STUDY REPORT

Adequacy and flexibility study 2026-2036

Assumptions for the assessment of short-term flexibility

FOR CONSULTATION

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Contents

Assumptions for the assessment of short-term flexibility

This appendix details the assumptions regarding the assessment of short-term flexibility. This section should be read along with the flexibility characteristics as specified in the 'Assumptions' workbook of this study.

1. Prediction data

Predictions made about the total load and renewable generation are based on the results of forecasting tools which are published on a real-time basis on Elia's website. Although the flexibility needs of the system are driven by the predictions and operational decisions of market players, this forecast data is assumed to be representative of the tools which are used by market players.

Time series for the estimated **real-time total load, real-time onshore/offshore wind and solar power generation as well as the other distributed generation** are based on measurements, monitoring and upscaling by Elia. The corresponding time series of forecasted values (day-ahead, intraday and last forecast) are obtained from external service providers. Note that a correction is made to the forecast error when Elia activates decremental bids on these units. In order to take a representative dataset into account, two subsequent full years (2023 and 2024) are selected.

Total load, real-time wind and solar power generation as well as the other distributed generation forecasts are corrected with **forecast improvements** towards 2036. An average cumulative improvement factor of 1% per year is taken into consideration between 2023-24 and 2036. This means that the forecast error is corrected to 99.00% of its value towards 2025, 98.01% for 2026 by means of a factor $(1 – 0.01)^y$ (in which 'y' is the year for which the forecast errors are calculated). This results in the original forecast errors from 2023-24 being reduced to 88.6% of their original value in 2036. Besides this yearly improvement factor, some improvement in the prediction of extreme weather conditions might be expected. Furthermore, the integration of new technologies such as EVs, HPs and other decentralised capacity are expected to result in new patterns which increase the complexity of forecasting algorithms.

Based on the results of the modelling of future offshore wind time series towards 2030 by the Technical University of Denmark (DTU) in the framework of the study on the Princess Elisabeth Zone, it was found that the forecast errors of the 5.8 GW fleet only amount up to 90% of the current 2.3 GW fleet. This correction made to forecasting accuracy is attributed to increasing geographical dispersion when accounting the wind power installed on the Princess Elisabeth Zone, which further smooths out prediction errors. This correction factor is therefore applied on the capacity of the Princess Elisabeth Zone.

2. Forced outage characteristics

The forced outage probability of power plants and HVDC interconnectors is based on the historic amount of forced outages per year and is used to determine the forced outage risks accounted for in the flexibility needs. The methodology to determine the amount of forced outages per year is consistent with the forced outage rate and forced outage duration used in the adequacy assessment: the parameter is determined per technology type based on the historical records of power plant outages and HVDC interconnector outages.

No forced outages for renewable generation, decentralised 'must run' generation (e.g. combined heat and power) or demand side management are accounted for. Demand side management volumes are typically based on aggregation and it is assumed that the forced outage probability is taken into account when determining the available capacity. The forced outages of renewable generation and decentralised 'must run' generation units are implicitly taken into account in the prediction and estimated generation profiles.

3. Technology characteristics

The technical characteristics concerning flexibility are based on a literature review, Elia's expertise and feedback received from stakeholders during the previous consultations held on input data. A detailed overview of the technical characteristics of each technology can be found in Section 4.4 in the workbook with input data. An overview of this is included in Figure 1. The upward (downward) arrows depicted in the figure correspond with the upward (downward) direction in which the flexibility can be delivered. When the arrow is depicted in orange, the flexibility is not included in the calculations and the results due to uncertainty (e.g. as with nuclear generation units, where the flexibility depends on several technical constraints), but can be considered as additional flexibility which might be available under exceptional conditions.

