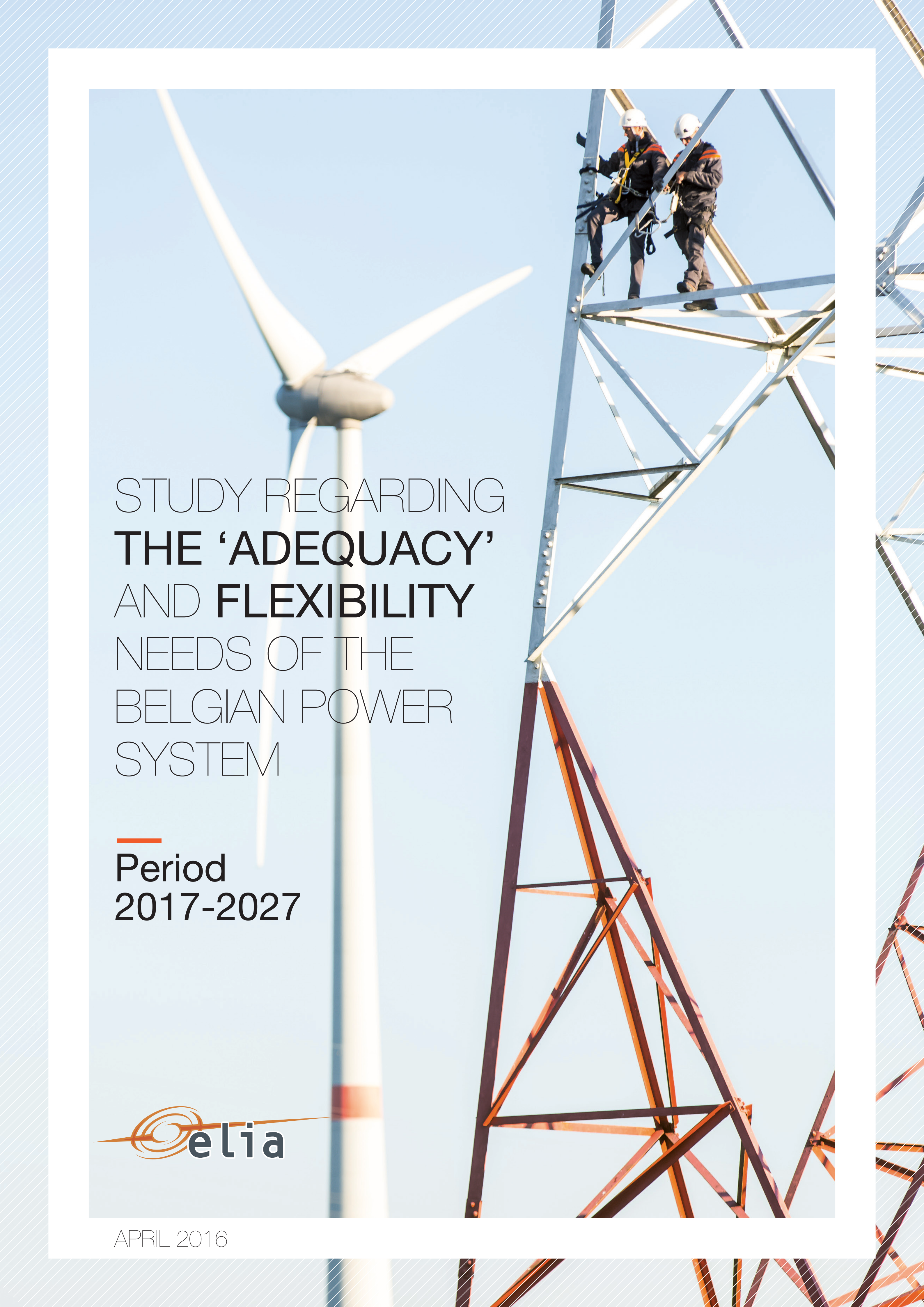

STUDY REGARDING **THE 'ADEQUACY'** AND **FLEXIBILITY** NEEDS OF THE BELGIAN POWER SYSTEM

Period 2017-2027

elia

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1 EXECUTIVE SUMMARY

This report summarises the conclusions of the study conducted by Elia at the request of the Belgian Federal Minister of Energy regarding two key aspects of the functioning of electricity-market in the run-up to 2027:

