# Belgian Long Term electricity system scenarios

## Central scenario

## Nuclear operation extension 10y-20y

18 September 2020

# Addendum

## Updates full presentation + Tableau website compared to version 09/09/2020

- 14/09/2020: Slide 9, 26, 32 Reported system costs for the ‘Current renewable ambition’ scenarios updated to the latest values as in the Tableau webviewer
- 18/09/2020: Slide 39 storage capacity update as charging+discharging capacity was presented in the graph causing double counting, in the model this was correct so no impact on result
- 18/09/2020: Slide 27, 42 Added investment cost of distribution grid upgrades, taking place from 2040 onwards in the ‘Current renewable ambition pathways’, from 2035 onwards in the ‘High renewable ambition pathways’. Modelling has been done including the distribution grid upgrade costs, but cost was not yet presented in the graphs.

# EnergyVille long-term electricity system scenarios

## Capitalizing on insights from multiple stakeholders …

### 2017 Horizon 2030

- ‘Energy Transition in Belgium: choices and costs’ ordered by Febeliec
  - Central scenario including nuclear phase out by 2025
  - High-Low gas price scenario, limited import, 2GW - 10 year nuclear lifetime extension

### 2018 Horizon 2040

- Updated scenarios post 2030 ordered by Greenpeace, BBL, IEW
  - 2040 outlook including nuclear phase out by 2025 and with 2GW - 10 year nuclear lifetime extension

### 2020 Horizon 2050

- 2050 scenarios ordered by Engie
  - ‘Current’ and ‘High’ renewable ambition pathway including 3 scenarios each
    - Central scenario including nuclear phase out by 2025
    - 2GW - 10 and 20 year nuclear lifetime extension
  - Updated import/export model including cross border impacts

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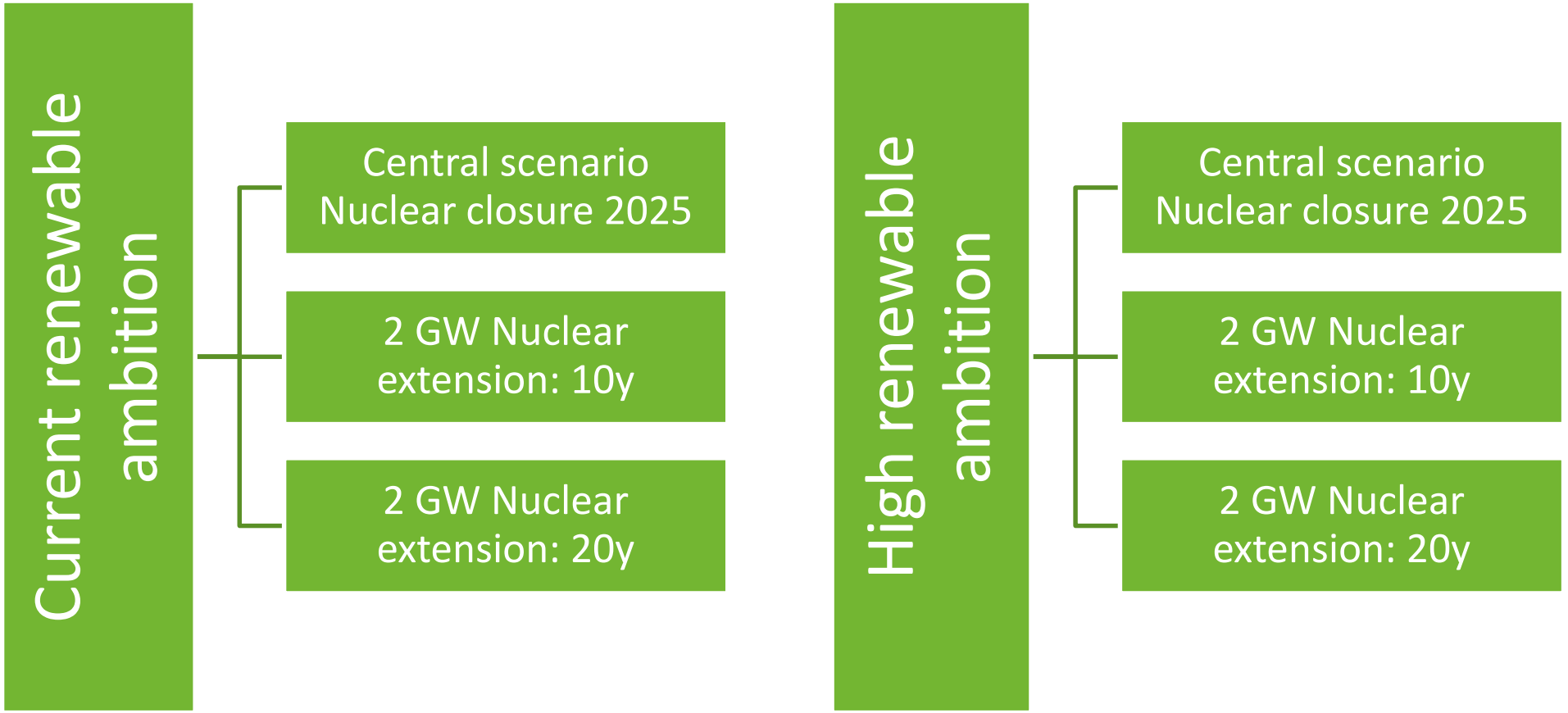
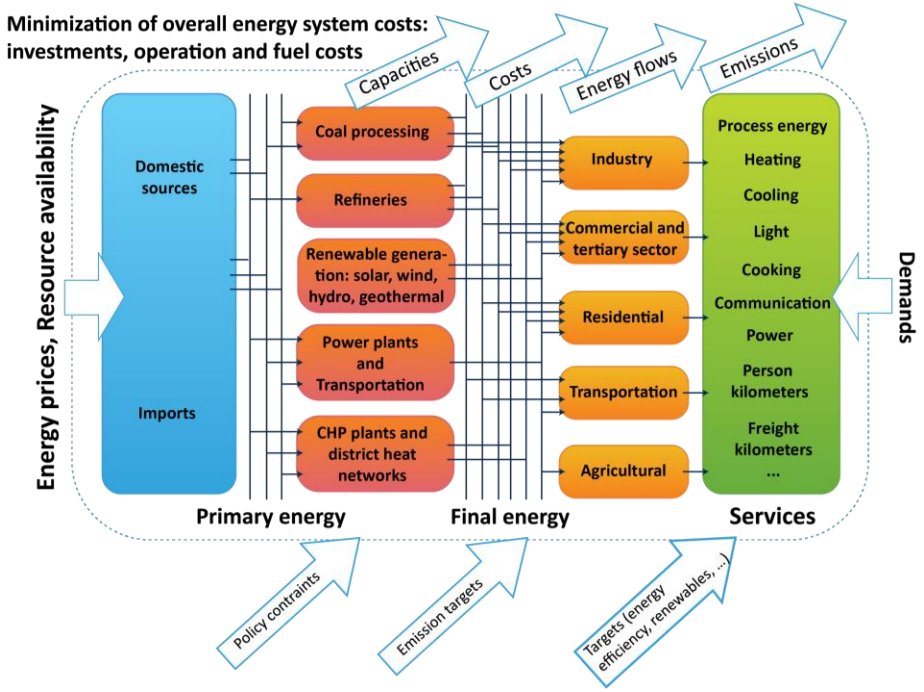
# 2 pathways of scenarios



# Updated assumptions and model framework

- TIMES model generator for ‘techno-economic energy system models’
  - Updated energy statistics to 2019 where available
  - Updated to 2019 process and commodity assumptions
  - Belgium as geographic region with explicitly modelled interconnections and electricity system in Nl, De, Fr, UK
  - Reporting years 2020-2050 with 5-year intervals, 2023-2026 modelled on yearly basis, to improve accuracy during nuclear closure
  - The model minimizes overall system costs (investment, operation,fuels costs…)
  - Existing support mechanisms (subsidies, green certificates, Capacity Remuneration Mechanism, …) are not taken into account
- No adequacy-flexibility study, but
  - Cost optimisation over the full time horizon
  - 2-hourly resolution, 10 representative days



# Changes in the electricity system – Current RE ambition scenarios Neighbouring countries

2020 → 2025 → 2030 → 2050

## Decreasing thermal capacity

2015-2020: Transparancy platform + Eurostat energy balance
2020-2040: TYNDP-DE scenario + EnergyVille assumptions on aging and gradual closure of existing gas units
>2040: extrapolation

## Increasing renewable capacity

2015-2020: Transparancy platform
2020-2040: DE: Netzentwicklungsplan Strom, UK/FR: TYNDP-DE, NL: TYNDP-NT
>2040: extrapolation

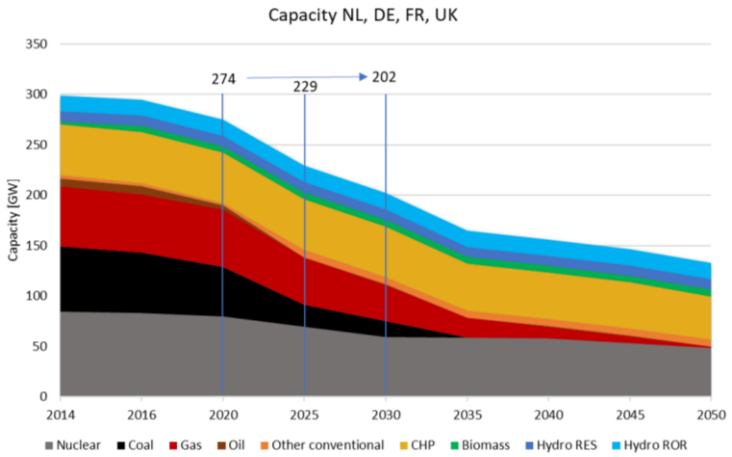
Including pumped hydro (90 GWh 2050), battery storage (104 GWh 2050)

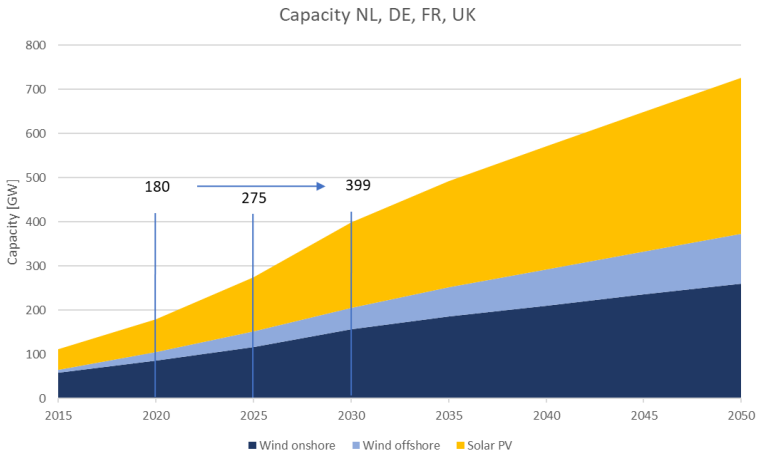
## Increasing electricity demand

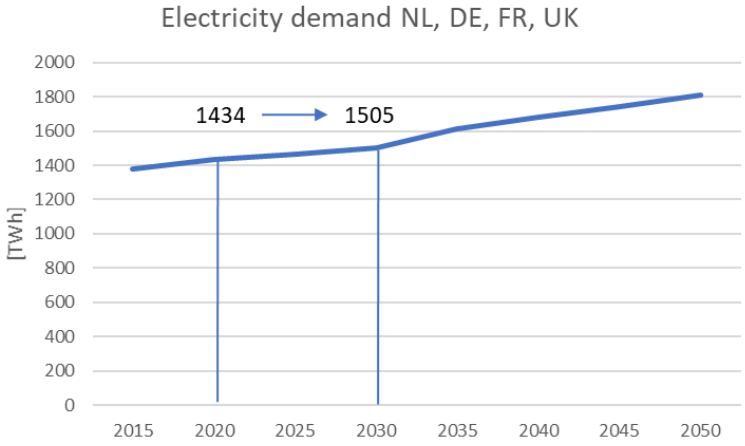
2015-2020: Transparancy platform
2020-2040: DE: Netzentwicklungsplan Strom, UK/FR: TYNDP-DE, NL: TYNDP-NT
>2040: extrapolation

Including demand side flexibility (67 GWh 2050)

## Electricity price



# Changes in the electricity system – Current RE ambition scenarios Belgium

2020 → 2025 → 2030 → 2050

| Be | Capacity [GW] | Model assumptions | | |
|---|---|---|---|---|
| Gas | 3,78 | <2020 existing capacity: 3,76 GW<br>New investments possible | <2020 existing capacity: 2,37 GW<br>New investments possible | <2020 existing capacity: 0 GW<br>New investments possible |
| Coal | 0 | No new investments possible | | |
| Biomass | 0,39 | Biomass limited to current level | | |
| CHP | 2,37 | New investments possible | | |
| Nuclear | 5,93 | Central scenario: Phase out<br>Alternative: 10y–20y extension | Lifetime extension: 80% annual availability, no flexibility taken into account | |
| Solar PV | 4,83 | New investments possible | | |
| Onshore | 2,28 | Annual max. growth rate<br>'20-'30: +250 MW | Annual max. growth rate >2030, including replacement old turbines: +450 MW | Tech.max.potential 8,6 GW |
| Offshore | 2,26 | Annual max. growth rate<br>'20-'25: +250 MW | Tech.max.potential 4,6 GW | Tech.max.potential 2040: 4,6 GW |
| Interconnection | 6,5<br>Simultaneous avail. cap. | 6,5 | 6,5 | 6,5 |
| Distribution grid | 7,0<br>Peak load cap. | Linear depreciation over 50 years<br>New capacity: 4300 MEUR/GW | | |
| Gas price €/GJ | 6,1 | 6,1 | 6,0 | 6,0 |
| $CO_2$ price €/ton | 25 | 40 | 84,3 | 160 |

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# Scenario results
# Current renewable ambitions

## Central – 10y/20y nuclear extension

# Key figures – 2030 results

| Belgium 2030 | Central | 10y LTO | 20y LTO | NECP WAM scenario |
|---|---|---|---|---|
| Gas [GW], CCGT + CHP | 7,8 | 6,7 | 6,1 | 11,3 |
| Generation gas [TWh] | 36,9 | 27,1 | 25,6 | |
| Operating new CCGT [h/y] | 6350 | 5600 | 6200 | |
| Nuclear [GW] | 0 | 2 | 2 | |
| Solar PV [GW] | 12,6 | 11,3 | 11,4 | 11,0 |
| Onshore [GW] | 4,6 | 4,6 | 4,6 | 8,9 |
| Offshore [GW] | 4,6 | 4,6 | 4,6 | |
| Net import [TWh] | 8,8 | 6,5 | 8,0 | |
| Electricity demand (incl. losses distribution & storage) [TWh] | 89,3 | 89,5 | 89,5 | |
| CO2 emissions power sector ETS [Mton] | 14,1 | 10,9 | 10,4 | |
| Annual electricity system cost [MEUR] | 4067 | 3933 | 3960 | |

# Key messages (1)

## CAPACITY & GENERATION

- Expected *thermal capacity decrease* in NW-Europe from today till 2030 has a major impact on the electricity system
  - DE, FR, UK, NL: -72 GW, closure coal, nuclear, old gas plants
    + Possible economic closure of less efficient hard coal plants in DE
  - BE: -6 GW nuclear plants from 2020-2025, -1,4 GW gasplants from 2025-2030
- Expected *renewable capacity increase* from today till 2030
  - DE, FR, UK, NL: + 219 GW solar, wind
  - BE: cost effective uptake of
    - Onshore wind: +2,3 GW leading to 4,6 GW by 2030
    - Offshore wind: +2,4 GW leading to 4,6 GW by 2030
    - PV: +7,5 GW leading to 12,6 GW by 2030

- Full nuclear closure in Belgium creates *cost optimal investment in new CCGT gasplants* – need for 3,85 GW new gas based capacity by 2025, or almost 5 large 800 MW units
  - Neighbouring countries cost optimal investment in new thermal/flexible capacity: + 30 GW by 2030
- 2 GW nuclear operation extension leads to
  - 10y extension: 2,7 GW new CCGT, -1150 MW compared to central
  - 20y extension: 2,1 GW new CCGT, -1800 MW compared to central
  - No impact on investments in renewable capacity

# Key messages (2)

- 50% of Belgian electricity generation based on renewables by 2030 in all scenarios
  - Belgium is net importer >2025: annually 10% of electricity demand (8,8 TWh)
  - 2 GW nuclear operation extension lowers net import by 10-20% to 7,4 - 9% of electricity demand (6,5 – 8 TWh)

## $CO_2$ EMISSIONS

- Belgian $CO_2$ emissions from power sector will peak by 2026: +5,6 Mton or 35% compared to 2020, but decrease with 1 Mton by 2030 compared to 2020
  - New gas based power plants at full load (7900 h/y) in 2026, dropping to 6350 h/y in 2030
- 2 GW nuclear operation extension leads to
  - 10y extension: - 3,2 Mton $CO_2$ emissions in the power sector in 2030 compared to Central scen, -25 Mton over the full lifetime extension
  - 20y extension: - 3,7 Mton $CO_2$ emissions in the power sector in 2030 compared to Central scen, -45 Mton over the full lifetime extension

## POWER SYSTEM COST

- Annual power system cost amounts to 4 G€ by 2030 in the Central scenario
  - 44% gas based production → fuel cost as main driver
  - 41% renewable production → investment and O&M cost as main driver
  - 12% import

  2 GW nuclear extension decreases annual power system cost by 106-134 M€/y (2,6-3,3%) due to import and fuel cost savings
- Nuclear extension has a limited impact on the wholesale price of electricity in Belgium
  - Central scenario 2030: 70 €/MWh → nuclear extension 1 €/MWh lower

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# Power system capacity - 2030 results

- BE capacity increases from 22,4 GW in 2020 to 30,5 GW in 2030 (+36%)
- Gas based CCGT investments
  - **Decrease in capacity in DE, UK, FR, NL** of 72 GW from 2020-2030, due to closure coal plants, nuclear and existing gas based capacity
  - Low gas price, high CO2 price → faster economic 'hard coal' power decline in DE, taking place >2020
  - Limited investments in new CCGT plants planned in DE, UK, NL
  - **Belgian investments need to take place now**
    - Central: Up to 3,85 GW investments in new CCGT by 2025, or 5 new 800 MW units
    - 2 GW 10y LTO: 2,7 GW new CCGT, -1150 MW compared to central
    - 2 GW 20y LTO: 2,1 GW new CCGT, -1800 MW compared to central
- Operating hours new CCGT by 2030
  - Central: 6350 h/y
  - 2 GW 10y LTO: 5600 h/y
  - 2 GW 20y LTO: 6200 h/y, higher than 10y LTO due to perfect foresight nature of model with lower CCGT capacity investments

| Belgium 2030 | 2017 Central | Model updates | Central | 10y LTO | 20y LTO |
|---|---|---|---|---|---|
| **Gas [GW], CCGT + CHP** | 6,1 | Lower gas price 21,6 €/MWh (27,3 €/MWh Febeliec 2030), lower CAPEX and higher efficiency new gas plants | **7,8** | **6,7** | **6,1** |
| **Generation gas [TWh]** | 32,2 | Updated, detailed existing gas capacity, efficiency | **36,9** | **27,1** | **25,6** |
| **Operating new CCGT [h/y]** | <6000 | | **6350** | **5600** | **6200** |
| **Nuclear [GW]** | 0 | | **0** | **2** | **2** |