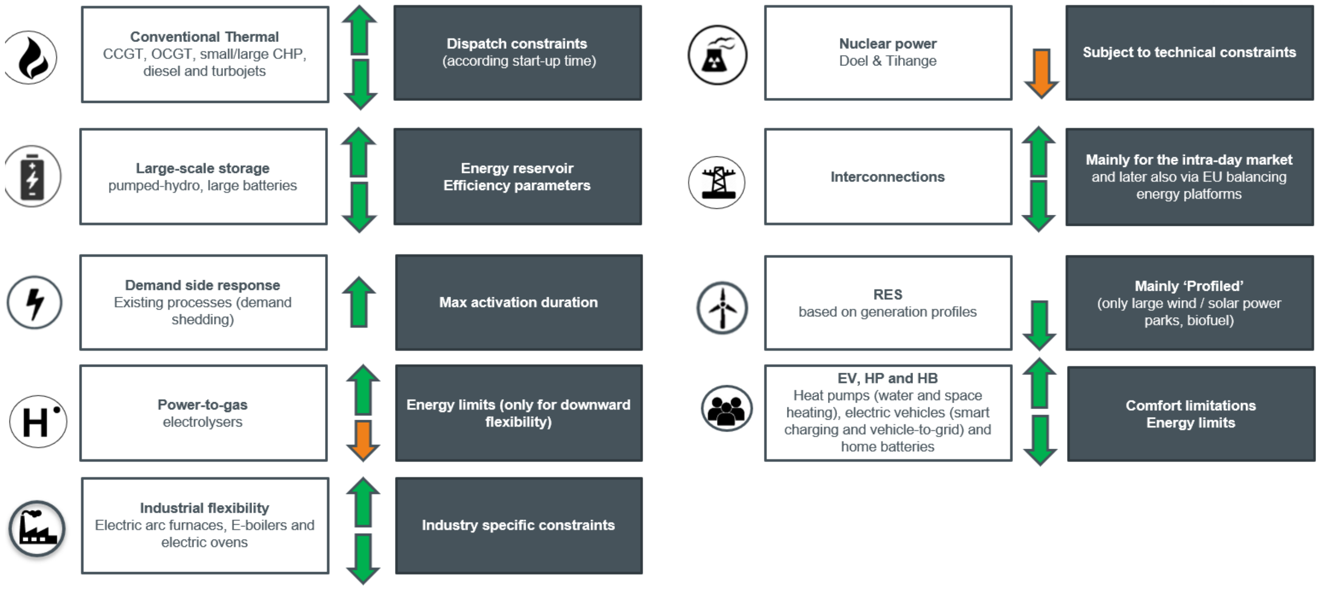

Figure 1: Summary of technological capabilities concerning flexibility.

Firstly, the ability to provide flexibility is determined by the **operational characteristics** (minimum up/down time; hot/warm/cold startup time; transition time from hot to warm/warm to cold; minimum stable power; rated power; and the ramp rate). In general, these constraints are particularly relevant for thermal power plants.

Secondly, where relevant, an **energy limit** is taken into account to represent the maximum duration a technology can be used to provide flexibility at its rated power. Although this is in general only relevant for non-thermal units (storage, demand side response), it may also apply to combined heat and power.

Thirdly, some particular technology assumptions are used to limit, where necessary, the **maximum flexibility which can be taken into account for each** type of flexibility needs considered in this study: ramping flexibility (able to be activated within minutes); fast flexibility (able to be activated within 15 minutes); and slow flexibility (able to be activated within 5 hours). In general, this constraint is based on the difference between the scheduled output of the adequacy simulations and the maximum rated power / minimum stable power of the technology unit.

- **Thermal generation**

Nuclear power units have been shown to provide flexibility, but this flexibility is subject to several technical limitations; for example, only some units are flexible and the flexibility of these units is limited in power, duration and frequency and depends on technical constraints such as the position in the fuel cycle. This makes it difficult to quantify the flexibility in a structural way and these units are therefore considered as non-flexible in the calculations. However, one can indeed assume that when assessing the results of the flexibility means, it is not unlikely that additional downward flexibility could be provided by the nuclear units.