– the **'adequacy' needs of the power system:** this assessment aims to identify the volume of adjustable electrical power[1] Belgium needs in order to be adequate;

– **flexibility needs[2]:** this assessment aims to identify the quantity of flexible sources needed, in particular those required for the balancing needs of the transmission system operator (TSO), along with their characteristics.

The study is based on **current knowledge and planned developments** in terms of generation unites, climate targets and the economic situation. Any major change in the assumptions will require a re-evaluation of the results.

Elia would like to point out **that the conclusions of this report are inextricably linked with the initial assumptions** as indicated here. Elia cannot guarantee that these assumptions will actually materialise. In most cases, they relate to developments that do not fall within the direct field of competence of the grid operator.

1. The adjustable electrical power is the power which can be varied depending on the requirements, including all of the natural-gas unites.
2. Flexibility needs correspond to the portion of adjustable power needed to deal with the variability of power injections and offtakes (in particular the power generated by variable renewable energy sources) including the TSO's balancing reserves.

About the **'adequacy'** of the electricity system

The assessment reveals the national volume of adjustable power, known as the 'structural block', required to meet the current legal criteria concerning 'adequacy', i.e. the balance between generation and consumption. This 'structural block' can comprise various types of generation, storage and/or consumption.

For the interpretation of the results, the 'structural block' must be carefully defined, and the implications of this definition need to be set out in detail. The calculation of the 'structural block' is based on the principle that certain sources are regarded as present in a given scenario: nuclear capacity based on the timeframe set by law for the nuclear phase-out, renewable sources and cogeneration based on the developments in the pipeline for these technologies, the existing pumped-storage power plants, the management of existing demand in the market, and the possibility of importing energy based on its availability in Belgium's neighbouring countries. The sum of these various sources is deducted from total expected consumption. The difference that emerges between them forms by definition the volume of the 'structural block'.

This definition has the following implications:

— All gas-fired power plants that are already installed and those that may be built in Belgium (mostly of the closed-cycle gas turbine (CCGT) and open-cycle gas turbine (OCGT) types), any additional pumped-storage power plants, additional demand or new storage capacity to be developed and interconnections on which no decision has taken so far are all considered to form part of the 'structural block'.

— The calculation gives an idea of the total capacity of the 'structural block', but not of the operating hours of the power plants making up this block, given that these, by dint of the very definition of the 'structural block', are ranked below all the other sources in the 'merit order'.

— The 'adequacy' model provides no information on the demand for power plants to supply any reserve or controlling power (balancing reserves).

— In the second phase, the results of the 'adequacy' model mentioned above will be complemented by assessments taking account of the economic 'merit order'. Assessing the flexibility requirements, both for market players and in terms of the operator's balancing reserves, makes up the third phase of the assessment.

— The assessment adopts a probabilistic approach, anticipating various potential future states, depending on the occurrence or absence of various factors (the unavailability of generation unites; the occurrence of certain climatic conditions, etc.). It also makes use of the possibility to exchange electrical energy with the neighbouring countries (imports/exports), depending on the economic conditions at that moment and based on a firm assumption regarding the maximum capacity that can be imported simultaneously by Belgium (6,500 MW starting from 2021). To this end, the assessment has a geographical scope of 19 European countries.

Applying the methodology described in Chapter 3 of the study, and based on assumptions established in Chapter 4, the results of the 'base case scenario' (without taking into account the flexibility needs) are as follows:

— In 2017, the capacity of the 'structural block' will be 2,500 MW, with the entire block being constituted on the basis of the existing resources.