# Power system capacity – 2030 results

- Renewable investments
  - **Wind onshore** growth limited to 250 MW/y from 2020-2030 due to low public acceptation, leading to 4,6 GW
    Additional 80 new wind turbines per year
  - **Wind offshore** needs to **grow fast, cost efficient implementation** of new wind zone by 2025 (+1,5 GW, total 3,7 GW) and full deployment (+2,4 GW, total 4,6 GW) by 2030.
    Need for speeding up grid infrastructure (Ventilus, Boucle du Hainaut) to enable this increase.
  - **PV** cost efficiency increases by 2030, significant growth from 2025 onwards, 12,6 GW installed by 2030
  - Limited impact of nuclear extension on renewable investments:
    - Nuclear extension impact on PV investments: -1,3 GW
      (still + 6,5 GW from now to 2030 leading to 11,3-11,4 GW)
- 50% of the Belgian electricity generation is based on renewables in all scenarios in 2030

| Belgium 2030 | 2017 Central | Model updates | Central | 10y LTO | 20y LTO |
|---|---|---|---|---|---|
| **Solar PV [GW]** | 7,9 | Lower CAPEX by 2030, LCOE 61-68 €/MWh for commercial-residential PV | **12,6** | **11,3** | **11,4** |
| **Onshore [GW]** | 8,6 | Lower CAPEX by 2030, LCOE 36 €/MWh, but limited maximum annual growth rate: +250 MW from 2020-2030 | **4,6** | **4,6** | **4,6** |
| **Offshore [GW]** | 2,2 | CAPEX as previous study, LCOE 58 €/MWh, additional zone available | **4,6** | **4,6** | **4,6** |

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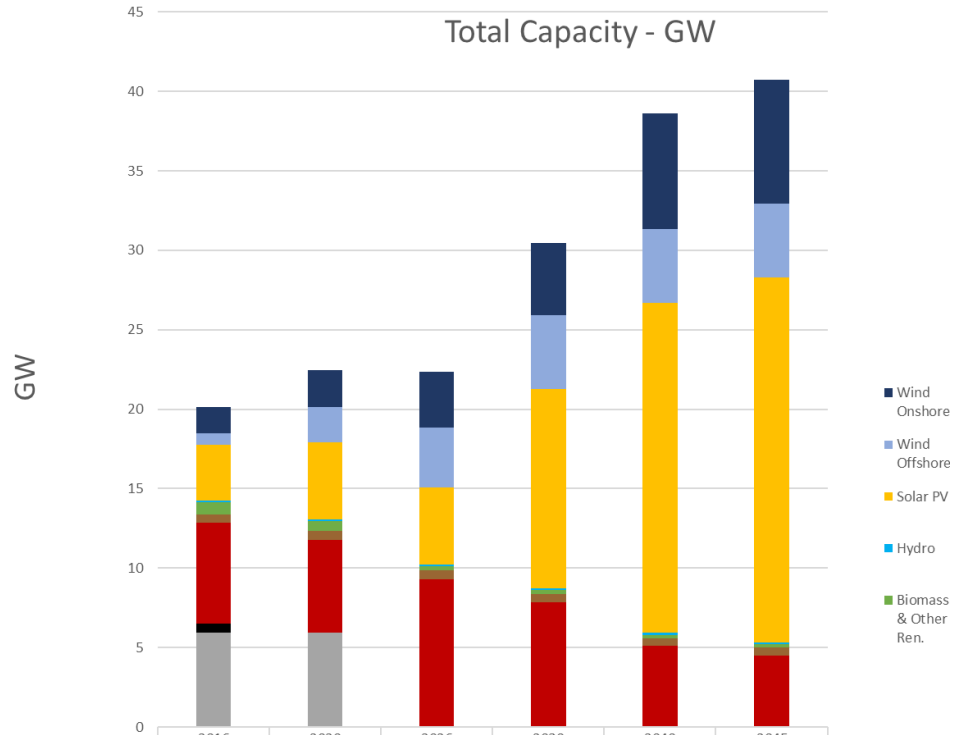
# Central scenario - Capacity

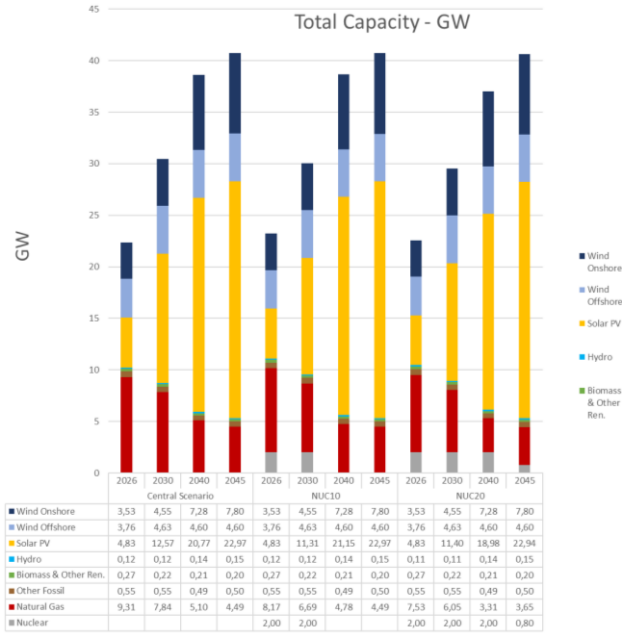
- Nuclear phase out by 2025
  - In 2025 on average 2,37 GW nuclear capacity available, but 0 GW at end of year
  - Results for 2026 are presented: interpretation is more straightforward
- Capacity increases from 22,43 GW in 2020 to 30,48 GW in 2030 (+36%)
- Investments in
  - New Gas plants (CCGT)
    - 3,85 GW by 2025, no additional investments >2025, leading to total gas based capacity (CCGT + CHP) of 9,3 GW in 2026 and 7,8 GW in 2030
    - Level of investments in Belgium also impacted by cross border evolution:
      - coal power closure in DE, UK, NL and
      - economic coal power decline due to low gas price and high CO2 price from 2020 onwards
      - limited investments in new CCGT plants planned in DE, UK, NL
  - Renewables
    - Wind onshore to 3,5 GW by 2025 and 4,6 GW by 2030 at max. annual growth level of 250 MW/y from 2020-2030, 450 MW/y post 2030
    - Wind offshore needs to grow fast, cost efficient implementation of new wind zone by 2025 leading to total of 3,76 GW and full operation by 2030 (4,6 GW).
      Need for speeding up grid infrastructure (Ventilus, Boucle du Hainaut) to enable this increase.
    - PV cost efficiency increases by 2030, delayed growth in 2025, but 12,6 GW installed by 2030



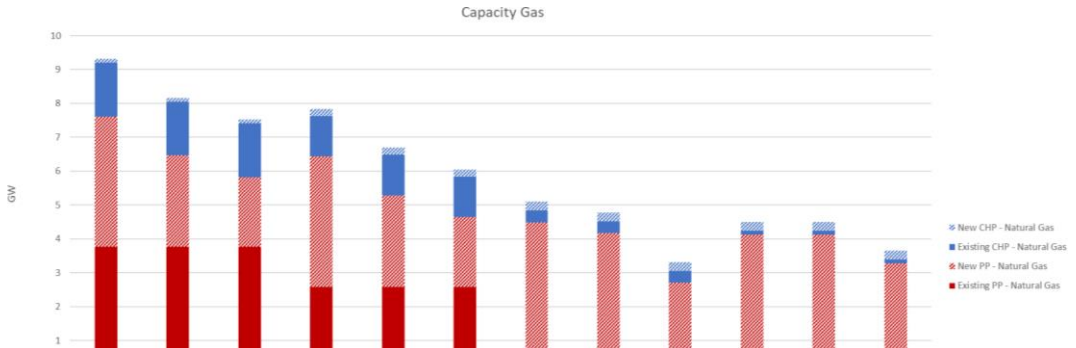

| Central Scenario | 2016 | 2020 | 2026 | 2030 | 2040 | 2045 |
|---|---|---|---|---|---|---|
| Wind Onshore | 1,66 | 2,28 | 3,53 | 4,55 | 7,28 | 7,80 |
| Wind Offshore | 0,71 | 2,26 | 3,76 | 4,63 | 4,60 | 4,60 |
| Solar PV | 3,54 | 4,83 | 4,83 | 12,57 | 20,77 | 22,97 |
| Hydro | 0,10 | 0,11 | 0,12 | 0,12 | 0,14 | 0,15 |
| Biomass & Other Ren. | 0,75 | 0,62 | 0,27 | 0,22 | 0,21 | 0,20 |
| Other Fossil | 0,56 | 0,55 | 0,55 | 0,55 | 0,49 | 0,50 |
| Natural Gas | 6,35 | 5,86 | 9,31 | 7,84 | 5,10 | 4,49 |
| Coal | 0,56 | | | | | |
| Nuclear | 5,93 | 5,93 | | | | |

# Nuclear operation extension – Capacity

- 2 GW nuclear extension
  - 10y: 2025-2034
  - 20y: 2025-2044
  - 80% availability per year: 2 or 1 GW
- Impact on renewables
  - No impact on onshore or offshore wind investments < 2040
  - Limited impact on PV investments: - 1,3 GW in 2030
- Impact on investments in CCGT gas capacity (2025-2030-2040)
  - 10y: - 1150 MW or – 2 units/plants
  - 20y: - 1800 MW or – 3 to 4 units/plants
    due to cost optimization of the need for gas based capacity in the long run
  - Gas based capacity remains lower in the 20y extension scenario: -850 MW in 2045 compared to Central scenario



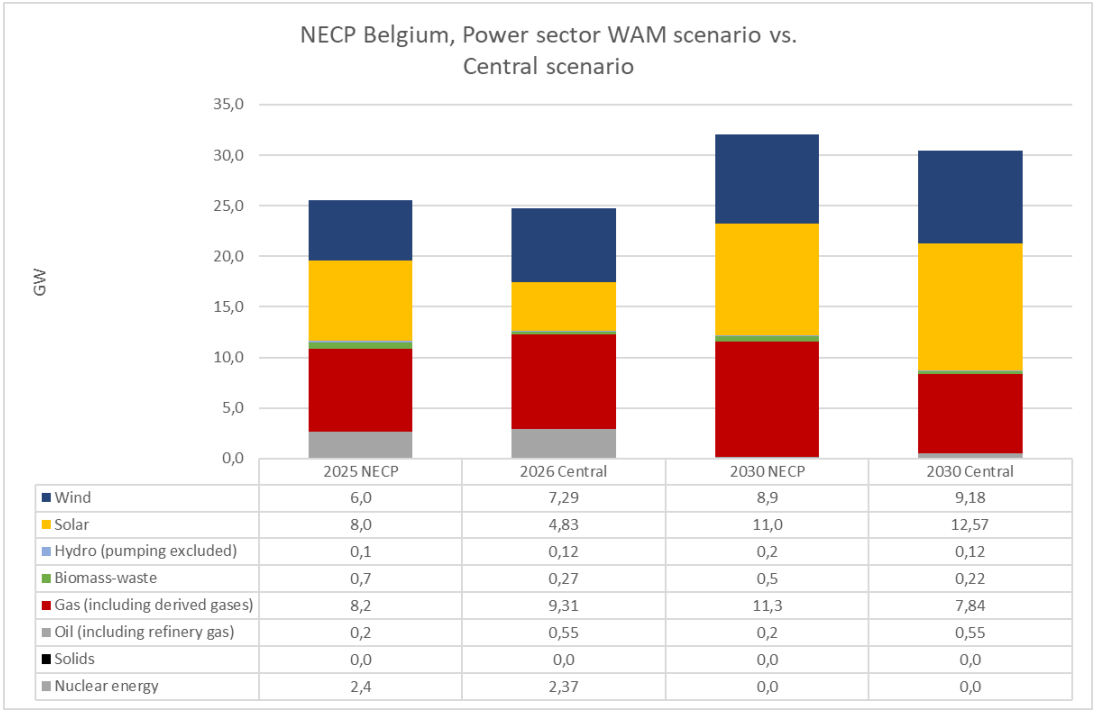

| | 2026 | 2030 | 2040 | 2045 | 2026 | 2030 | 2040 | 2045 | 2026 | 2030 | 2040 | 2045 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Central Scenario | | | | NUC10 | | | | NUC20 | | | |
| Wind Onshore | 3,53 | 4,55 | 7,28 | 7,80 | 3,53 | 4,55 | 7,28 | 7,80 | 3,53 | 4,55 | 7,28 | 7,80 |
| Wind Offshore | 3,76 | 4,63 | 4,60 | 4,60 | 3,76 | 4,63 | 4,60 | 4,60 | 3,76 | 4,63 | 4,60 | 4,60 |
| Solar PV | 4,83 | 12,57 | 20,77 | 22,97 | 4,83 | 11,31 | 21,15 | 22,97 | 4,83 | 11,40 | 18,98 | 22,94 |
| Hydro | 0,12 | 0,12 | 0,14 | 0,15 | 0,12 | 0,12 | 0,14 | 0,15 | 0,11 | 0,11 | 0,14 | 0,15 |
| Biomass & Other Ren. | 0,27 | 0,22 | 0,21 | 0,20 | 0,27 | 0,22 | 0,21 | 0,20 | 0,27 | 0,22 | 0,21 | 0,20 |
| Other Fossil | 0,55 | 0,55 | 0,49 | 0,50 | 0,55 | 0,55 | 0,49 | 0,50 | 0,55 | 0,55 | 0,49 | 0,50 |
| Natural Gas | 9,31 | 7,84 | 5,10 | 4,49 | 8,17 | 6,69 | 4,78 | 4,49 | 7,53 | 6,05 | 3,31 | 3,65 |
| Nuclear | | | | | 2,00 | 2,00 | | | 2,00 | 2,00 | 2,00 | 0,80 |




| | Central Scenario | NUC10 | NUC20 | Central Scenario | NUC10 | NUC20 | Central Scenario | NUC10 | NUC20 | Central Scenario | NUC10 | NUC20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2026 | | | 2030 | | | 2040 | | | 2045 | | |
| New CHP - Natural Gas | 0,11 | 0,12 | 0,11 | 0,21 | 0,21 | 0,21 | 0,26 | 0,26 | 0,26 | 0,26 | 0,26 | 0,26 |
| Existing CHP - Natural Gas | 1,59 | 1,59 | 1,59 | 1,20 | 1,20 | 1,20 | 0,35 | 0,35 | 0,35 | 0,11 | 0,11 | 0,11 |
| New PP - Natural Gas | 3,85 | 2,70 | 2,06 | 3,85 | 2,70 | 2,06 | 3,85 | 3,53 | 2,06 | 4,13 | 4,13 | 3,28 |
| Existing PP - Natural Gas | 3,76 | 3,76 | 3,76 | 2,58 | 2,58 | 2,58 | 0,64 | 0,64 | 0,64 | | | |

# Central scenario – compare with NECP WAM scenario

- PV
  - gradual growth in NECP, taking into account existing support mechanism, 8 GW by 2025
  - Leading to 11 GW by 2030 in NECP compared to 12,6 GW in Central scenario
- Wind
  - gradual growth in NECP, to 6 GW by 2025, Central scenario shows need for faster, cost efficient growth offshore wind leading to total wind capacity of 7,29 GW by 2026
  - 2030 capacity of wind (on- + offshore) is almost the same for NECP and Central scenario
- CCGT
  - NECP investments in new gas capacity leading to 8,2 GW in 2025 and 11,3 GW in 2030
  - Central scenario shows need for higher total gas based capacity by 2026 (9,31 GW),
    but no additional investments post 2026 and gas capacity decreases by 2030 due to closure old plants (7,84 GW)




| | 2025 NECP | 2026 Central | 2030 NECP | 2030 Central |
|---|---|---|---|---|
| Wind | 6,0 | 7,29 | 8,9 | 9,18 |
| Solar | 8,0 | 4,83 | 11,0 | 12,57 |
| Hydro (pumping excluded) | 0,1 | 0,12 | 0,2 | 0,12 |
| Biomass-waste | 0,7 | 0,27 | 0,5 | 0,22 |
| Gas (including derived gases) | 8,2 | 9,31 | 11,3 | 7,84 |
| Oil (including refinery gas) | 0,2 | 0,55 | 0,2 | 0,55 |
| Solids | 0,0 | 0,0 | 0,0 | 0,0 |
| Nuclear energy | 2,4 | 2,37 | 0,0 | 0,0 |

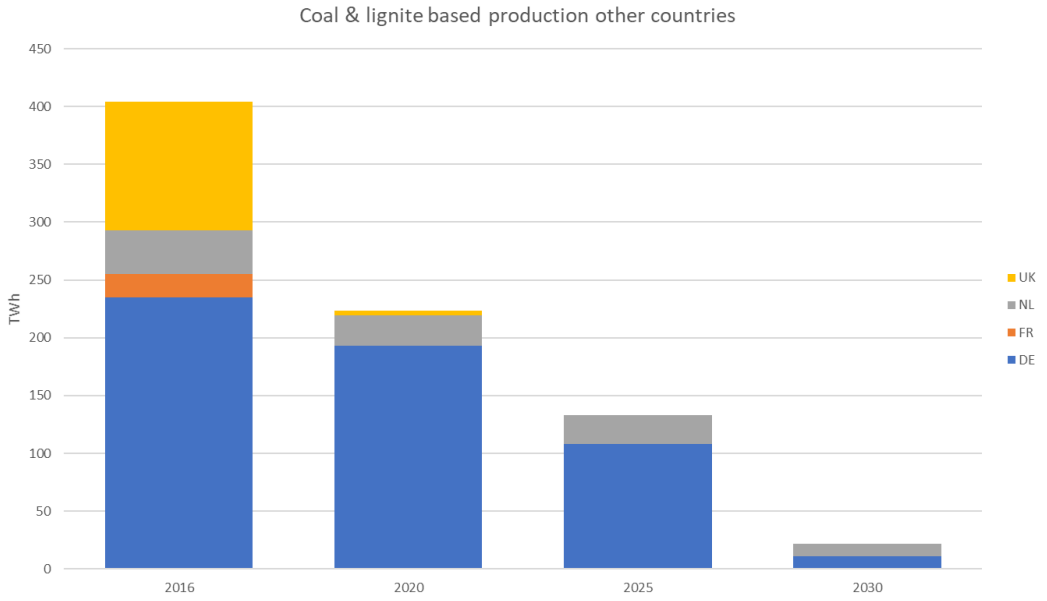
# Import/Export & demand – 2025 - 2030 results