Conventional thermal units are considered flexible and can deliver each type of flexibility when dispatched. The main constraint stems from the difference between the day-ahead schedule and their minimum stable power (downward flexibility) and the difference between the day-ahead schedule and the rated power (upward flexibility). However, most units require a startup time and cannot deliver fast or ramping flexibility (i.e. old, recent and new CCGT) when not already dispatched. Other types such as new and existing OCGT, turbojets and diesel generators can deliver fast upward flexibility from standstill due to their fast startup times. The ramping flexibility is only provided by units which are effectively dispatched and is limited by the maximum ramp rate of the unit.

Combined heat and power (CHP) units are considered as two different types, i.e. 'individually modelled' and 'profiled'. The former type, namely individually modelled CHPs, can be based on CCGT and OCGT units, while the latter type consists of mostly small CHP units that follow pre-defined generation profiles and are considered 'must run'. Both types can provide upwards and downwards flexibility. An additional constraints for CHP's is that have an energy limit (considering that other processes cannot last a long time without steam). However, in reality various applications exist for CHPs.

- **Renewable generation**

When assessing variable renewable generation, the main contributor in Belgium today is **wind power.** It is generally considered to be able to provide downward flexibility (capabilities for upward flexibility are considered to be limited as their generation is driven by weather conditions) if they are equipped with appropriate communication and control capabilities. This is generally the case for larger installations and it falls within the obligation of units larger than 25 MW to offer available downward flexibility to Elia. It is assumed that these technologies will mainly provide fast and slow flexibility, although some units may also provide ramping flexibility if properly equipped.

The potential flexibility of wind power is capped to 65% of the scheduled output for offshore power and 90% for onshore power, based on the day-ahead forecast error (the capacity that is considered to be available in real time at least 99.0% of the time following a certain predicted capacity). Note also that large **solar power** installations, i.e. larger than 25 MW, are assumed to contribute to downward flexibility. For this reason, this capacity is accounted for, similar to onshore wind power, in fast and slow downward flexibility, by taking into account a cap set to 90% of the scheduled output.

While no further limits are assumed for fast and slow flexibility, it is assumed that part of the offshore wind power installations can provide up to 400 MW (18% of the current park) and up to 925 MW (through the Princess Elisabeth Zone) of ramping flexibility. This value, representing 21% of the initially foreseen 4.4 GW, is extrapolated towards the current ambitions of increasing offshore wind power up to 5.8 GW. Furthermore, no ramping flexibility for onshore wind and solar power is assumed. For fast and slow flexibility the following shares are taken into account:

- The share of controllable offshore wind parks is assumed to be 100%.
- The share of controllable onshore wind parks is assumed to be 10%.
- The share of controllable solar parks is assumed to be 2%.

Following existing uncertainty on the share of smaller units to react on explicit activation signals of Elia or on market prices, sensitivities will be applied in the study for different participation rates.

In addition to variable renewable generation, biofuel units are assumed to provide all types of downward flexibility (assuming they are always scheduled at maximum power following generation support mechanisms). To provide downward flexibility, they are subject to the same type of technical constraints as conventional thermal units.

- **Technologies with energy limits**

Large batteries and **pumped hydro storage** are the most relevant storage technologies for Belgium. Large-scale batteries can deliver all types of flexibility in both directions without ramp rate limitations. This even means a potential inversion from full offtake to full injection. However, they do face an energy limitation depending on their energy storage capacity. In contrast, while pumps and turbines in pumped-storage units can also deliver ramping flexibility, this is only assumed to be the case when the pump or turbine is dispatched. The energy limit of pumped hydro storage is assumed to be 4.5 hours at full capacity.

Electrolysers (power-to-gas technologies) can in principle provide all types of flexibility if properly equipped for it. However, most value is expected to be held in long-term storage (e.g. seasonal) rather than in the intra-day and balancing time frames. For this reason, these units are only accounted as upward fast and slow flexibility during periods when the assets are scheduled for gasification (and electricity offtake can be reduced by shutting down the process). In such cases, it is assumed that fast and slow upward flexibility increases can be delivered by reducing offtake without any technical constraints.