— In 2021, the 'structural block' will have a capacity of 0 MW, following the commissioning of two new interconnections (NEMO and ALEGrO) accounting for 2 GW, the expansion of the offshore wind farms and 600 MW of capacity from new biomass-fired power plants.

— In 2023, the 'structural block' will have a capacity of 500 MW.

— In 2027, the 'structural block' will have a capacity of 4,000 MW, with the first 2,000 MW needed for from 500 to 2,000 hours on average during the year. The next tranche of 1,000 MW will be required for on average around 200 hours through the year, only being used during the winter, but this capacity will need to be activated at least once during the year. The remaining 1,000 MW will only be required for an average of some 15 hours per year and indeed should not necessarily be activated every year and, when this capacity is activated, this should only be for very limited periods in the course of the year.

If in 2027, the 'structural block' were only activated for periods of structural shortage, Belgium would import almost 50% of its national electricity consumption. The competitiveness of the 'structural block' compared with the neighbouring countries' production parks will determine Belgium's level of imports. These outcomes are sensitive to changes in the various parameters and assumptions, including:

— the increases in electricity consumption: a sharper rise (+0.6% per year) in demand would lead to a need for an additional 1,000 MW (a need which would increase the size of the 'structural block' by 2027);

— additional shutdowns of generation units in other countries, which would increase the size of the 'structural block' to an extra 4,000 MW in 2027, but operating for only a fairly small number of hours;

— extra storage or renewable-energy capacity or higher or lower market response; while these changes do not justify any modifications to the size of the 'structural block', they do affect its characteristics in terms of probability of activation or number of operating hours.

‘Adequacy’ assessment complemented by the **economic functioning of the market**

As indicated above, the ‘adequacy’ model has implications in terms of the total capacity of the ‘structural block’ and the length of time these units must be used for ‘adequacy’ reasons, but not in relation to the length of use resulting from the economic dispatching of the relevant units, given that the ‘adequacy’ model is based on the principle that the entire generation capacity of the ‘structural block’ comes after the ‘known sources’ in the ‘merit order’.

Therefore, in the second phase the yearly equivalent full-load hours of high-performance OCGT and CCGT units was calculated on the Belgian grid, in the context of an international ‘merit order’. It turns out that the results of these simulations vary very substantially depending on the assumptions adopted. The operating hours of a high-performance CCGT unit in 2027 varies from less than 2,000 hours in the ‘High RES’ scenario to almost 8,000 hours in the ‘Gas before Coal’ scenario.

In this economic dispatching model, the potential net revenues (the intramarginal return) of a CCGT power plant were also calculated in an ‘energy-only’ market as is familiar to us today, with market coupling. For the various 2027 scenarios, this amount varies between about €15/kW per year (‘base case’ scenario) through to €50/kW per year (scenario with annual growth in demand of 0.6%). These amounts are not enough to cover investment costs, at least according to the data of the European Union’s Joint Research Centre (JRC).

The previous observation leads to the consideration of two aspects:

1. The economic dispatching model starts out from the principle that all units of the ‘structural block’ participate in the ‘energy-only’ market. If some of them should be part of the strategic reserve, their activation will cause scarcity prices, currently coming to €3,000/MWh. Such spikes, if they occur for a few hours each year, will have a (very) positive impact on market revenues, and therefore also on the performance of the units in that market.
2. The market model does not take into account revenues of gas-fired power plants arising from the ancillary services, such as analysed in the third part of the study and summarised below.

Given the relatively high level of interconnection of the Belgian grid in 2027, estimated at 6.5 GW of import capacity, which corresponds to about 50% of peak demand, the economic functioning hours of gas-fired plants depend very much on their competitiveness at European level. This high level of interconnection is necessary because of the need to both ensure competitive prices on the national market and enable the large-scale integration of renewable energy sources.