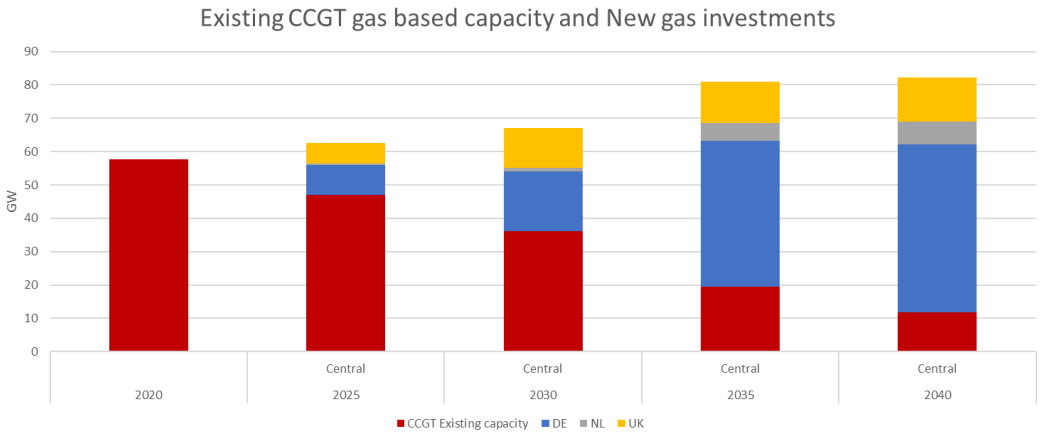
| Belgium 2030 | 2017 Central | Model updates | Central | 10y LTO | 20y LTO |
|---|---|---|---|---|---|
| **Net import [TWh]** | 15,6 | DE, FR, UK, NL electricity system and specific interconnections modelled | **8,8** | **6,5** | **8,0** |
| **Electricity demand [TWh]** | 86,6 | Higher CO2 price for ETS and non-ETS sectors, 84,3 €/ton → higher electrification in end-use sectors | **89,3** | **89,5** | **89,5** |

- Belgium can be net exporter 2020 - 2025
  - Economic decisions cross border will determine level of export
  - Coal and lignite – economic impact of high $CO_2$, low gas price
    - Subcritical hard coal plants (DE, UK) : economic closure of less efficient plants, due to increasing $CO_2$ price
    - Newest (ultra) supercritical hard coal plants (DE, NL): operational until 2025
    - Lignite plants (DE): operational at full load until 2025, increasing $CO_2$ price pushes lignite out of market > 2025
  - CCGT investments to follow economic closure of coal plants
    - Model assumption: Limited to 6 GW (UK), 9 GW (DE), 0,5 GW (NL) in 5-years period >2020
- Belgium will be net importer from 2026 onwards
  - Belgium is net importer of electricity: 8,8 TWh or 9,8% of total demand in the Central scenario in 2030
  - Nuclear lifetime extension lowers need for import to 6,5-8 TWh, or 7,4%-9% of total demand

# Central scenario – Cross border evolution - Import/Export

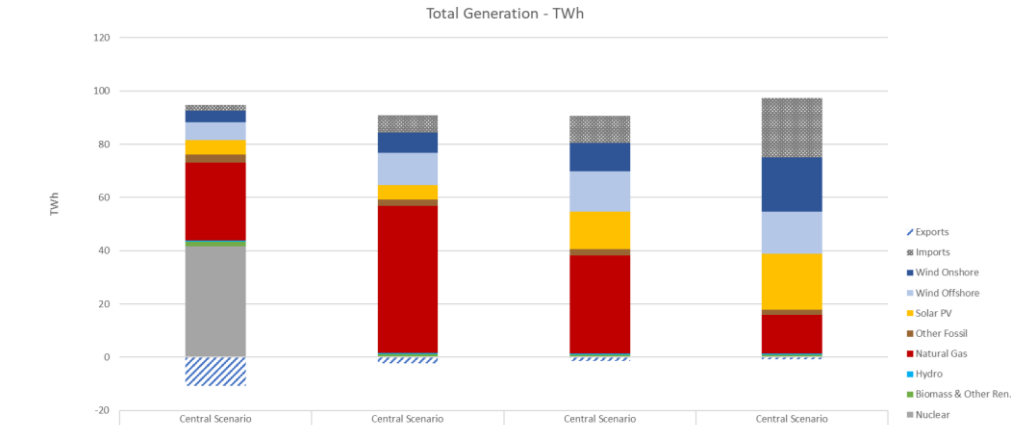
- Coal based production DE, UK, NL
  - Political decision: Coal & lignite phase out by 2025 (UK), 2030 (NL) and 2038 (DE)
  - Lignite based electricity production in DE at full load (85% annually) until 2025
  - Cost optimization model approach shows faster economic hard coal power decline due to $CO_2$ price (25 €/ton in 2020, 40 €/ton in 2025) + low gas price (21,6 €/MWh)
    - DE, UK: large stock of old subcritical plants, low efficiency (<38%) : DE 21 GW >35y, UK 7,7 GW >45y
  - Newest (ultra) super critical plant in DE, NL still operational in 2025, efficiency 44%
- High investment need in new gas plants in DE, UK
  - Model invests up to imposed upper limits in 2025-2030 in high efficient new CCGT
    - UK: max + 6 GW in 5-year period
    - DE: max + 9 GW in 5-year period
  - Gradual decrease of existing CCGT >2020
    - Drop of 180 TWh in hard coal based production from 2016-2020 can be compensated by existing + new investments in CCGT capacity



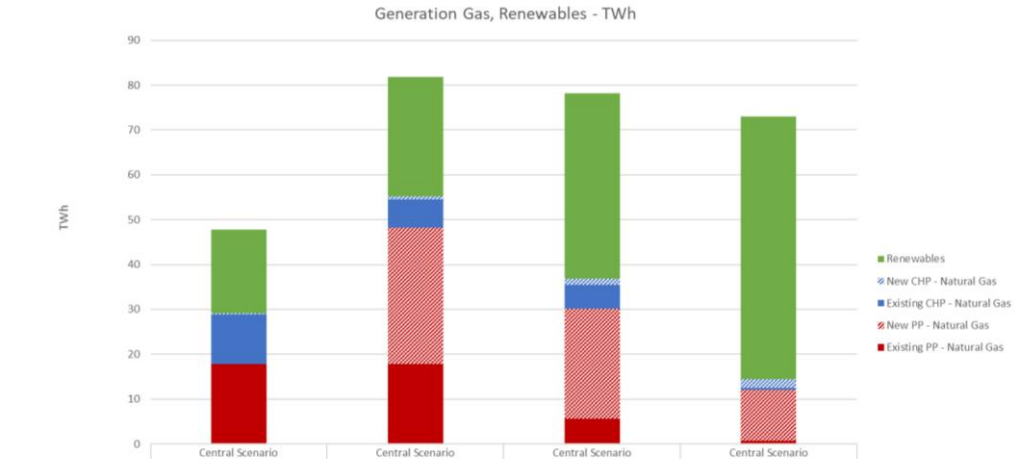



# Central scenario - Generation

- Gas based electricity production almost doubles by 2026 compared to 2020
  - From 29,2 TWh in 2020 to 55,2 TWh in 2026
  - Full load operation (7900 h/y) new gas plants
- Gas based production decreases by 31% from 2025 to 2030
  - Be nuclear phase-out, closure old gas plants and no additional investments >2025
  - New gas plants operating at 6350 h/y
  - Steep rise in renewable investments in Belgium and other countries, renewable production up to 41,3 TWh or 50% of Belgian production
  - Net import 8,8 TWh, 9,8 % of total demand
- Further increase of renewable and decrease of gas based production in 2040
  - Increasing renewable production, up to 58,6 TWh or 77% of Belgian production (60% of total demand)
  - Gas based production declines to 14,5 TWh, 'new' gas plants operating at 3000 h/y
  - Electricity demand Belgium increases to 96,6 TWh (+15% compared to 2020, 84,1 TWh in 2020)



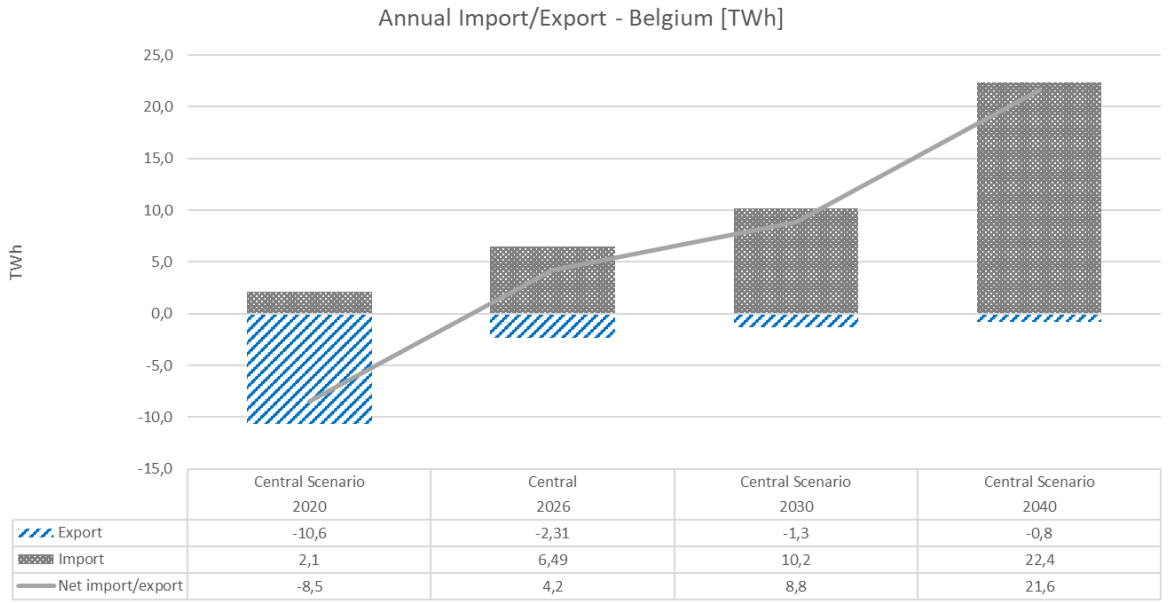

| | Central Scenario 2020 | Central Scenario 2026 | Central Scenario 2030 | Central Scenario 2040 |
|---|---|---|---|---|
| Exports | -10,62 | -2,31 | -1,33 | -0,78 |
| Imports | 2,13 | 6,49 | 10,17 | 22,37 |
| Wind Onshore | 4,30 | 7,58 | 10,75 | 20,41 |
| Wind Offshore | 6,80 | 12,05 | 15,12 | 15,68 |
| Solar PV | 5,39 | 5,40 | 14,04 | 21,14 |
| Other Fossil | 3,09 | 2,41 | 2,29 | 1,98 |
| Natural Gas | 29,17 | 55,18 | 36,91 | 14,47 |
| Hydro | 0,38 | 0,38 | 0,38 | 0,38 |
| Biomass & Other Ren. | 1,74 | 1,25 | 1,01 | 0,96 |
| Nuclear | 41,70 | | | |




| | Central Scenario 2020 | Central Scenario 2026 | Central Scenario 2030 | Central Scenario 2040 |
|---|---|---|---|---|
| Renewables | 18,61 | 26,66 | 41,30 | 58,56 |
| New CHP - Natural Gas | 0,34 | 0,69 | 1,52 | 1,96 |
| Existing CHP - Natural Gas | 11,09 | 6,33 | 5,25 | 0,38 |
| New PP - Natural Gas | | 30,36 | 24,48 | 11,43 |
| Existing PP - Natural Gas | 17,75 | 17,80 | 5,67 | 0,70 |

# Central scenario – Cross border evolution - Import/Export

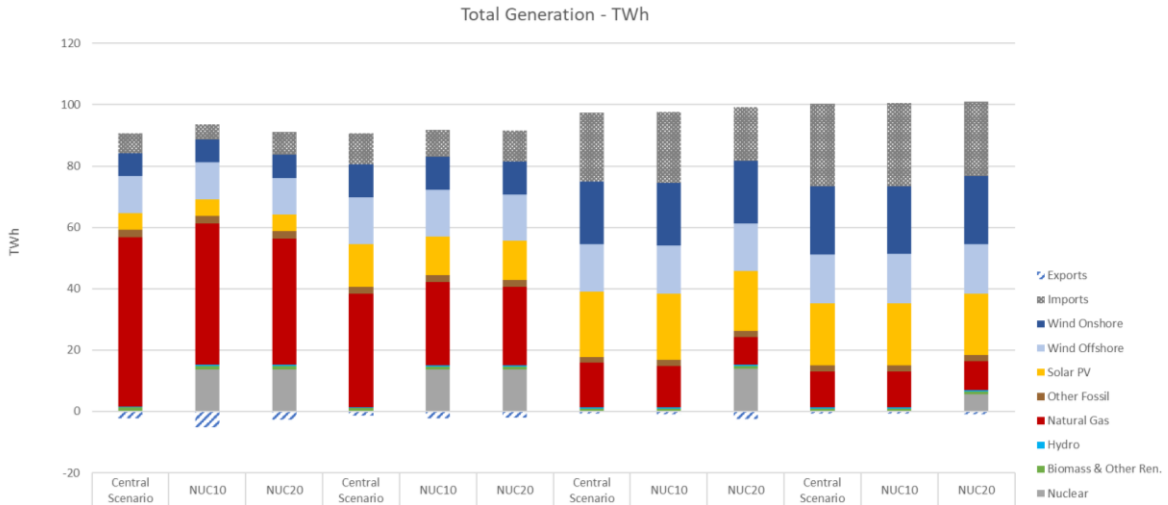
- Belgium is net exporter in 2020-2025
  - 2020: annual 8,5 TWh export
  - Depending on nuclear availability and timely investments in new gas plants, net exporter until 2025
- Belgium is net importer from 2026 onwards
  - 2026: annual 4,2 TWh import
  - 2030: annual 8,8 TWh import
  - 2040: annual 21,6 TWh import
  - Sharp increase in renewable capacity in other countries (+200 GW from 2020-2030) enables more import




| | Central Scenario 2020 | Central 2026 | Central Scenario 2030 | Central Scenario 2040 |
|---|---|---|---|---|
| Export | -10,6 | -2,31 | -1,3 | -0,8 |
| Import | 2,1 | 6,49 | 10,2 | 22,4 |
| Net import/export | -8,5 | 4,2 | 8,8 | 21,6 |

# Nuclear operation extension – Generation

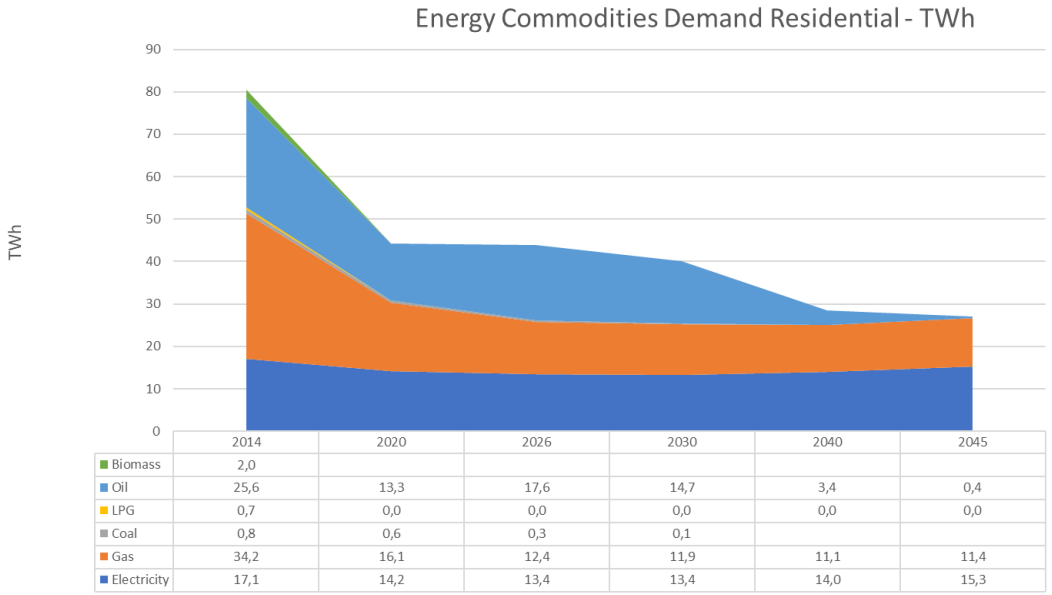
- Nuclear operation 2026
  - Annually 13,6 TWh nuclear generation
  - 10y 2 GW extension with 1,15 GW lower gas capacity leads to 9,2 TWh lower gas based production and no net import
  - 20y 2 GW extension with 1,8 GW lower gas capacity leads to 14,1 TWh lower gas based production and import at the same level as Central scenario (4,7 TWh)
- Nuclear operation 2030
  - Lower Gas based production:
    - 10y: - 9,8 TWh
      - Operating hours new gas plants decrease from 6350 h/y (central) to about 5600 h/y (-12%)
    - 20y: - 11,3 TWh
      - Operating hours new gas plants decrease from 6350 h/y (central) to about 6200 h/y (-2,4%)
  - Lower import:
    - 10y: net – 6,5 TWh import (7,4 % of BE demand)
    - 20y: net – 8,0 TWh import (9 % of BE demand
- Situation in 2040
  - 10y: after closure of nuclear plants, new investments in gas based capacity, almost up to same level as in Central Scenario
  - 20y: lower gas based production and lower net import