Demand side response consists of existing processes. The existing DSR can deliver ramping, fast and slow flexibility, typically only in an upward direction (reduction in consumption or demand shedding). The reaction times depend on the application. For existing processes, it is assumed that a total share of around 100%, 40% and 10% of installed market response can participate in slow, fast and ramping flexibility respectively. The energy limit of this category is related to 5 groups (no limit; 1 hour; 2 hours; 4 hours; and 8 hours).

Industrial flexibility consists of the demand side response of new large-scale load with industrial players. Of the modelled categories in adequacy simulations, electric arc furnaces (EAF) primarily for steelmaking, electric boilers and electric ovens are considered for short term flexibility. Of the electric boilers and electric ovens considered flexible, 100% can provide ramping, fast and slow flexibility. These two categories can provide both up- and downward flexibility as they are assumed flexible through modulation of a gas back-up alternative. Of the electric arc furnaces (EAF), the part considered flexible for adequacy simulations, can only provide slow up- and downward flexibility by shifting its consumption as it needs to be informed at least several hours in advance to adapt the production process.

Electric vehicles (EVs), heat pumps (HPs) and Home batteries (HB) are assumed to deliver flexibility through electrification, digitalisation and market design reforms. Home batteries are assumed to face an energy limitation of 2 hours at full capacity. For electric vehicles (EVs) and heat pumps (HPs) the energy limitation is based on energy usage needs, which change from day to day based on user behaviour and external factors such as temperature. Apart from an energy constraint, a power profile limit is modelled for EVs and HPs to limit the impact on end consumer comfort.

Accounting for the mentioned constraints, flexibility is first optimised in adequacy simulations. Closer to real-time, EVs, HPs and HBs provide the remaining available short-term flexibility. Note that the share of short-term flexibility is set to 10% of the market flexible assets in the adequacy simulations due to the fact that flexibility closer to real-time is assumed to be lower. Towards 2036, this percentage share is assumed to increase to 40%.

Electric vehicles and heat pumps are assumed to provide both upwards- (temporarily reducing consumption) and downwards flexibility (temporarily increasing consumption) through smart charging or smart heating. Additionally, home batteries and EVs with bi-directional charging capabilities can change offtake and injection both in an upwards and downwards direction. All controllable EV, HP and HB assets are assumed to deliver ramping, fast and slow flexibility.

- **Cross-border flexibility**

Cross-border flexibility is assumed to be constrained by the **remaining available interconnection capacity (ATC) after day-ahead trading**. This is estimated based on the hourly import/export schedule following the adequacy simulations, which are compared with a reference representing the maximum import/export schedules. Note that to simplify the process, this maximum is fixed at 7,500 MW (import) and 8,000 MW (export) for the investigated period between 2026 and 2036, but that in reality, these values can vary on hourly basis.

The available cross-border flexibility also depends on the **liquidity in cross-border intra-day and balancing markets**. It is possible that not all required flexibility is available in other regions, since this flexibility might also be constrained, or already used to deal with unforeseen variations in these countries. For slow flexibility, a liquid intra-day market is assumed and full capacity is taken into account, unless prices below €0/MWh and above €300 /MWh indicate a regional excess or shortage (respectively), and limit the available capacity in intra-day and the balancing time frame.

For fast and ramping flexibility, cross-border flexibility through FRR reserve sharing and imbalance netting (iGCC) is in place. From 2024 (aFRR) and 2025 (mFRR) onwards, the European balancing energy platforms facilitate cross-border balancing energy exchange for aFRR and mFRR. Unfortunately, no estimations or projections are available regarding the expected liquidity on these balancing energy platforms and TSOs depend on a return on experience after implementation. This means that a current ‘firm’ reserve sharing of 250 MW (upward fast flexibility) and 350 MW (downward fast flexibility), and 0 MW of iGCC (ramping flexibility) are the starting points for the analyses. These are complemented with sensitivities.

Note that it is far from certain that the current cross-border capacities considered as ‘firm’ will increase, since optimising the use of the grid during day-ahead and intra-day may leave less capacity available for the balancing time.