European market integration has the objective (and, as such, the consequence) of ensuring that the ‘merit order’ is no longer determined at national but rather at European level due to market coupling. The implications are twofold:

— first, plants with a low ranking in the European ‘merit order’ will be rendered obsolete, in terms of operating time, by higher-performance units in neighbouring countries;

— second, efficient CCGT units will be used based on a European ‘merit order’. In practice, this means that due to interconnections a relatively efficient CCGT unit will operate for significantly longer. An illustration of this impact can be seen in the ‘Gas before Coal’ ‘merit order’ as mentioned above, under which an efficient Belgian CCGT unit acts almost in base-load mode in 2027, while Belgium should have cogeneration facilities and renewable energy sources totalling around 15 GW, with these taking priority in the market.

BALANCING RESERVES: TECHNICAL DESCRIPTION OF THE R1, R2 AND R3 RESERVES

In order to ensure a constant balance between electricity supply and demand, the grid operator holds and manages various reserves, namely the primary, secondary and tertiary reserves. The grid operator enters into contracts governing these reserves through tendering procedures, under the supervision of the regulator.

Traditionally, these reserves came from fossil-fuel-fired power plants in the Belgian control area. Now, following recent developments, renewable and decentralised generation, active demand management and international exchanges may also contribute to these reserves. However, the actual participation of these sources in these reserves is subject to compliance with the technical characteristics of the respective reserves. A brief description of these characteristics is given below.

PRIMARY RESERVE R1

(FCR - Frequency Containment Reserve)

This reserve is all about stabilising the frequency within a range between 49.8 and 50.2 Hertz. Given that a lack of generation capacity immediately causes a drop in frequency (and overproduction a rise in frequency), the primary reserve has to respond very quickly. This reserve is expected to increase generation capacity in less than 30 seconds in the event of a decrease in frequency (and conversely in the event of a rise in frequency). The volume of R1 is governed by international agreements. In the case of Elia, the future volume is estimated within the range from 80 to 100 MW upwards and downwards. Elia may acquire up to 70% of this volume outside Belgium. The required speed of the response means that R1 can only be supplied by already running machinery or by consumers able to adjust their consumption very quickly (for example, by means of electrolysis or cooling systems).

SECONDARY RESERVE R2

(aFRR - automatic Frequency Restoration Reserve)

This reserve has two aims:

1. reduce the frequency to 50 Hz so as to relieve the pressure on R1;
2. ensure that the constant physical import/export balance in a control area always corresponds to the import/export balance contractually agreed by the market players (Elia's control area consists of Belgium and part of Luxembourg).

Technically, R2 is the most complex type of reserve. Whereas a local measurement of the difference in frequency suffices to activate R1, the R2 setpoint signal is also based on ongoing measurements of the difference between physical flows and the contractually agreed exchanges. Elia calculates the setpoint signal every 10 seconds, which is then transmitted to all the power plants participating in R2.

Given its aims, this reserve (R2) is by its very nature associated with the control area. However, an international collaborative platform exists for R2 activations, namely International Grid Control Cooperation (IGCC), but this does not reduce the R2 control capacity needed within a given control area. Elia forecasts that the need for R2 will be between 140 and 175 MW during the period covered by this study, again upwards or downwards.

TERTIARY RESERVE R3

(mFRR – manual Frequency Restoration Reserve)

This reserve relieves the burden on R2 when the latter is saturated or is at risk of getting saturated, for example following the loss of a key generation unit. R3 is activated and controlled manually by Elia's dispatchers during a period ranging from a few minutes to a maximum of quarter of an hour.