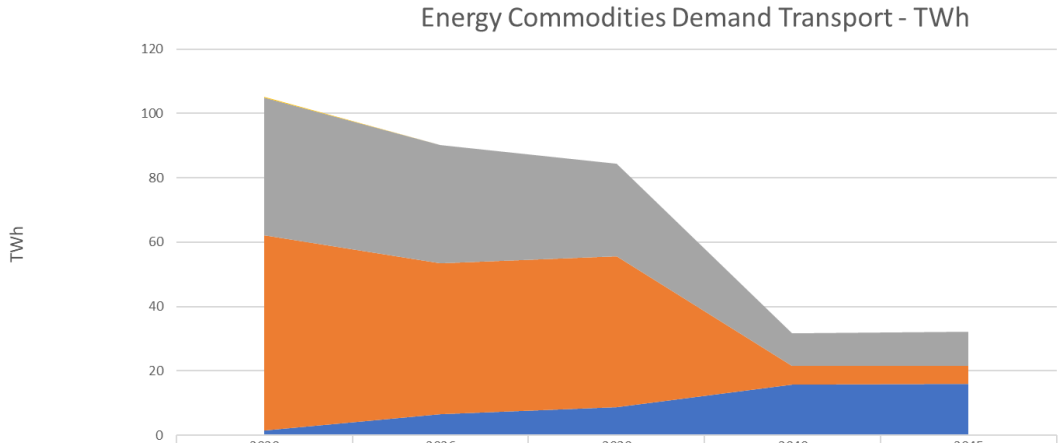

| | Central Scenario | NUC10 | NUC20 | Central Scenario | NUC10 | NUC20 | Central Scenario | NUC10 | NUC20 | Central Scenario | NUC10 | NUC20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2026 | | | 2030 | | | 2040 | | | 2045 | |
| Exports | -2,31 | -5,21 | -2,71 | -1,33 | -2,35 | -1,99 | -0,78 | -0,92 | -2,49 | -0,60 | -0,66 | -1,02 |
| Imports | 6,49 | 4,93 | 7,43 | 10,17 | 8,89 | 9,96 | 22,37 | 23,17 | 17,50 | 26,92 | 26,98 | 24,30 |
| Wind Onshore | 7,58 | 7,58 | 7,58 | 10,75 | 10,75 | 10,75 | 20,41 | 20,41 | 20,41 | 22,19 | 22,19 | 22,19 |
| Wind Offshore | 12,05 | 12,05 | 12,05 | 15,12 | 15,12 | 15,12 | 15,68 | 15,68 | 15,68 | 16,11 | 16,11 | 16,11 |
| Solar PV | 5,40 | 5,40 | 5,40 | 14,04 | 12,63 | 12,74 | 21,14 | 21,44 | 19,45 | 20,21 | 20,22 | 20,02 |
| Other Fossil | 2,41 | 2,41 | 2,41 | 2,29 | 2,29 | 2,29 | 1,98 | 1,98 | 1,98 | 1,94 | 1,94 | 1,94 |
| Natural Gas | 55,18 | 46,03 | 41,04 | 36,91 | 27,14 | 25,61 | 14,47 | 13,56 | 9,04 | 11,69 | 11,69 | 9,59 |
| Hydro | 0,38 | 0,38 | 0,38 | 0,38 | 0,38 | 0,38 | 0,38 | 0,38 | 0,38 | 0,38 | 0,38 | 0,38 |
| Biomass & Other Ren. | 1,25 | 1,25 | 1,25 | 1,01 | 1,01 | 1,01 | 0,96 | 0,96 | 0,96 | 0,94 | 0,94 | 0,94 |
| Nuclear | | 13,63 | 13,63 | | 13,63 | 13,63 | | | 13,87 | | | 5,55 |

# Central scenario – Demand

- $CO_2$ price drives decarbonization and electrification of demand sectors
  - $CO_2$ price for ETS and non-ETS sectors in line with IEA 'Sustainable Development'* scenario
- Residential buildings
  - Energy efficiency and demand reduction is cost optimal leading to large reduction from 2014-2020 → much faster than what we observe
  - Fuel oil phase out >2040
  - Electrification of heat demand with heat pumps → due to cost optimal energy efficiency measures this only leads to modest increase in electricity demand
  - $CO_2$ emissions decrease by 4 Mton or 57% from 2020 to 2040
- Transport sector
  - Electricity demand goes up from 1 TWh in 2020 to 16 TWh by 2045
  - Strong electrification of passenger transport and high efficiency of electric motor leads to sharp decrease in diesel and gasoline use:
    - Diesel: -54,9 TWh or -91% from 2020-2040
    - Gasoline: -32,7 TWh or –76% from 2020-2040
  - $CO_2$ emissions decrease by 22,1 Mton or 57% from 2020 to 2040




| | 2014 | 2020 | 2026 | 2030 | 2040 | 2045 |
|---|---|---|---|---|---|---|
| Biomass | 2,0 | | | | | |
| Oil | 25,6 | 13,3 | 17,6 | 14,7 | 3,4 | 0,4 |
| LPG | 0,7 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| Coal | 0,8 | 0,6 | 0,3 | 0,1 | | |
| Gas | 34,2 | 16,1 | 12,4 | 11,9 | 11,1 | 11,4 |
| Electricity | 17,1 | 14,2 | 13,4 | 13,4 | 14,0 | 15,3 |




| | 2020 | 2026 | 2030 | 2040 | 2045 |
|---|---|---|---|---|---|
| LPG | 0,2 | | | | |
| Gasoline | 42,9 | 36,7 | 28,8 | 10,1 | 10,7 |
| Diesel | 60,6 | 46,7 | 47,0 | 5,8 | 5,6 |
| Electricity | 1,4 | 6,7 | 8,7 | 15,7 | 16,0 |

* Source: IEA, World Energy Outlook 2019, p. 758

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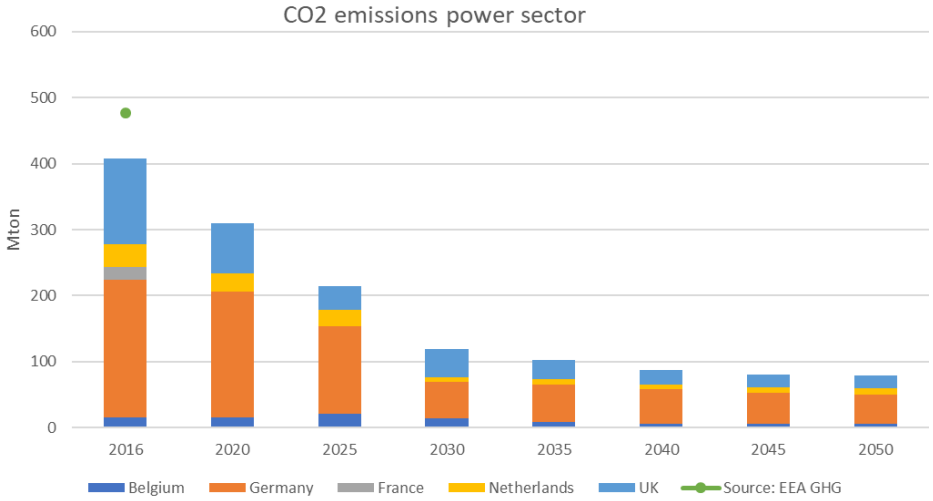
# $CO_2$ emissions – 2025 - 2030 results

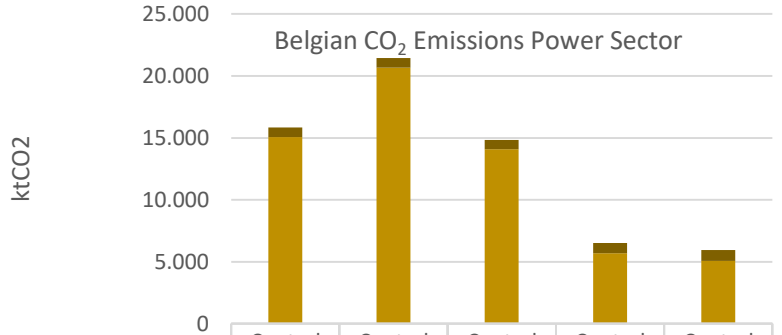
- **$CO_2$ emissions** power sector
  - Belgian emissions will be determined by operating gas plants, import/export of electricity
  - DE, FR, UK, NL emissions are expected to decline with 95 Mton or 31% from 2020 to 2025 and with 190 Mton or 61,5% from 2020 to 2030,
  - Belgian emissions peak in 2026, + 5,6 Mton or + 35% compared to 2020
  - Belgian emissions decline by 1 Mton or 6,5% in the central scenario from 2020 to 2030
  - Nuclear extension will lower Belgian emissions with an additional 3,2 Mton (10y LTO) to 3,7 Mton (20y LTO) compared to the central scenario, determined by the CCGT generation.

| Belgium 2030 | 2017 Central | Model updates | Central | 10y LTO | 20y LTO |
|---|---|---|---|---|---|
| **$CO_2$ emissions power sector ETS [Mton]** | 12,7 | | **14,1** | **10,9** | **10,4** |

# Central scenario - $CO_2$ emissions power sector

- Strong decrease in NW-EU $CO_2$ emissions power sector from 2020 to 2030
  - -190 Mton or -61,5%
  - BE emissions represent <4% of total power sector emissions (DE, UK, NL, FR, BE) in 2016
- Belgian emissions peak in 2026
  - Nuclear closure, higher gas based production (55,2 TWh)
  - $CO_2$ emissions increase by 5,6 Mton from 2020 to 2026
- Belgian emissions decrease from 2020 to 2030
  - By 1 Mton
  - With 50% renewable generation (41,3 TWh) compared to total Belgian generation
  - With net import of 8,8 TWh

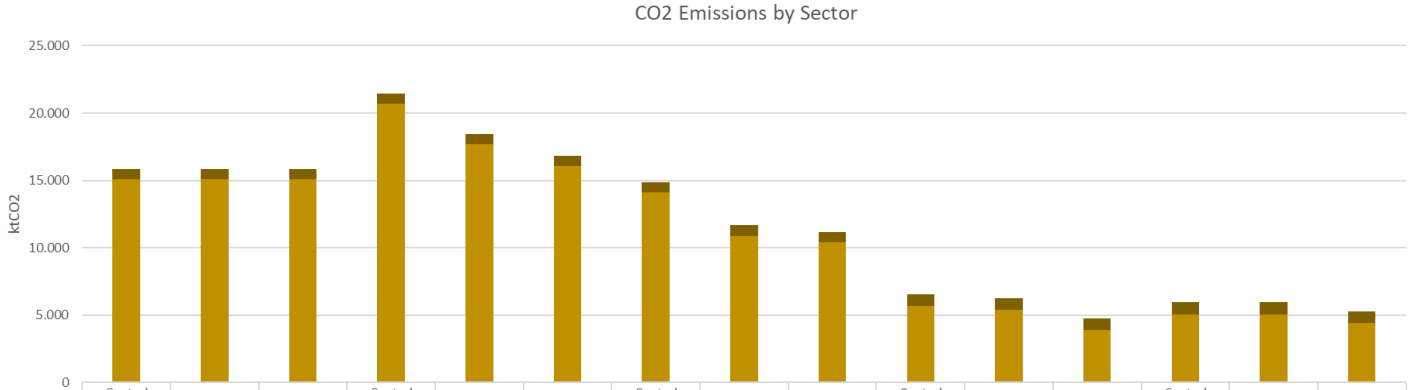



| | Central Scenario 2020 | Central Scenario 2026 | Central Scenario 2030 | Central Scenario 2040 | Central Scenario 2045 |
|---|---|---|---|---|---|
| Power (Non-ETS) | 768 | 759 | 761 | 844 | 883 |
| Power (ETS) | 15073 | 20683 | 14086 | 5678 | 5060 |

# Nuclear operation extension - $CO_2$ emissions

- Nuclear operation extension leads to
  - 2026:
    - 10y: - 3,0 Mton $CO_2$ emissions in the power sector, due to – 9,2 TWh gas based production
    - 20y: - 4,6 Mton $CO_2$ emissions in the power sector, due to – 14,1 TWh gas based production
  - 2030: lower $CO_2$ emissions in nuclear extension scenarios, due to lower gas based capacity and operation
  - 2040:
    - 10y: after closure of nuclear capacity, new investments in gas based capacity, emissions are almost equal to Central scenario
    - 20y: impact of nuclear lifetime extension on $CO_2$ emissions decreases gradually to – 1,8 Mton compared to Central scenario, due to increase in renewable electricity in Be and other countries (import)
  - Emission reduction estimate over full lifetime extension horizon (cumulative)
    - 10y: 22 Mton $CO_2$ emissions in the power sector
    - 20y: 45 Mton $CO_2$ emissions in the power sector




| | Central Scenario | NUC10 | NUC20 | Central Scenario | NUC10 | NUC20 | Central Scenario | NUC10 | NUC20 | Central Scenario | NUC10 | NUC20 | Central Scenario | NUC10 | NUC20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2020 | | | 2026 | | | 2030 | | | 2040 | | | 2045 | | |
| Power (Non-ETS) | 768 | 768 | 768 | 759 | 759 | 759 | 761 | 757 | 761 | 844 | 844 | 844 | 883 | 883 | 883 |
| Power (ETS) | 15073 | 15084 | 15073 | 20683 | 17701 | 16076 | 14086 | 10897 | 10417 | 5678 | 5387 | 3906 | 5060 | 5060 | 4377 |

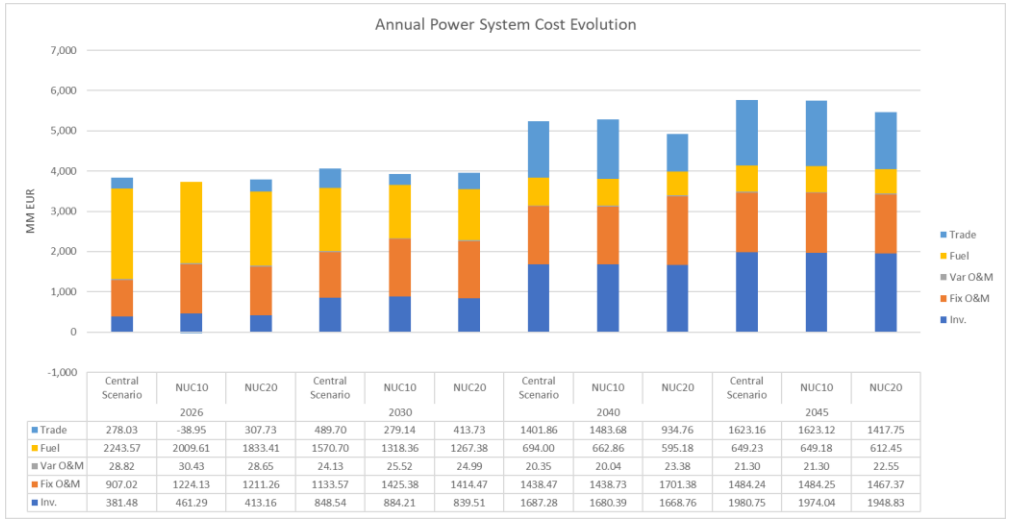
# Costs – 2025 - 2030 results

- Annual electricity system cost
  - Low gas price and discount rate leads to lower impact of nuclear extension compared to 2017 central scenario.
    Nuclear extension = 106-134 MEUR lower annual system cost than central scenario in 2030
  - Marginal electricity production cost ≈ wholesale electricity price
    Nuclear extension = 0,9 – 1,3 €/MWh lower price compared to central scenario in 2030

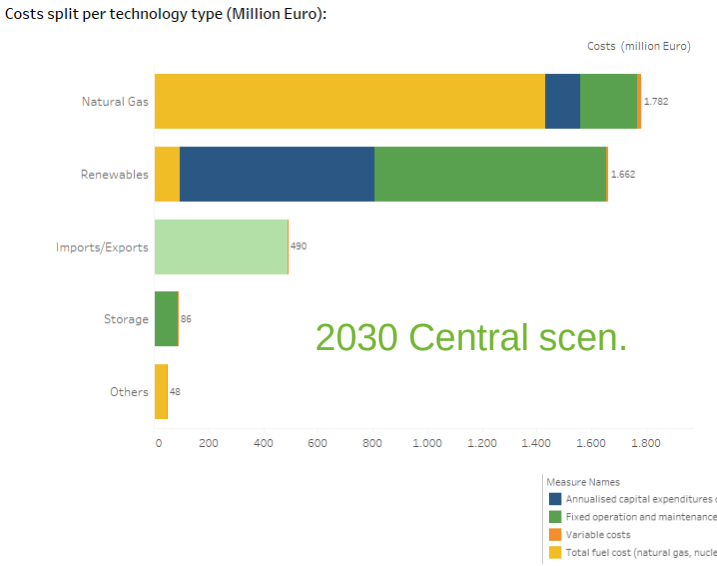
| Belgium 2030 | 2017 Central | Model updates | Engie Central | 10y LTO | 20y LTO |
|---|---|---|---|---|---|
| **Annual electricity system cost [MEUR]** | 6180 | Lower gas price, lower CAPEX renewables<br>Discount rate 3% | **4067** | **3933** | **3960** |

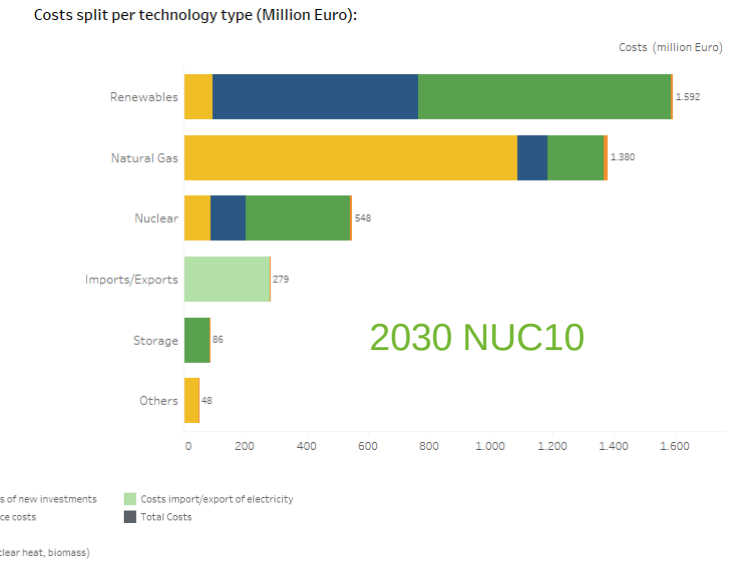
# Annual electricity supply cost (excluding $CO_2$ price)

- Fuel cost (gas price) – import/export: most variable and leading parameters in cost evolution
- Nuclear extension in 2030: 106-134 M€/y lower compared to Central scen.
  - Import – fuel cost ↓
  - Fixed O&M (+ Investments) ↑
- LTO electricity system costs over full lifetime extension horizon (cumulative)
  - 10y: up to 2 G€ lower than Central scenario
  - 20y: up to 5,8 G€ lower than Central scenario
- Investment cost of distribution grid upgrades from 2040 onwards
  - 2040: 77 – 86 M€/y depending on scenario
  - 2045: 233 – 240 M€/y depending on scenario



