yr +D3/T2 2030-2050	2030 D4/T3 10yr	2030 D4/T3 20yr	2030 D4/T3 20yr +D3/T2 2030-2050	2040 D4/T3 10yr	2040 D4/T3 20yr	2040 D4/T3 20yr +D3/T2 2030-2050	2050 D4/T3 10yr	2050 D4/T3 20yr	2050 D4/T3 20yr +D3/T2 2030-2050
Transmission net imports	6.500	6.500	6.500	8.880	8.880	8.880	13.026	13.026	13.026	13.026	13.026	13.026
Hydro	111	111	111	194	197	215	550	503	308	550	503	308
Solar PV	5.824	5.824	5.824	20.986	20.903	19.593	31.573	28.935	23.850	38.932	38.727	39.309
Wind Offshore	2.260	2.260	2.260	8.100	8.100	8.100	18.500	18.140	17.348	23.487	23.932	24.000
Wind Onshore	2.762	2.762	2.762	4.985	4.985	4.985	11.837	10.017	8.537	11.651	9.831	9.171
Biogas CHP	4	4	4	3	3	3						
Biomass CHP	238	238	238	652	665	563	1.182	1.177	1.045	2.189	2.188	2.344
Biomass Power Plant	285	285	285									
Other Renewables	78	78	78	182	182	182	335	335	335	491	491	491
Nuclear Power Plant	5.930	5.930	5.930	2.000	2.000	4.000		2.000	4.000	5.946	6.017	6.797
Blast Furnace Gas Power Plant	305	305	305	538	531	635	538	531	635			
Coal CHP (Existing)	43	43	43	23	23	23	16					
Fossil Heat CHP	10	10	10	9	9	9	10	9	9	36	36	36
Municipal Waste CHP	16	16	16	53	53	53	13	13	13			
Natural gas CHP (Existing)	537	537	539	1.130	1.130	1.131	140	116	116			
Natural gas CHP (New)	154	154	161	476	529	242	688	736	321	140	140	140
Natural gas Power Plant (Existing)	3.570	3.570	3.570	2.580	2.580	2.580	639	639	639			
Natural gas Power Plant (New)				480	302		796	302				
Oil CHP (Existing)	247	247	247	96	96	96	2	2	2			
Other Fossil Power Plant	698	698	698	621	621	621	211					
Refinery Gas	10	10	10	123	123	101	120	120	98			
sum fossil	5.588	5.588	5.598	6.128	5.997	5.491	3.172	2.467	1.833	175	176	175

Yearly electrical generation in GWh

Yearly generation (GWh)	2020 D4/T3 10yr	2020 D4/T3 20yr	2020 D4/T3 20yr +D3/T2 2030-2050	2030 D4/T3 10yr	2030 D4/T3 20yr	2030 D4/T3 20yr +D3/T2 2030-2050	2040 D4/T3 10yr	2040 D4/T3 20yr	2040 D4/T3 20yr +D3/T2 2030-2050	2050 D4/T3 10yr	2050 D4/T3 20yr	2050 D4/T3 20yr +D3/T2 2030-2050
Transmission imports	3.763	3.763	3.763	5.677	5.819	6.179	9.740	7.989	8.994	9.096	9.368	8.733
Hydro	302	302	302	378	378	378	378	378	378	378	378	378
Solar PV	5.916	5.916	5.916	21.352	21.263	20.067	31.396	28.774	23.928	38.084	37.880	37.822
Wind Offshore	8.015	8.015	8.015	35.118	35.118	35.089	84.787	83.499	80.665	112.420	114.011	114.253
Wind Onshore	5.006	5.006	5.006	10.261	10.261	10.261	25.269	21.724	18.733	24.988	21.443	20.109
Biogas CHP				0	0	0						
Biomass CHP	1.148	1.148	1.148	2.896	2.898	2.336	2.798	2.922	2.457	4.308	4.308	4.311
Biomass Power Plant	1.917	1.917	1.917									
Other Renewables	15	15	15	1.489	1.489	1.487	2.811	2.800	2.780	4.122	4.123	4.128
Nuclear Power Plant	41.459	41.459	41.459	12.687	12.687	25.374		13.522	27.044	36.579	39.479	43.270
Blast Furnace Gas Power Plant	2.265	2.265	2.265	2.196	2.194	2.210	515	208	322			
Coal CHP (Existing)	56	56	56	1	3	1	2					
Fossil Heat CHP	51	51	51	50	50	43	48	48	48	53	53	53
Municipal Waste CHP				10	10	6	3	3	4			
Natural gas CHP (Existing)	2.154	2.154	2.154	2.571	2.608	2.484	91	28	37			
Natural gas CHP (New)	932	932	932	2.289	2.416	1.159	1.185	1.271	780	616	616	616
Natural gas Power Plant (Existing)	20.726	20.726	20.726	5.532	5.710	4.365	1.037	848	1.010			
Natural gas Power Plant (New)				1.545	985		1.686	617				
Oil CHP (Existing)	564	564	564	470	472	391	0	1	1			
Other Fossil Power Plant	801	801	801	81	81	81	28					
Refinery Gas	73	73	73	916	916	755	284	279	302			