This reserve (R3) can be supplied by various sources, for instance by generation unites that are running or not (in the latter case as long as the start-up time is short enough) or by various consumers on the distribution or transmission grids. Elia is anticipating a growing demand for R3, reaching between 1,065 and 1,600 MW for upwards adjustments, and between 825 and 1,000 MW for downwards adjustments in 2027. Given that the transmission capacity between the control areas is primarily reserved for commercial exchanges, it cannot be assumed that these needs will be met by Belgium's neighbours

Flexibility requirements that have to be met

As well as the 'adequacy' and the economic dispatching of the production park, the study also addresses the flexibility needs of the market and those for balancing purposes. This assessment is particularly necessary to determine the balancing reserves, i.e. the capacity Elia needs to ensure the balance of the power system at any given moment.

The chart on page 9 of the study gives a technical illustration of the various Elia balancing reserves.

During the period covered by this study, a number of factors will play a key role in the development of the need for balancing reserves in particular the extent to which Belgium's centralised generation units are required to provide these balancing reserves, namely the integration of **renewable energy**, the continuing development of the **intraday and balancing markets** in the context of the European network codes, the development of **active demand management** and **decentralised storage**, and finally **international cooperation** between grid operators with regard to the balancing reserves.

An increase in **renewable generation** will lead to an increase in the need for balancing reserves. However, this increase can be reduced through the ongoing development of the **intraday and balancing markets**. The intraday and balancing markets provide their players with mechanisms and facilitate exchanges, allowing them to maintain the balance of their portfolio at all times and, as the case may be, help to restore the general balance of the system. Elia will continue to focus on developing these markets in the years ahead.

Other factors are the anticipated strong development of **demand management** (targeted actions relating to 'demand side response') and the general demand elasticity (adjustment of consumption to temporary price levels) which is also expected to grow strongly, as well as the development of **decentralised storage** (batteries). These developments will contribute to the reserves and to the balancing services.

The **international cooperation** in the field of balancing reserves always depends on the availability of transmission capacity between control areas, since this capacity is primarily made available to the market players. This does not prevent considerable synergies being achieved in terms of energy efficiency. However, for the capacity required for control facilities, Elia must, as a default, work on the assumption that a substantial share of capacity to constitute the future balancing reserves will need to be available in the Belgian control area.

The results of this study in relation to reserves R1, R2 and R3 can be summed up as follows:

1. **R1 :** in view of the relatively low volume and the potential to develop R1 using demand management and decentralised generation units or batteries, and the possibility of acquiring an important share of R1 in an international environment, Elia works on the basic assumption that **R1 will have no structural impact on the composition of the centralised production park**. This does not mean that a substantial proportion of R1, in synergy with R2, will continue to be supplied by centralised generation units, in accordance with the results of periodic auctions that will be held in this regard.

2. Due to its technical characteristics, **R2** should be delivered by units that constitute the 'structural-block'. This has major implications for the centralised production park which needs to take into account the uncertain future of these power plants. Elia makes a distinction between two R2 scenarios:
   — An *'innovative R2 scenario'* involves the development of new R2 control services, and therefore a substantial impact on the need for CCGT power plants, which traditionally provide this service. This scenario reaffirms the development of 'aggregated R2' and the involvement of cogeneration in R2. The involvement of renewable energies in R2 may continue to grow if the economic obstacle formed by the high opportunity costs of lost green certificates is removed. This could generate considerable potential for large-scale biomass facilities. In this regard, a side effect of renewable energies' contribution to R2 should be pointed out. At first glance, this development appears to reduce their contribution to achieving the climate targets, since these renewable resources would not be used at full capacity. However, the overall impact on emissions would be positive, since if renewable energy sources were to play a major role in R2, this could lead to the gas-fired power plants being replaced if these are outside the 'merit order', but have to be declared 'must run' for the sake of supplying R2. Under this scenario, **two CCGT power plants would be sufficient for the Belgian market**.
   — In a *'usual R2 scenario'* with no significant breakthrough of the new R2 developments as mentioned in the previous scenario, the assessment highlights the **need to have four CCGT units in the market** to be able to buy these services in a competitive environment and if periods of maintenance and failures are taken into account.