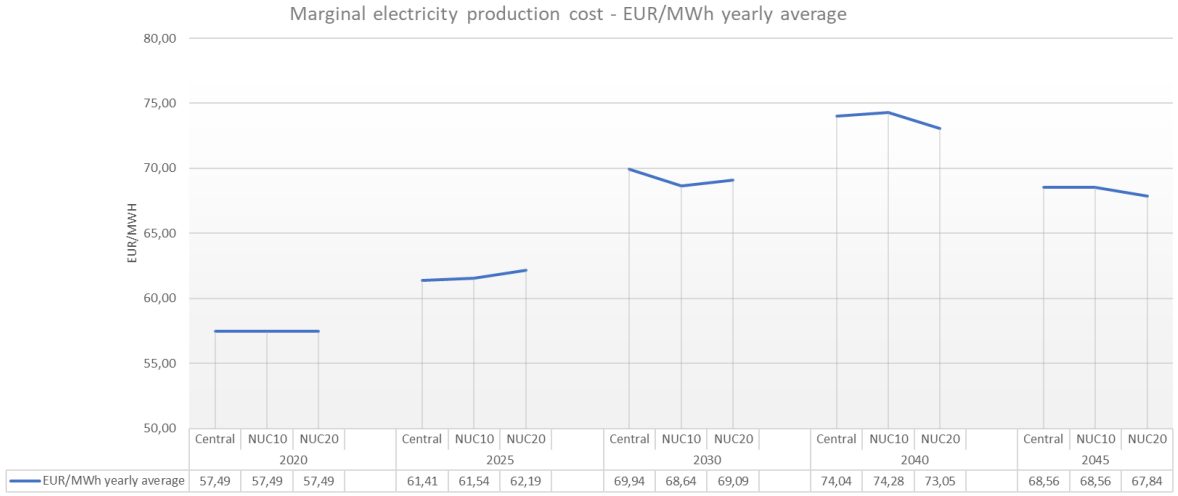

| | Central Scenario | NUC10 | NUC20 | Central Scenario | NUC10 | NUC20 | Central Scenario | NUC10 | NUC20 | Central Scenario | NUC10 | NUC20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2026 | | | 2030 | | | 2040 | | | 2045 | | |
| Trade | 278.03 | -38.95 | 307.73 | 489.70 | 279.14 | 413.73 | 1401.86 | 1483.68 | 934.76 | 1623.16 | 1623.12 | 1417.75 |
| Fuel | 2243.57 | 2009.61 | 1833.41 | 1570.70 | 1318.36 | 1267.38 | 694.00 | 662.86 | 595.18 | 649.23 | 649.18 | 612.45 |
| Var O&M | 28.82 | 30.43 | 28.65 | 24.13 | 25.52 | 24.99 | 20.35 | 20.04 | 23.38 | 21.30 | 21.30 | 22.55 |
| Fix O&M | 907.02 | 1224.13 | 1211.26 | 1133.57 | 1425.38 | 1414.47 | 1438.47 | 1438.73 | 1701.38 | 1484.24 | 1484.25 | 1467.37 |
| Inv. | 381.48 | 461.29 | 413.16 | 848.54 | 884.21 | 839.51 | 1687.28 | 1680.39 | 1668.76 | 1980.75 | 1974.04 | 1948.83 |

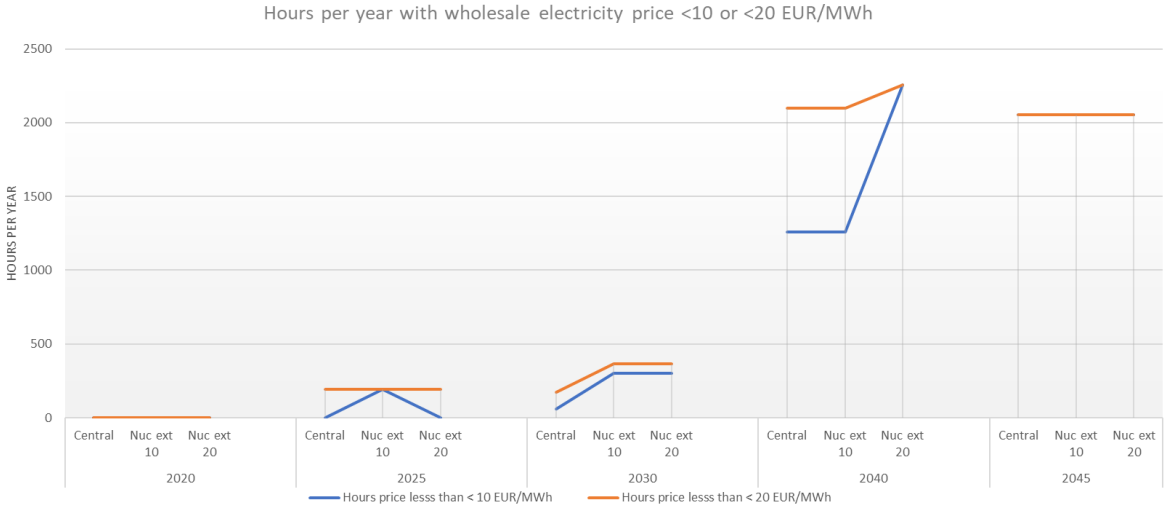


# Marginal electricity production cost – wholesale price

- Nuclear extension has a limited impact on the wholesale price of electricity in Belgium
  - Wholesale price determined by gas units and gas price
  - 2030:
    - Central: almost 70 EUR/MWh
    - 10y LTO: - 1,3 EUR/MWh compared to Central
    - 20y LTO: - 0,9 EUR/MWh compared to Central
  - 2040: - 1,0 EUR/MWh in 20y extension scenario
- Number of hours per year with low wholesale price, <10 or <20 EUR/MWh
  - 2030, <10 EUR/MWh: 300 h/y in nuclear extension vs. 58 h/y in central scenario
  - Sharp increase from 2040 onwards, 2100 h/y with wholesale price <20 EUR/MWh and 2260 h/y in 20y nuclear extension scenario



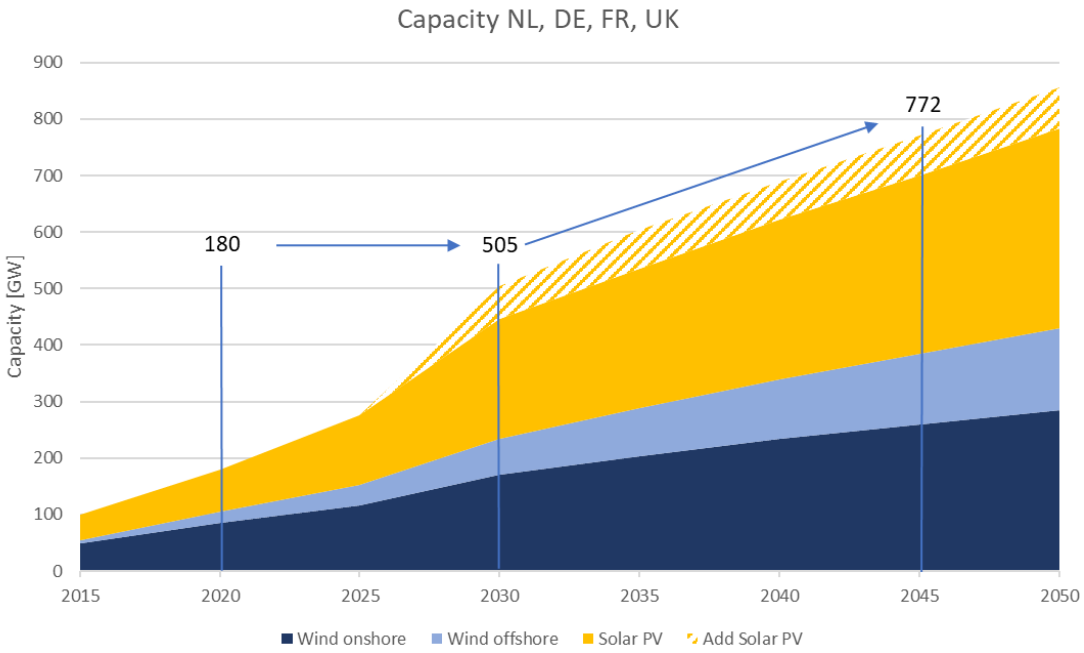



# Scenario results
# High renewable ambitions (High RES)

## Central – 10y/20y nuclear extension

# High RES - Changes in assumptions

- Exogenous renewable capacity neighbouring countries
  - Highest available TYNDP scenario results
  - Additional 266 GW renewables from 2020-2030 = solid area in graph
- Endogenous changes
  - PV
    - Investment cost PV: lower estimate IRENA projections
      - 2030: 306 €/kW (vs 540 €/kW)
      - 2050: 148,5 €/kW (vs 324 €/kW)
    - Allow investments in all countries, in neighbouring countries on top of exogenous capacity = 'Add solar PV" in graph (result from model)
  - Batteries
    - Lifetime extension from 10 to 20y starting from 2035
    - Allow investments in all countries
  - Onshore wind Belgium
    - Post 2030 annual capacity *increase* max. 500 MW/y → maximum capacity 12,5 GW by 2050
  - Offshore wind Belgium
    - Maximum potential implemented: 6 GW from 2040 onwards



# High RES - Changes in the electricity system – Belgium

## Difference with 'Current renewable ambition pathway' *highlighted*

2020 → 2025 → 2030 → 2050

| Be | Capacity [GW] | Model assumptions | | |
|---|---|---|---|---|
| Gas – Coal – Biomass - CHP | | Same as Current renewable pathway | | |
| Nuclear | 5,93 | High RES Central scenario: Phase out<br>High RES Alternative: 10y–20y extension | | |
| Solar PV | 4,83 | | *Investment cost commercial PV: 306 €/kW**<br>*Allow investments in BE and other countries*<br>(Current renewable pathway: 540 €/kW) | *Investment cost commercial PV: 148,5 €/kW**<br>*Allow investments in BE and other countries*<br>(Current renewable pathway: 324 €/kW) |
| Onshore | 2,28 | Annual max. growth rate<br>'20-'30: +250 MW | ***Annual **additional** max. growth rate >2030, **excluding** replacement old turbines: +500 MW* | ***Tech.max.potential 12,5 GW*<br>(Current renewable pathway: 8,6 GW) |
| Offshore | 2,26 | Annual max. growth rate<br>'20-'25: +250 MW | Tech.max.potential 4,6 GW | ***Tech.max.potential 2040: 6 GW forced result*<br>(Current renewable pathway: 4,6 GW) |
| Interconnection | 6,5<br>Simultaneous avail. cap. | 6,5<br>Same as Current renewable pathway | 6,5 | 6,5 |
| Distribution grid | 7,0<br>Peak load cap. | Same as Current renewable pathway | | |
| Battery storage | | | ***Lifetime extension from 10y to 20y from 2035 onwards*<br>*Allow investments in BE and other countries* | |
| Gas price €/GJ | 6,1 | 6,1<br>Same as Current renewable pathway | 6,0 | 6,0 |
| $CO_2$ price €/ton | 25 | 40<br>Same as Current renewable pathway | 84,3 | 160 |

*Source: IRENA, Future of Solar Photovoltaics – Deployment, investment, technology, grid integration and socio-economic aspects, Nov.2019
** EnergyVille assumption

# High RES - Key messages – 2030 results

- Capacity increases from 22,4 GW in 2020 to 37,0 GW in 2030 (+65%), due to higher PV investments compared to 'Current RES ambition scenarios'
- Gas based CCGT investments
  - Perfect foresight, cost optimization approach decides for lower investment in new CCGT plants as more renewable capacity becomes available in 2030 in BE and other countries
    - Central: Up to 2,7 GW investments in new CCGT by 2025, or <4 new 800 MW units
    - 2 GW 10y LTO: 1,8 GW new CCGT, -940 MW compared to central
    - 2 GW 20y LTO: 1,4 GW new CCGT, -1300 MW compared to central
- Renewable investments
  - **Wind onshore** and **Wind offshore** same results as Current renewable pathway, higher growth from 2040 onwards
  - **PV** cost efficiency increases by 2030 → 20,1 GW installed by 2030
  - No impact of nuclear extension on renewable investments
- Electricity demand >2030
  - High share of renewables has impact on marginal electricity production cost: 46 €/MWh in 2040, or almost 30 €/MWh lower than in Current renewable pathway
  - Electrification of end-use demand increases in industrial sectors leading to total electricity demand (incl. losses in distribution and storage)
    - 106 TWh in 2040 (+10% compared to 96,6 TWh Current renewable ambition Central)
    - 122 TWh in 2045 (+22% compared to 99,8 TWh Current renewable ambition Central)
- CO2 emissions
  - Lower gas based electricity generation leads to 33% CO2 savings in 2030 in the Central scenario: 9,5 Mton compared to 14,1 Mton in the Current renewable ambition Central scenario

| | | High RES | | |
|---|---|---|---|---|
| **Belgium 2030** | **Central** | **Central** | **10y LTO** | **20y LTO** |
| Gas [GW], CCGT + CHP | 7,8 | 6,7 | 5,7 | 5,4 |
| Generation gas [TWh] | 36,9 | 20,6 | 16,3 | 15,4 |
| Operating new CCGT [h/y] | 6350 | 3650 | 3360 | 3400 |
| Nuclear [GW] | 0 | 0 | 2 | 2 |
| Solar PV [GW] | 12,6 | 20,1 | 19,7 | 19,7 |
| Onshore [GW] | 4,6 | 4,6 | 4,6 | 4,6 |
| Offshore [GW] | 4,6 | 4,6 | 4,6 | 4,6 |
| Net import [TWh] | 8,8 | 19,5 | 11,2 | 12,1 |
| Electricity demand [TWh] | 89,3 | 91,1 | 91,4 | 91,4 |
| CO2 emissions power sector ETS [Mton] | 14,1 | 9,5 | 8,1 | 7,8 |
| Annual electricity system cost [MEUR] | 4067 | 4305 | 3978 | 3979 |

# High RES Key messages (1)

## CAPACITY & GENERATION

- Expected *thermal capacity decrease* in NW-Europe from today till 2030 has a major impact on the electricity system
- Expected *renewable capacity increase* from today till 2030
  - DE, FR, UK, NL: + 325 GW solar, wind
  - BE: cost effective uptake of
    - Onshore wind: +2,3 GW leading to 4,6 GW by 2030
    - Offshore wind: +2,4 GW leading to 4,6 GW by 2030
    - PV: + 1500 MW/year → +15,3 GW leading to 20,1 GW by 2030
- Need for substantial day/night storage technology
  - Home batteries + Medium Voltage grid connected batteries : more than 10 GW by 2040

- Full nuclear closure in Belgium creates *cost optimal investment in new CCGT gasplants* – need for 2,7 GW new gas based capacity by 2025, or almost 4 large 800 MW units
- 2 GW nuclear operation extension leads to
  - 10y extension: 1,8 GW new CCGT, -940 MW compared to central
  - 20y extension: 1,4 GW new CCGT, -1300 MW compared to central
  - No impact on investments in renewable capacity

# High RES Key messages (2)

- 66% of Belgian electricity generation based on renewables by 2030 in all scenarios
  - Belgium is net importer >2025: annually 21% of electricity demand (19,5 TWh)
  - Higher renewable generation in BE and other countries leads to more cross border trade

## $CO_2$ EMISSIONS

- Belgian $CO_2$ emissions from power sector will peak by 2026 but the increase is only half of the 'current renewable ambition central scenario': +2,7 Mton or +17% compared to 2020.
  Emissions strongly decrease with 6,3 Mton or 42% by 2030 compared to 2020.

## POWER COST

- Annual power system cost amounts to 4,3 G€ by 2030 in the Central scenario
- Wholesale electricity price will be 64 €/MWh or 9% lower than in the current renewable ambition central scenario by 2030 and will decrease further to 46 €/MWh by 2040.
- Number of hours with marginal electricity production cost <20 €/MWh increases to 4300 h/y from 2040 onwards

## ELECTRIFICATION OF END USE SECTORS

- Lower wholesale electricity price leads to stronger electrification of end use demand in most sectors: electrification of passenger transport, heat pumps for heating buildings, electrification in industry sectors
- Electricity demand in 2040 will be 106 TWh which is 28% higher than today, or 10% higher than 'current renewable ambition pathway'.

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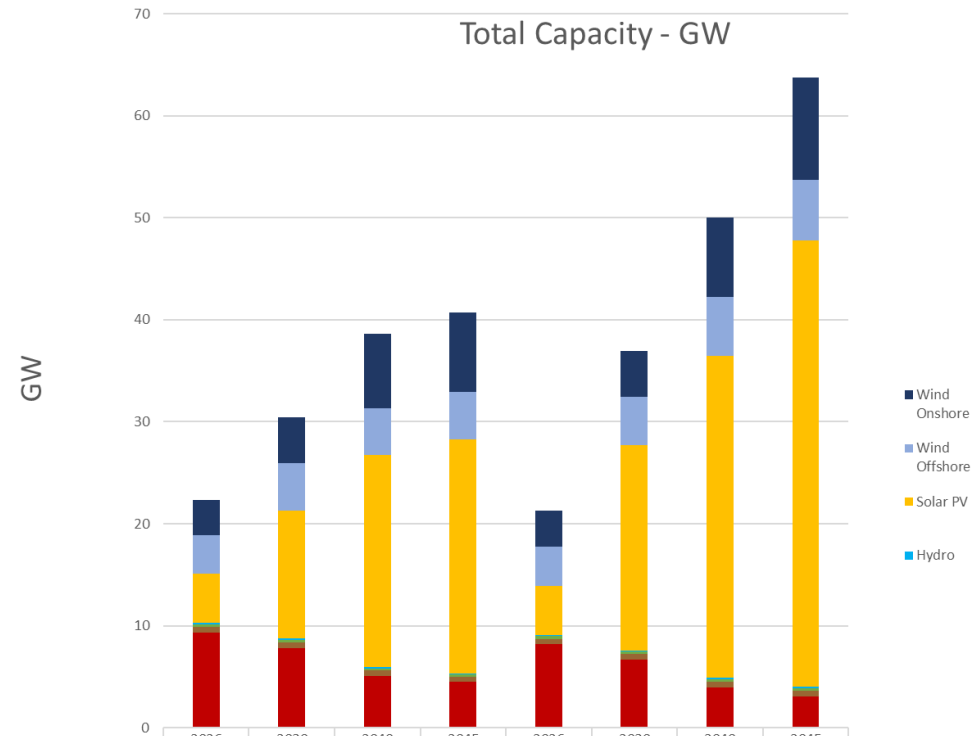
# High RES Central scenario - Capacity

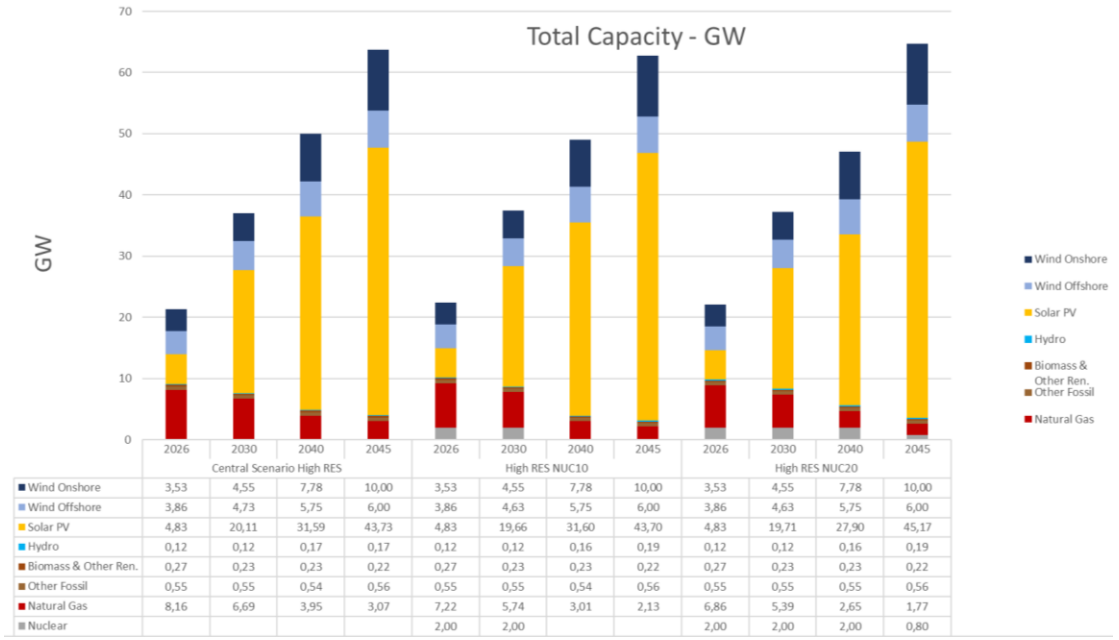
- Nuclear phase out by 2025
- Investments in
  - New Gas plants (CCGT)
    - 2,7 GW by 2026, >1 GW lower than Central Scenario
    - no additional investments >2026, leading to total gas based capacity (CCGT + CHP) of 8 GW in 2026 and almost 4 GW in 2040
  - Renewables
    - Wind onshore increases up to max. annual growth level of 250 MW/y from 2020-2030, 500 MW/y post 2030 (additional) → 10 GW by 2045
    - Wind offshore grows further > 2030 to 6 GW by 2045
      Need for additional offshore zones to grow > 4,6 GW
    - PV: lower investment cost assumption leads to drastic increase
      By 2045: almost double PV capacity compared to Central scenario
      - 2030: 20 GW
      - 2040: 32 GW
      - 2045: 44 GW



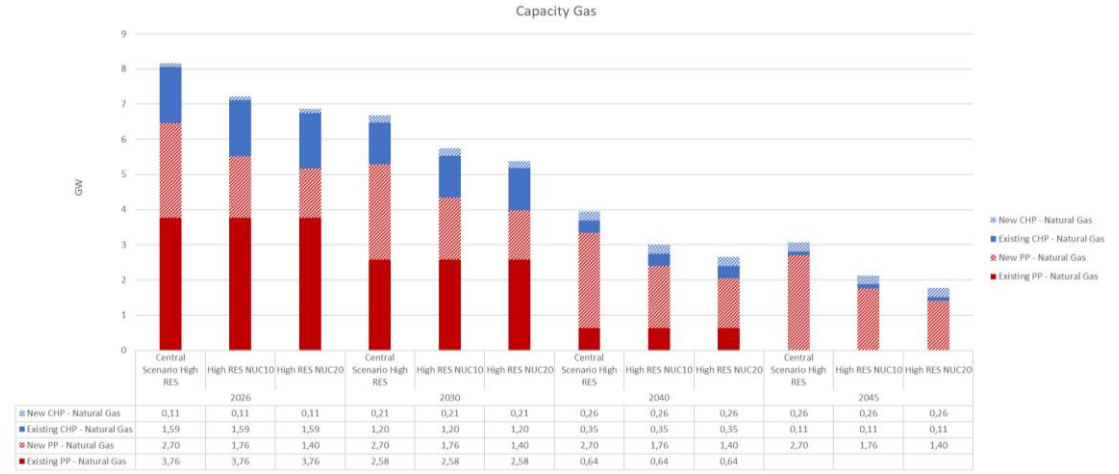

| | 2026 | 2030 | 2040 | 2045 | 2026 | 2030 | 2040 | 2045 |
|---|---|---|---|---|---|---|---|---|
| | Central Scenario | | | | Central Scenario High RES | | | |
| Wind Onshore | 3,53 | 4,55 | 7,28 | 7,80 | 3,53 | 4,55 | 7,78 | 10,00 |
| Wind Offshore | 3,76 | 4,63 | 4,60 | 4,60 | 3,86 | 4,73 | 5,75 | 6,00 |
| Solar PV | 4,83 | 12,57 | 20,77 | 22,97 | 4,83 | 20,11 | 31,59 | 43,73 |
| Hydro | 0,12 | 0,12 | 0,14 | 0,15 | 0,12 | 0,12 | 0,17 | 0,17 |
| Biomass & Other Ren. | 0,27 | 0,22 | 0,21 | 0,20 | 0,27 | 0,23 | 0,23 | 0,22 |
| Other Fossil | 0,55 | 0,55 | 0,49 | 0,50 | 0,55 | 0,55 | 0,54 | 0,56 |
| Natural Gas | 9,31 | 7,84 | 5,10 | 4,49 | 8,16 | 6,69 | 3,95 | 3,07 |

# High RES Nuclear operation extension – Capacity

- 2 GW nuclear extension by
  - 10y: 2025-2034
  - 20y: 2025-2044
  - 80% availability per year: 2 or 1 GW
- Impact on renewables
  - No impact on onshore or offshore wind investments
  - Limited/no impact on PV investments
- Impact on investments in CCGT gas capacity (2026-2030-2040)
  - 10y: - 940 MW or – 2 units/plants
  - 20y: - 1300 MW or – 3 units/plants
    due to cost optimization of the need for gas based capacity in the long run



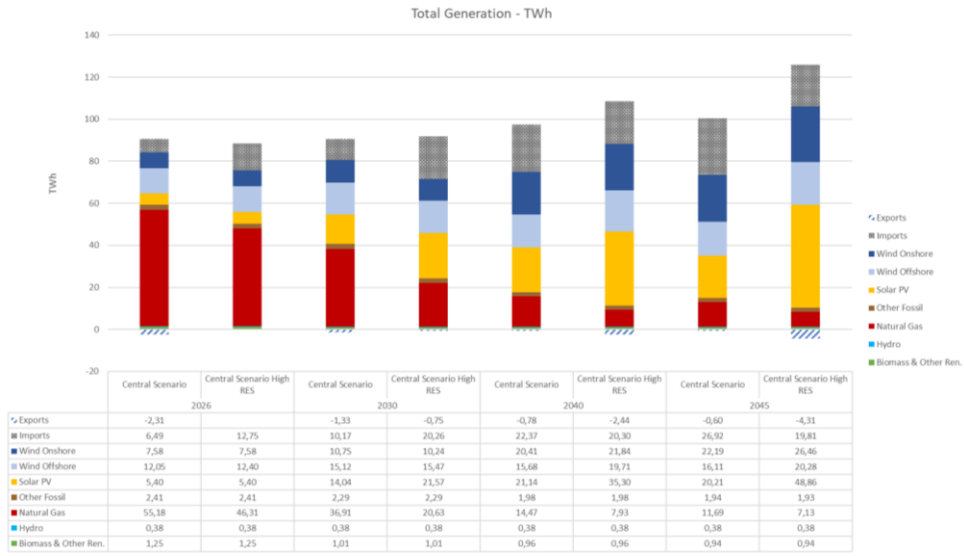

| | Central Scenario High RES | | | | High RES NUC10 | | | | High RES NUC20 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2026 | 2030 | 2040 | 2045 | 2026 | 2030 | 2040 | 2045 | 2026 | 2030 | 2040 | 2045 |
| Wind Onshore | 3,53 | 4,55 | 7,78 | 10,00 | 3,53 | 4,55 | 7,78 | 10,00 | 3,53 | 4,55 | 7,78 | 10,00 |
| Wind Offshore | 3,86 | 4,73 | 5,75 | 6,00 | 3,86 | 4,63 | 5,75 | 6,00 | 3,86 | 4,63 | 5,75 | 6,00 |
| Solar PV | 4,83 | 20,11 | 31,59 | 43,73 | 4,83 | 19,66 | 31,60 | 43,70 | 4,83 | 19,71 | 27,90 | 45,17 |
| Hydro | 0,12 | 0,12 | 0,17 | 0,17 | 0,12 | 0,12 | 0,16 | 0,19 | 0,12 | 0,12 | 0,16 | 0,19 |
| Biomass & Other Ren. | 0,27 | 0,23 | 0,23 | 0,22 | 0,27 | 0,23 | 0,23 | 0,22 | 0,27 | 0,23 | 0,23 | 0,22 |
| Other Fossil | 0,55 | 0,55 | 0,54 | 0,56 | 0,55 | 0,55 | 0,54 | 0,56 | 0,55 | 0,55 | 0,55 | 0,56 |
| Natural Gas | 8,16 | 6,69 | 3,95 | 3,07 | 7,22 | 5,74 | 3,01 | 2,13 | 6,86 | 5,39 | 2,65 | 1,77 |
| Nuclear | | | | | 2,00 | 2,00 | | | 2,00 | 2,00 | 2,00 | 0,80 |



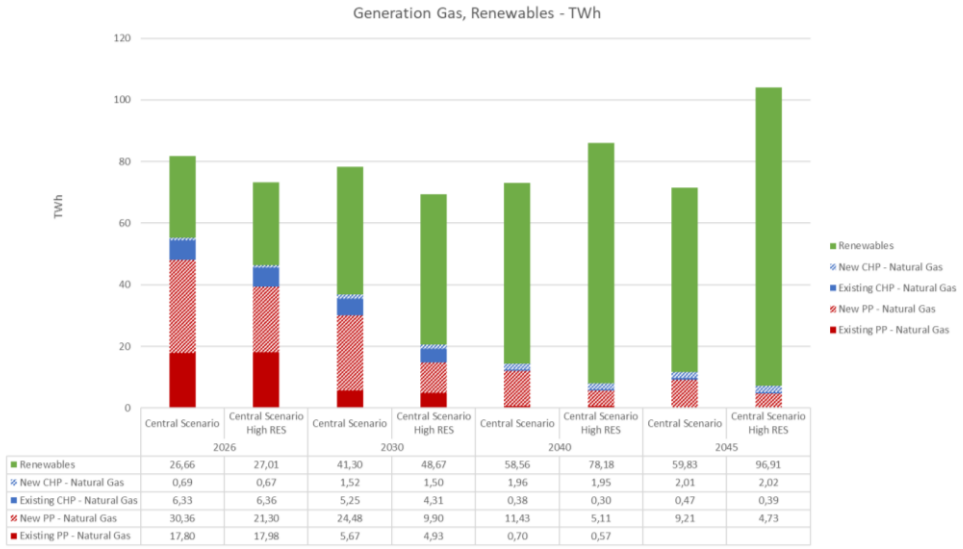

| | Central Scenario High RES | High RES NUC10 | High RES NUC20 | Central Scenario High RES | High RES NUC10 | High RES NUC20 | Central Scenario High RES | High RES NUC10 | High RES NUC20 | Central Scenario High RES | High RES NUC10 | High RES NUC20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2026 | | | 2030 | | | 2040 | | | 2045 | | |
| New CHP - Natural Gas | 0,11 | 0,11 | 0,11 | 0,21 | 0,21 | 0,21 | 0,26 | 0,26 | 0,26 | 0,26 | 0,26 | 0,26 |
| Existing CHP - Natural Gas | 1,59 | 1,59 | 1,59 | 1,20 | 1,20 | 1,20 | 0,35 | 0,35 | 0,35 | 0,11 | 0,11 | 0,11 |
| New PP - Natural Gas | 2,70 | 1,76 | 1,40 | 2,70 | 1,76 | 1,40 | 2,70 | 1,76 | 1,40 | 2,70 | 1,76 | 1,40 |
| Existing PP - Natural Gas | 3,76 | 3,76 | 3,76 | 2,58 | 2,58 | 2,58 | 0,64 | 0,64 | 0,64 | | | |

# High RES Central scenario – Generation

- Gas based production decreases by 55% from 2026 to 2030
  - New gas plants operating at full load in 2026
  - New gas plants operating at <50% load or 3650 h/y in 2030
  - Steep rise in renewable investments in Belgium and other countries, renewable production up to 48,7 TWh or 66% of Belgian production in 2030
  - Net import doubles to total of 19,5 TWh, 21 % of total demand in 2030
- High share of renewables in Be and cross border leads to
  - Increase in electrification of end-use demand > 2035
    - 2040: 106 TWh (+10% compared to 96,6 TWh Central scenario)
    - 2045: 122 TWh (+22% compared to 99,8 TWh Central scenario)
  - Lower gas based production and lower import in Belgium
- Further increase of renewable and decrease of gas based production in 2040
  - Increasing renewable production, up to 78 TWh or 89% of Belgian production (74% of total demand)
  - Gas based production declines to 8,0 TWh, 'new' gas plants operating at 1900 h/y



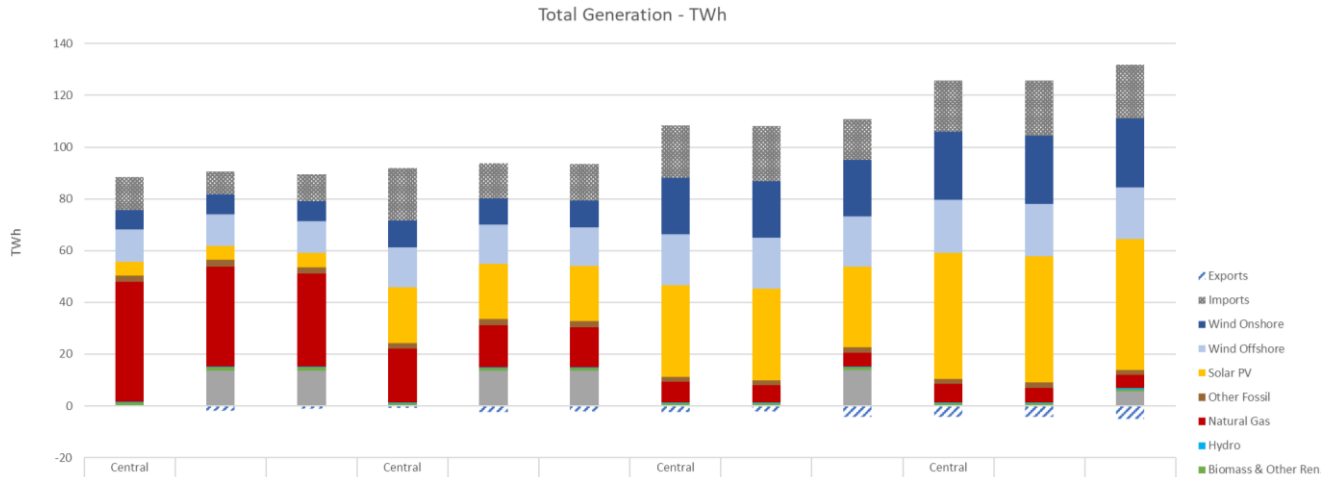

| | Central Scenario 2026 | Central Scenario High RES 2026 | Central Scenario 2030 | Central Scenario High RES 2030 | Central Scenario 2040 | Central Scenario High RES 2040 | Central Scenario 2045 | Central Scenario High RES 2045 |
|---|---|---|---|---|---|---|---|---|
| Exports | -2,31 | | -1,33 | -0,75 | -0,78 | -2,44 | -0,60 | -4,31 |
| Imports | 6,49 | 12,75 | 10,17 | 20,26 | 22,37 | 20,30 | 26,92 | 19,81 |
| Wind Onshore | 7,58 | 7,58 | 10,75 | 10,24 | 20,41 | 21,84 | 22,19 | 26,46 |
| Wind Offshore | 12,05 | 12,40 | 15,12 | 15,47 | 15,68 | 19,71 | 16,11 | 20,28 |
| Solar PV | 5,40 | 5,40 | 14,04 | 21,57 | 21,14 | 35,30 | 20,21 | 48,86 |
| Other Fossil | 2,41 | 2,41 | 2,29 | 2,29 | 1,98 | 1,98 | 1,94 | 1,93 |
| Natural Gas | 55,18 | 46,31 | 36,91 | 20,63 | 14,47 | 7,93 | 11,69 | 7,13 |
| Hydro | 0,38 | 0,38 | 0,38 | 0,38 | 0,38 | 0,38 | 0,38 | 0,38 |
| Biomass & Other Ren. | 1,25 | 1,25 | 1,01 | 1,01 | 0,96 | 0,96 | 0,94 | 0,94 |




| | Central Scenario 2026 | Central Scenario High RES 2026 | Central Scenario 2030 | Central Scenario High RES 2030 | Central Scenario 2040 | Central Scenario High RES 2040 | Central Scenario 2045 | Central Scenario High RES 2045 |
|---|---|---|---|---|---|---|---|---|
| Renewables | 26,66 | 27,01 | 41,30 | 48,67 | 58,56 | 78,18 | 59,83 | 96,91 |
| New CHP - Natural Gas | 0,69 | 0,67 | 1,52 | 1,50 | 1,96 | 1,95 | 2,01 | 2,02 |
| Existing CHP - Natural Gas | 6,33 | 6,36 | 5,25 | 4,31 | 0,38 | 0,30 | 0,47 | 0,39 |
| New PP - Natural Gas | 30,36 | 21,30 | 24,48 | 9,90 | 11,43 | 5,11 | 9,21 | 4,73 |
| Existing PP - Natural Gas | 17,80 | 17,98 | 5,67 | 4,93 | 0,70 | 0,57 | | |

# High RES Nuclear operation extension –Generation

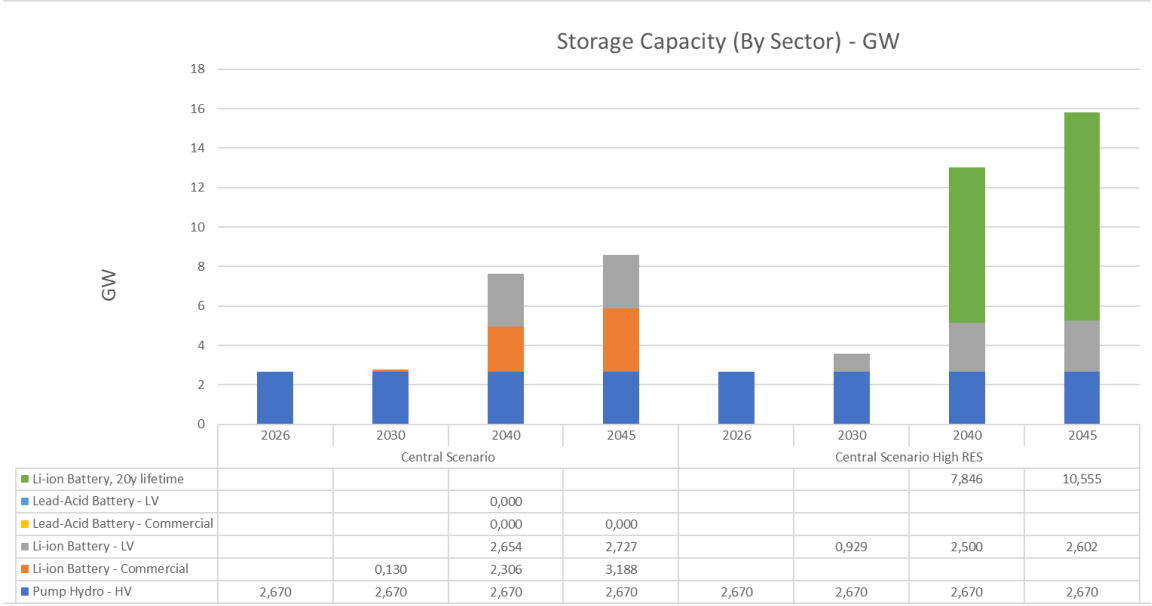
- 20y nuclear operation extension in combination with high share of renewables in Be and cross border leads to
  - Higher increase in electrification of end-use demand by 2045
    - 127 TWh (vs 122 TWh in High RES Central scenario)
    - Almost equal net import compared to Central High RES
- Other results are in line with the findings of the Central and NUC10-NUC20 scenarios