   The periodic auctions organised by Elia for purchases of control power are in essence the capacity mechanism earmarked for this objective. However, while bearing in mind new technologies, the continuous availability of the CCGT units should be monitored at all times with a view to future R2 needs, and where necessary additional measures should be taken. This is in order to avoid a situation where the level of supply was too low to cover the R2 needs.

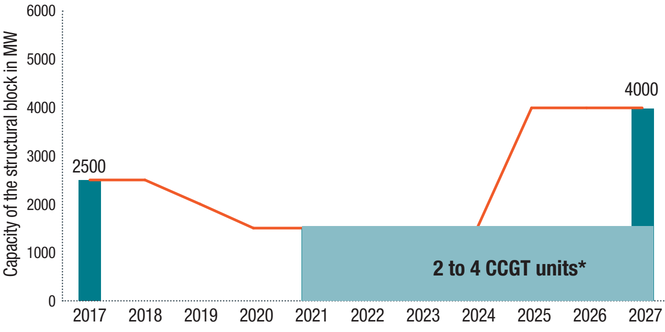
   The existing pumped-storage power plants can only participate in R2 for a few hours a day. If new plants of this type are built, it would be worth examining whether these units can be continuously deployed, as a result of new technological developments.
3. Finally, in the case of **R3**, Elia expects that in future it will be possible to acquire a substantial proportion of this type of reserve (650 MW) outside the 'structural block', by means of demand management and decentralised units. Otherwise, repowering from old-style CCGT power plants to OCGT plants is a positive development.

Pooling of the results:

The conclusions of the 'adequacy' assessment show that the 'structural block' will not be needed between 2021 and the year when the first nuclear reactors in the Belgian production park will be phased out (2023).

However, the flexibility assessment reveals that a number of CCGT units might be necessary in 2021 and 2023 to cover the need for secondary control (aFRR). If the capacity mechanism currently in place does not guarantee this coverage, one or more targeted solutions should be envisaged to ensure that the TSO is able to fulfil its mission of maintaining the balance of the Belgian control area over the timeframes mentioned above.

CAPACITY OF 'THE STRUCTURAL BLOCK' RESULTING FROM THE 'ADEQUACY' AND FLEXIBILITY ASSESSMENT FOR THE 'BASE CASE' SCENARIO



* Depending in particular on the technological maturity of the other flexibility sources and on the current balancing mechanism.

Potential measures to respond to adequacy problems

As regards potential measures to take to respond to the ‘adequacy’ problems, the following remarks can be made:

— The assessments performed do not point to significant ‘adequacy’ problems in **the first few years of the period investigated** (2017-2022): given the current composition of the production park, the current strategic reserve mechanism should be sufficient to cover the defined ‘adequacy’ needs without the development of an additional or alternative structural mechanism.

— **For the subsequent years of the period investigated** (2023-2027): a clear ‘adequacy’ issue emerges, hence the increase in the ‘structural block’ up to 4,000 MW in 2027. In addition, this result is particularly sensitive to the situation in the other countries considered here: for example, in a scenario of more substantial decommissioning of generation units in Belgium’s neighbouring countries, the Belgian ‘structural block’ could even reach a capacity of 8,000 MW. Furthermore, by 2027 a large proportion of the ‘structural block’ will only be operating for a very limited number of hours.

Therefore, it would be worth considering appropriate mechanisms to ensure the availability of such resources by 2025, given that there is no guarantee that the current mechanisms (the ‘energy-only’ market complemented by the strategic-reserve mechanism) will be sufficient in order to ensure that market players will make the necessary investments to cover all the anticipated needs.

The size of the problem, its characteristics and the main parameters affecting it are described in this study. The potential solutions should be considered while keeping in mind these factors and in consultation with all relevant stakeholders (market players and the public and regulatory authorities).

In particular, Belgium’s position in the European market must be taken into account.

As part of these deliberations on future mechanisms, Elia suggests the following non-exhaustive list of options that might be worth exploring:

— Given Belgium’s high level of interconnection with neighbouring countries and its central position in Europe, any deliberations on whether to eventually introduce a potential capacity remuneration mechanism should preferably be examined (and, as the case may be, implemented) in a coordinated/harmonised way with these neighbouring countries and not in an isolated manner.

— Targeted improvements to the current strategic-reserve mechanism might also provide answers to the problems if there is insufficient market response. These improvements relate to:
  - first, the irreversible nature of including generation units in the strategic reserve, with a view to reducing the ‘slippery slope’ effect and the uncertainty regarding the future developments of the generation units in the market, which hinders new investments;
  - second, considering new production units as part of the strategic reserve, with a view to tackling the shortage of investments by the market players; and
  - last but not least, introducing a market stabilisation mechanism, which makes the strategic-reserve capacity available to market players under certain conditions to mitigate the impact of multiple price spikes on the functioning of the market operation and the Belgian economy.

Discussions with the aim of taking decisions in this regard should not be started overhastily but nevertheless should start as soon as possible, as it is absolutely essential that market players have a clear and stable framework so that they can make appropriate, well-informed decisions and anticipate the planned shifts in the Belgian energy mix. Elia is at the authorities’ disposal to participate in these deliberations and provide its input.

Disclaimer

This study should be considered a non-binding response to the request of the Belgian Federal Minister of Energy Ms Marie-Christine Marghem, as received by Elia on 21 December 2015. This document does not weigh the various options described in this report against the Belgian and/or European legal framework, which will need to be the subject of a further assessment based on the option(s) chosen. Accordingly, Elia accepts no legal responsibility for their appropriateness. Instead, it has drafted this contribution in its role as a market facilitator.

FINDINGS REGARDING THE BELGIAN SYSTEM IN A EUROPEAN CONTEXT:

Among the findings of this study, certain trends can be discerned in future developments:

— There will be a huge, sharp decrease in nuclear capacity, with a timetable for a nuclear phase-out defined in the German and Belgian legislation and a reduction in the use of nuclear power planned in France, based on a volume that still needs to be precisely determined.

— Under the influence of current climate policy, the capacity of the coal- and lignite-fired power plants will decrease considerably in all the countries in the CWE control area.

— While there will be clear overall growth in renewable sources, given their variability, this increase will not completely offset the capacity losses mentioned above, with a view to ensuring security of supply. Geographical disparities, in terms of area, population density, length of the coastline and latitude, explain the differences in renewable potential between countries.

— Active demand management and storage will also grow substantially, based on the finding that the 'adequacy' problem will be an issue for an ever-decreasing number of hours.

— A new range of CCGT gas-fired power plants will be constructed based on the information received from Belgium's neighbours. Taking France and German together, this new capacity will be 5 GW in the 'base case' scenario for 2025. If lignite- and coal-fired power plants are shut down early, the need will be revised considerably upwards.

— Given the high level of interconnection of the Belgian system and market coupling, there has been a shift from the national to the European level (or at least the CWE control area) for the 'merit order' and economic dispatching, while competences for the energy mix and security of supply remain strictly at national level.

— It is found that the short-term markets (which constitute the economic 'merit order') have reached a degree of cross-border maturity, whereas the economic model for managing the required investments remains unclear and requires European coordination.

These findings are an invitation to define, in consultation with the public authorities, regulators and stakeholders, the scenarios for the future in a European context, with choices to be made in the following areas:

— the level of autonomy needed, in terms of both the energy balance (MWh) and the capacity relating to security of supply (MW);

— how to avoid distortions due to non-harmonised support measures having an adverse economic effect on the country and on its autonomy;

— capitalising on innovative developments such as storage and active demand management;

— optimal use of the country's energy infrastructure and the high level of interconnection, for both natural gas and electricity; and considering our specific geographical situation in terms of developing renewable sources.