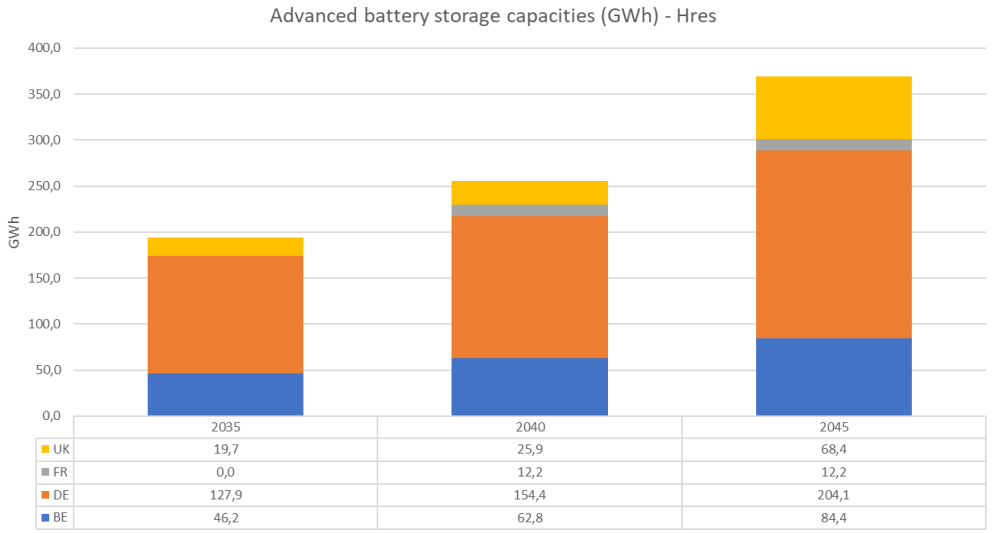



| | Central Scenario High RES | High RES NUC10 | High RES NUC20 | Central Scenario High RES | High RES NUC10 | High RES NUC20 | Central Scenario High RES | High RES NUC10 | High RES NUC20 | Central Scenario High RES | High RES NUC10 | High RES NUC20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2026 | | | 2030 | | | 2040 | | | 2045 | |
| Exports | | -1,99 | -1,01 | -0,75 | -2,30 | -2,06 | -2,44 | -2,24 | -4,21 | -4,31 | -4,33 | -5,12 |
| Imports | 12,75 | 8,79 | 10,54 | 20,26 | 13,47 | 14,11 | 20,30 | 21,56 | 15,69 | 19,81 | 21,24 | 20,82 |
| Wind Onshore | 7,58 | 7,58 | 7,58 | 10,24 | 10,27 | 10,26 | 21,84 | 21,84 | 21,84 | 26,46 | 26,46 | 26,61 |
| Wind Offshore | 12,40 | 12,40 | 12,40 | 15,47 | 15,12 | 15,12 | 19,71 | 19,71 | 19,44 | 20,28 | 20,28 | 20,18 |
| Solar PV | 5,40 | 5,40 | 5,40 | 21,57 | 21,32 | 21,28 | 35,30 | 35,30 | 31,17 | 48,86 | 48,82 | 50,46 |
| Other Fossil | 2,41 | 2,41 | 2,41 | 2,29 | 2,29 | 2,29 | 1,98 | 1,98 | 1,98 | 1,93 | 1,93 | 1,93 |
| Natural Gas | 46,31 | 38,66 | 35,94 | 20,63 | 16,25 | 15,35 | 7,93 | 6,54 | 5,44 | 7,13 | 5,70 | 5,11 |
| Hydro | 0,38 | 0,38 | 0,38 | 0,38 | 0,38 | 0,38 | 0,38 | 0,38 | 0,38 | 0,38 | 0,38 | 0,38 |
| Biomass & Other Ren. | 1,25 | 1,25 | 1,25 | 1,01 | 1,01 | 1,01 | 0,96 | 0,96 | 0,96 | 0,94 | 0,94 | 0,94 |
| Nuclear | | 13,63 | 13,63 | | 13,63 | 13,63 | | | 13,87 | | | 5,55 |

# High RES Central scenario – Curtailment & Storage

- Curtailment
  - Model cost optimization objective leads to limited need for curtailment
- Batteries
  - Higher need for day-night battery storage >2030
    - Belgium: Home batteries + Medium Voltage grid connected batteries increase to more than 10 GW by 2040 and 13 GW by 2045
    - MV grid connected batteries increase to 7,85 GW (8 hours storage capacity) by 2040 (compared to 2,3 GW in Central scenario) = 62,8 GWh storage
    - Total MV grid connected batteries in BE, DE, FR, UK
      - 2040: 255 GWh
      - 2045: 369 GWh

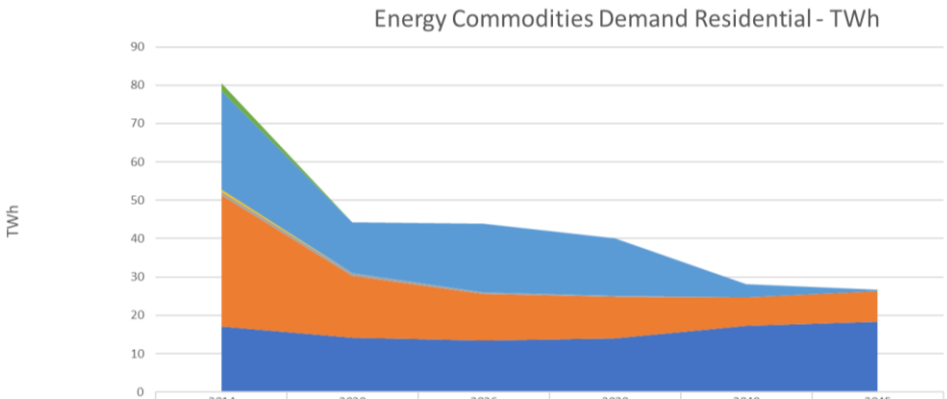


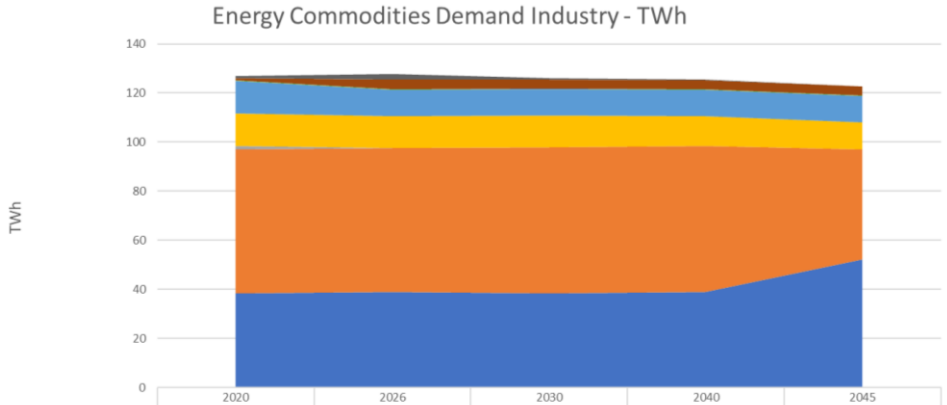
# High RES Central scenario – Demand

- $CO_2$ price and high RES penetration (lower electricity prices) drives decarbonization and electrification of demand sectors
  - $CO_2$ price for ETS and non-ETS sectors in line with IEA 'Sustainable Development'* scenario
- Residential buildings
  - Energy efficiency and demand reduction is cost optimal leading to large reduction from 2014-2020 → much faster than what we observe
  - Fuel oil phase out >2040
  - Electrification of heat demand with heat pumps increases >2030 compared to 'Current RES pathways' and pushes out more gas boilers (11,9 vs 8 TWh in 2045)
  - $CO_2$ emissions decrease by 4,6 Mton or 65% from 2020 to 2040
- Industry
  - Direct electrification in High RES scenario leads to lower gas use:
    - Gas: -14,7 TWh or –25% from 2030-2045
  - $CO_2$ emissions decrease by 7,1 Mton or 30% from 2020 to 2045

* Source: IEA, World Energy Outlook 2019, p. 758



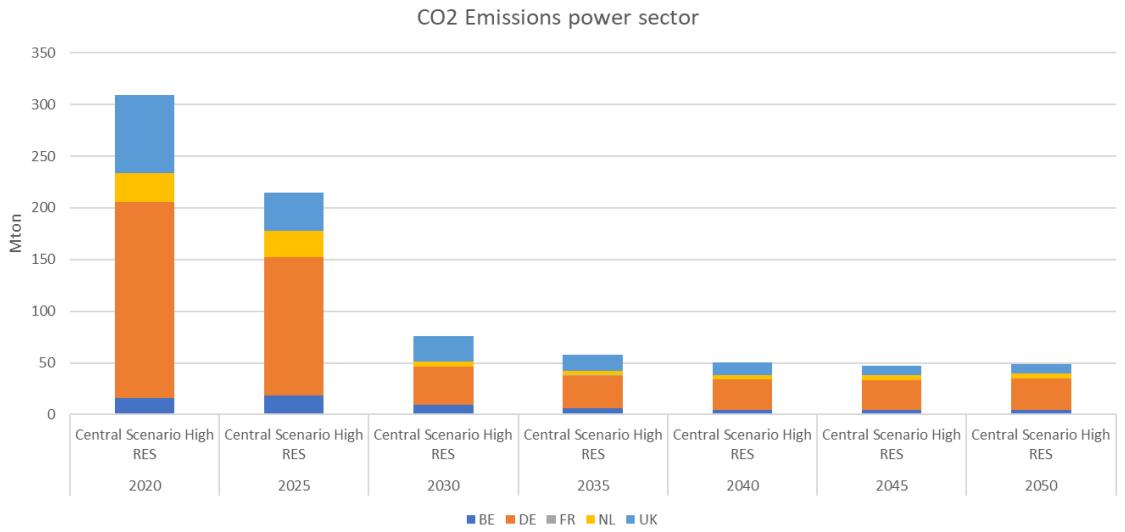

| | 2014 | 2020 | 2026 | 2030 | 2040 | 2045 |
|---|---|---|---|---|---|---|
| Biomass | 2,0 | | | | | |
| Oil | 25,6 | 13,3 | 17,9 | 15,0 | 3,5 | 0,4 |
| LPG | 0,7 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| Coal | 0,8 | 0,6 | 0,3 | 0,1 | | |
| Gas | 34,2 | 16,2 | 12,2 | 11,0 | 7,4 | 8,0 |
| Electricity | 17,1 | 14,2 | 13,4 | 13,9 | 17,2 | 18,3 |

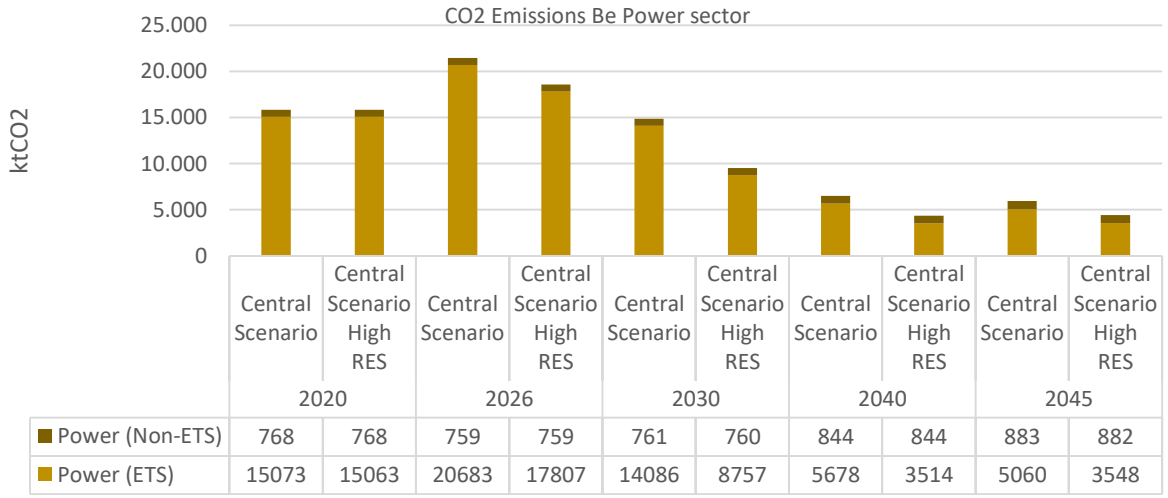



| | 2020 | 2026 | 2030 | 2040 | 2045 |
|---|---|---|---|---|---|
| Light Fuel Oil | 0,9 | 2,2 | 0,5 | 0,2 | |
| Hydrogen | 0,8 | 3,8 | 3,8 | 3,8 | 3,8 |
| Heavy Fuel Oil | 0,2 | 0,2 | 0,1 | 0,1 | 0,0 |
| Coke Oven Gas | 0,2 | 0,2 | 0,2 | 0,2 | 0,2 |
| Coke | 13,1 | 10,6 | 10,6 | 10,6 | 10,6 |
| Coal | 13,4 | 13,2 | 13,0 | 12,1 | 11,2 |
| Blast Furnace Gas | 1,3 | | | | |
| Gas | 58,8 | 58,4 | 59,5 | 59,6 | 44,8 |
| Electricity | 38,4 | 39,0 | 38,3 | 39,0 | 52,1 |

# High RES Central scenario - $CO_2$ emissions power sector

- Stronger decrease of -76% in NW-EU $CO_2$ emissions of the power sector from 2020 to 2030
  - 2030: 76 Mton (vs. 119 Mton in 'Current renewable pathway')
- Belgian emissions peak in 2026
  - Nuclear closure, higher gas based production, but lower than in 'Current renewable pathway'
  - $CO_2$ emissions increase by 2,7 Mton, or 17% from 2020 to 2026
- Belgian emissions strongly decrease from 2020 to 2030
  - By 6,3 Mton
  - With 66% renewable generation (48,7 TWh) compared to total Belgian generation
  - With double net import of 19,5 TWh compared to 'Current renewable pathway'

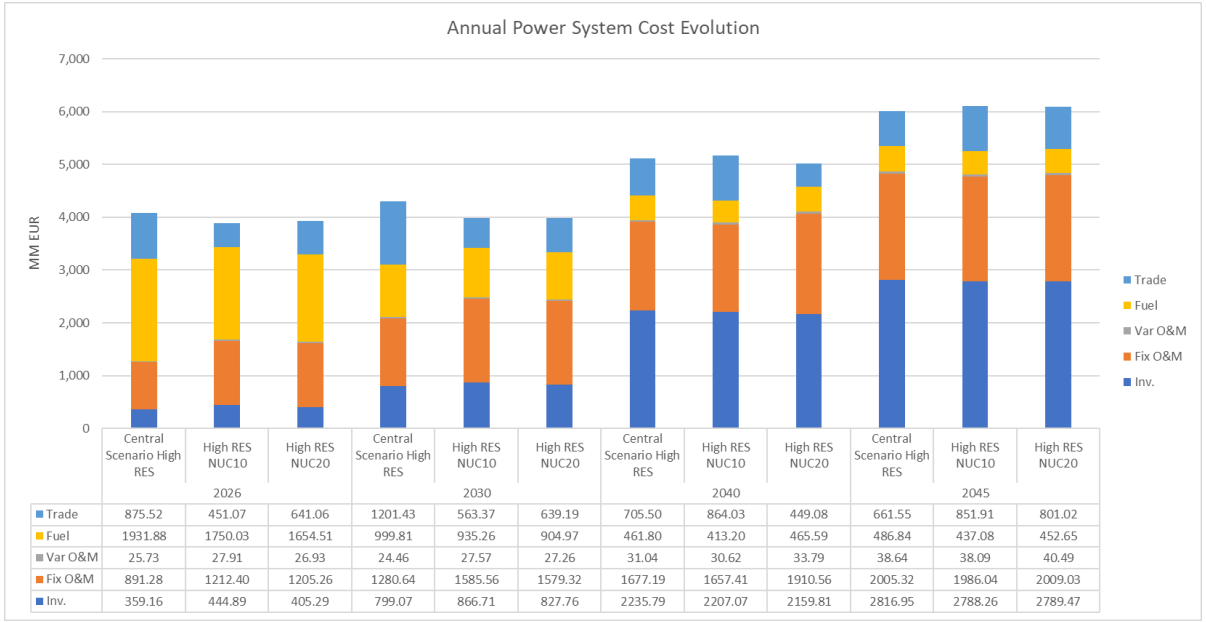


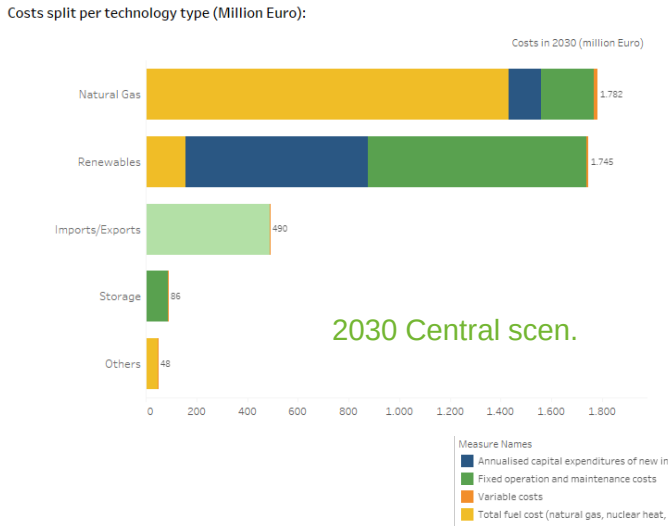

| | Central Scenario 2020 | Central Scenario High RES 2020 | Central Scenario 2026 | Central Scenario High RES 2026 | Central Scenario 2030 | Central Scenario High RES 2030 | Central Scenario 2040 | Central Scenario High RES 2040 | Central Scenario 2045 | Central Scenario High RES 2045 |
|---|---|---|---|---|---|---|---|---|---|---|
| Power (Non-ETS) | 768 | 768 | 759 | 759 | 761 | 760 | 844 | 844 | 883 | 882 |
| Power (ETS) | 15073 | 15063 | 20683 | 17807 | 14086 | 8757 | 5678 | 3514 | 5060 | 3548 |

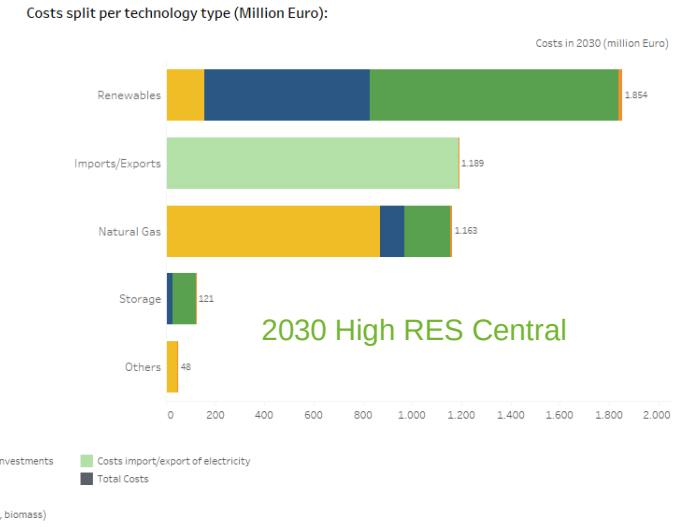
# High RES scenarios - Annual electricity supply cost (excluding $CO_2$ price)

- Comparison of costs of the High RES scenarios with the 'Current renewable pathway' is not straightforward
  - Cost assumptions of PV and battery storage lifetime is different leading to different annualized costs
  - But clear shift from highest costs for 'Natural gas based' production in Central scenario to highest costs for 'Renewable production' in High RES scenario in 2030
- Fuel cost (gas price) – import/export: most variable and leading parameters in cost evolution
- Nuclear extension → impacts gas based generation and import/export
  - 2030 High RES Nuclear extension: 327 M€ lower compared to *High RES* Central scen.
    - Import – fuel cost ↓
    - Fixed O&M (+ investments) ↑
- Investment cost of distribution grid upgrades from 2035 onwards
  - 2035: 65 - 92 M€/y depending on scenario
  - 2040: 321 – 340 M€/y depending on scenario
  - 2045: 477 M€/y in all scenarios




| | Central Scenario High RES | High RES NUC10 | High RES NUC20 | Central Scenario High RES | High RES NUC10 | High RES NUC20 | Central Scenario High RES | High RES NUC10 | High RES NUC20 | Central Scenario High RES | High RES NUC10 | High RES NUC20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2026 | | | 2030 | | | 2040 | | | 2045 | | |
| Trade | 875.52 | 451.07 | 641.06 | 1201.43 | 563.37 | 639.19 | 705.50 | 864.03 | 449.08 | 661.55 | 851.91 | 801.02 |
| Fuel | 1931.88 | 1750.03 | 1654.51 | 999.81 | 935.26 | 904.97 | 461.80 | 413.20 | 465.59 | 486.84 | 437.08 | 452.65 |
| Var O&M | 25.73 | 27.91 | 26.93 | 24.46 | 27.57 | 27.26 | 31.04 | 30.62 | 33.79 | 38.64 | 38.09 | 40.49 |
| Fix O&M | 891.28 | 1212.40 | 1205.26 | 1280.64 | 1585.56 | 1579.32 | 1677.19 | 1657.41 | 1910.56 | 2005.32 | 1986.04 | 2009.03 |
| Inv. | 359.16 | 444.89 | 405.29 | 799.07 | 866.71 | 827.76 | 2235.79 | 2207.07 | 2159.81 | 2816.95 | 2788.26 | 2789.47 |

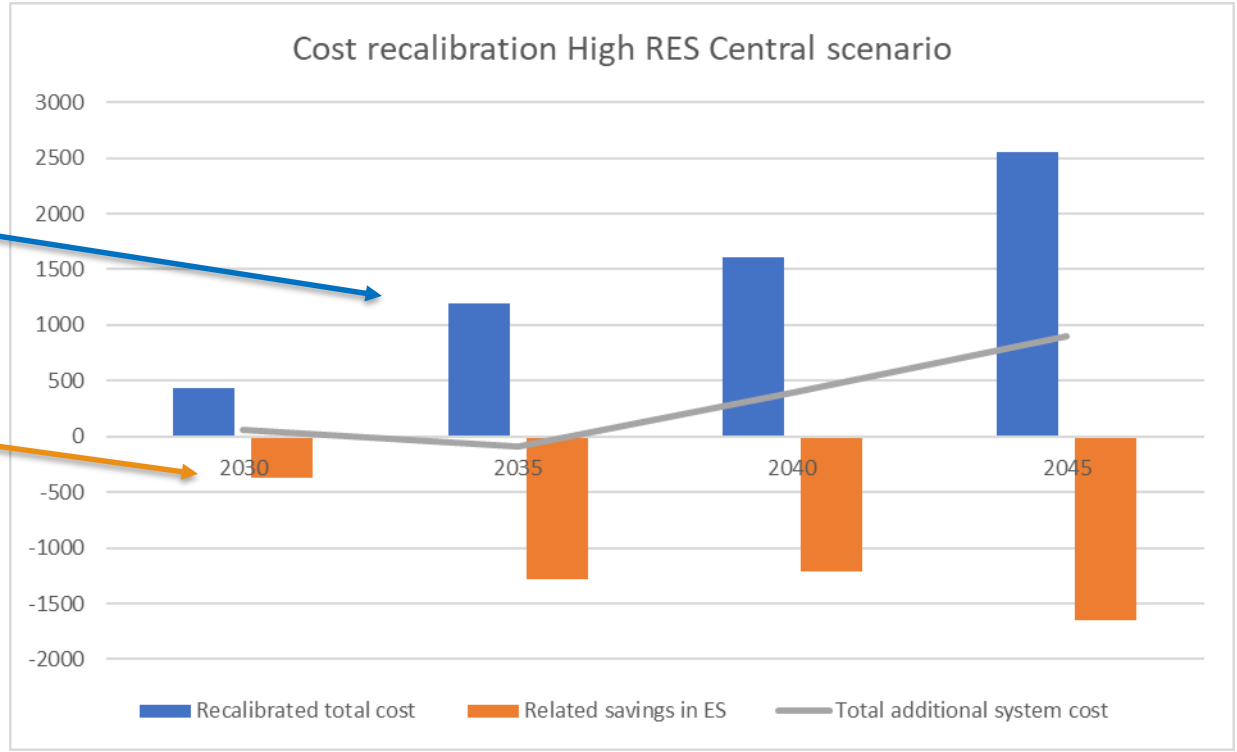


# High RES scenarios - Annual electricity supply cost (excluding $CO_2$ price)

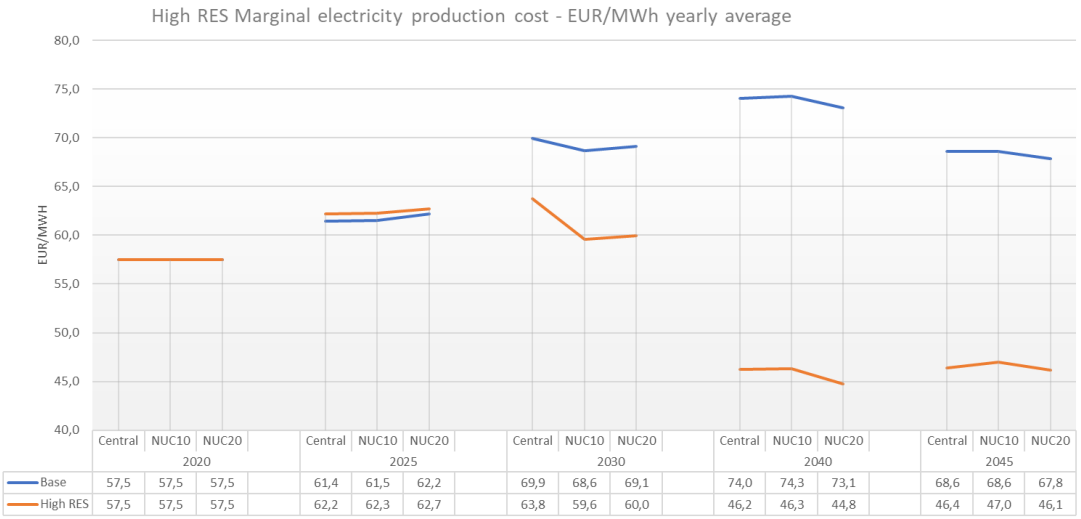
What if cost of PV and batteries would not decrease to the level assumed in the High RES ambitions pathway?

- Recalibrate the result of the 'High RES Central scenario' to the higher cost assumptions for PV and batteries of the 'Current RES ambitions'
- Higher electricity generation of High RES scenarios creates benefits/cost savings → bigger shift from fossil fuels to electricity in end-use sectors
- Result (grey line)
  - Recalibrated cost:
    - 2030 → 433 M€ higher
    - 2040 → 1622 M€ higher
  - Benefits compensate 2/3th of the higher costs, leading to 'Total additional power system cost':
    - 2030 → 64 M€ (1,5 % higher than presented Annual electricity supply cost)
    - 2040 → 396 M€

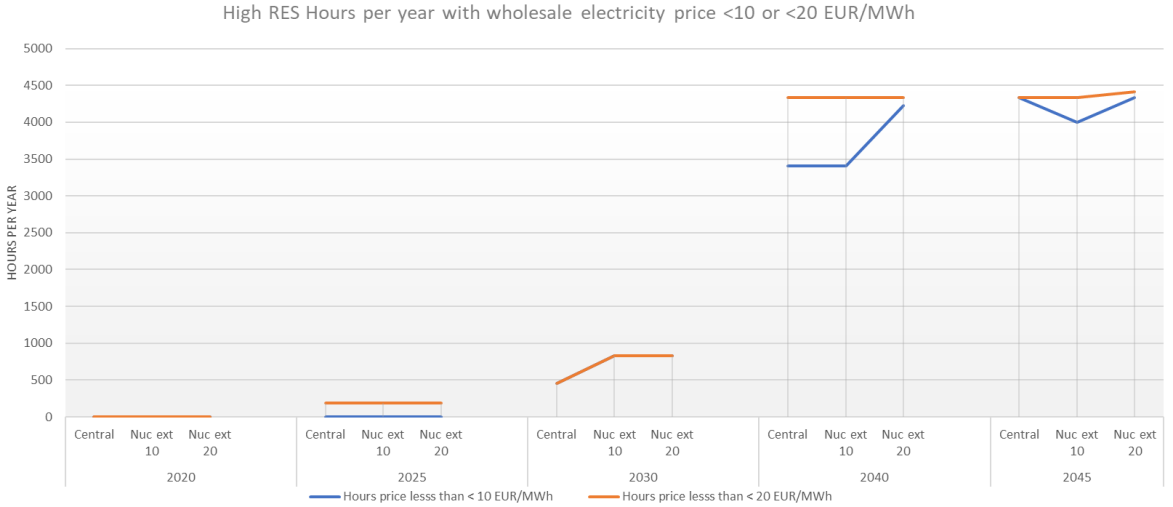


# Marginal electricity production cost – wholesale price

- Nuclear extension has a larger impact on the wholesale price of electricity in Belgium in the High RES scenarios
  - Wholesale price determined by gas units and gas price
  - 2030:
    - High RES scenarios are well below Current renewable ambition scenarios: 6,1 – 9,1 €/MWh lower
  - 2040:
    - High RES scenarios difference with Base scenarios increases to almost 30 €/MWh
- Number of hours per year with low wholesale price, <10 or <20 EUR/MWh
  - 2030, <10 EUR/MWh: 800 h/y in nuclear extension vs. 450 h/y in High RES central scenario
  - Sharp increase from 2040 onwards, 3400 h/y with wholesale price <10 EUR/MWh and 4300 h/y in 20y nuclear extension scenario




| | Central | NUC10 | NUC20 | Central | NUC10 | NUC20 | Central | NUC10 | NUC20 | Central | NUC10 | NUC20 | Central | NUC10 | NUC20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2020 | | | 2025 | | | 2030 | | | 2040 | | | 2045 | | |
| Base | 57,5 | 57,5 | 57,5 | 61,4 | 61,5 | 62,2 | 69,9 | 68,6 | 69,1 | 74,0 | 74,3 | 73,1 | 68,6 | 68,6 | 67,8 |
| High RES | 57,5 | 57,5 | 57,5 | 62,2 | 62,3 | 62,7 | 63,8 | 59,6 | 60,0 | 46,2 | 46,3 | 44,8 | 46,4 | 47,0 | 46,1 |



# Annex

## Current renewable ambition pathway

# Technology assumptions – cost, efficiency, availability

| | Technology | Efficiency (%) | Investment Cost (€$_{2019}$/kW) | | | | Fixed O&M (€$_{2019}$/kW) | | | | Average Availability /Year (%) | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2016 | 2020 | 2030 | 2050 | 2016 | 2020 | 2030 | 2050 | | |
| Natural Gas | Combined Cycle Steam Turbine | 62% from 2020 onwards | 855 | 600 | 600 | 600 | 20 | 20 | 20 | 20 | | Gas Turbine World, 2019 handbook for CAPEX from 2020, average FOM from ETRI, ASSET (cf. Elia 2019) |
| | OCGT Peak device advanced | 42% | 586 | 400 | 400 | 400 | 10 | 10 | 10 | 10 | | Low CAPEX and average FOM from ETRI, ASSET (cf. Elia 2019) |
| Nuclear | Nuclear Existing | 33% | N/A | N/A | N/A | N/A | 140 | 140 | / | / | 80%* | Engie (2020) |
| | Nuclear Extension by 10 years | 33% | N/A | 500 | 500 | / | / | 170 | 170 | / | 80%* | Engie (2020) |
| | Nuclear Extension by 20 years | 33% | N/A | 650 | 650 | / | / | 170 | 170 | / | 80%* | Engie (2020) |
| Biomass | Central Biomass Plant | 39% | 2000 | 2000 | 2000 | 2000 | 80 | 80 | 80 | 80 | | JRC (2013) |

| | CAPEX (€/kW) | | | | OPEX - fixom (€/kW/year) | | | | Availability (full load) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [€2019] | 2016 | 2020 | 2030 | 2050 | 2016 | 2020 | 2030 | 2050 | 2016 | 2020 | 2030 | 2050 |
| Onshore wind | 1400 | 1340 | 965 | 737 | 47 | 47 | 42,5 | 37,5 | 22% | 30% | 33% | 33% |
| Off-shore wind | | | | | | | | | | | | |
| <2,2 GW | 2000 | 2000 | 1750 | 1500 | 80 | 80 | 65 | 50 | 40% | 40% | 40% | 45% |
| >2,2GW (+500€/kW) | n/a | 2500 | 2250 | 2000 | 80 | 80 | 65 | 50 | n/a | 40% | 40% | 45% |
| >4,6 GW (+1000€/kW) | n/a | n/a | n/a | 3000 From 2040 | 80 | 80 | 65 | 50 | n/a | 40% | 40% | 45% |
| Solar PV - residential | 1400 | 1080 | 600 | 360 | 25 | 25 | 25 | 25 | 12% | 12% | 12% | 12% |
| Solar PV - commercial | 1260 | 972 | 540 | 324 | 23 | 20 | 17 | 15 | 12% | 12% | 12% | 12% |

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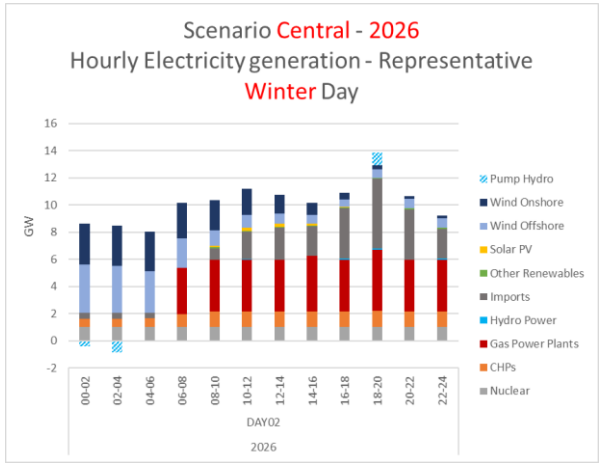
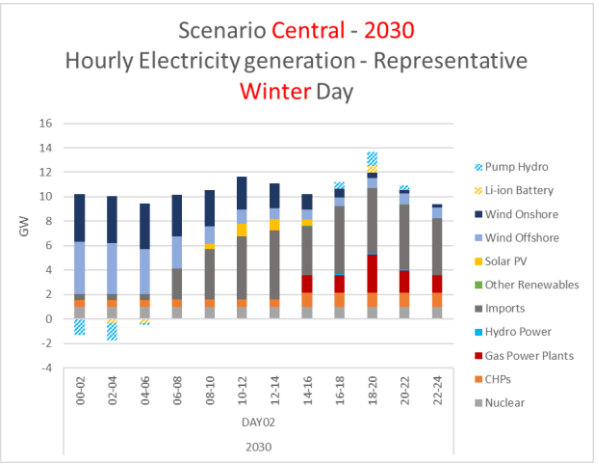
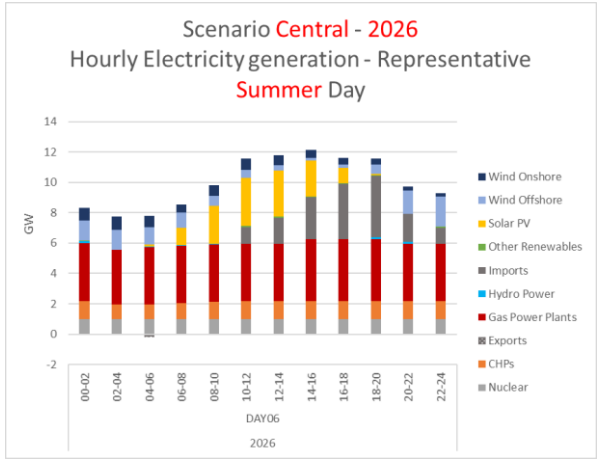
# Central scenario – Cross border evolution - Import/Export

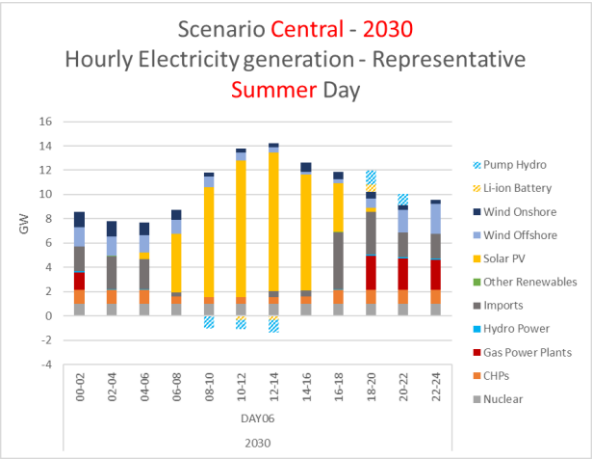
- Zoom in on ‘Representative winter day 2026-2030’
  - Winter day with high wind speed and low sun
  - 2026: Production strongly based on wind and gas
  - 2030: Important import in off-peak period, additional gas based production during evening peak




- Zoom in on ‘Representative summer day 2026-2030’
  - Summer day with low wind speed and high sun
  - 2025: Important gas based production
  - 2030: High PV generation, pumped hydro and local battery storage during day and discharge at evening peak, import at peak

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# Investments in renewables - NW-Europe

- Annualised investments in renewables in Belgian power system amount to ≈ 0,7 bEUR by 2030 in all scenarios
- Estimated annual investment costs in wind and solar in DE, UK, FR, NL
  - Translated the assumed TYNDP scenario to annualized investment costs using same renewable price assumptions
  - 34,4 bEUR  from 2021-2025
  - 23,5 bEUR average from 2026-2040