WHITE PAPER

The future of battery storage in Belgium

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Table of Contents

List of Acronyms	
aFRR	Automatic Frequency Containment Reserve
BESS	Battery Energy Storage System
BELPEX	Belgian Power Exchange
CIM	Continuous Intra-day Market
CMU	Capacity Market Units
CRM	Capacity Remuneration Mechanism
CREG	Commission for Electricity and Gas Regulation
DA	Day-Ahead
DAM	Day-Ahead Market
DNO	Distribution Network Operator
DOD	Depth of Discharge
FCR	Frequency Containment Reserve
IoT	Internet of Things
mFRR	Manual Frequency Containment Reserve
PGM	Power Generation Module
PPM	Power Park Module
RES	Renewable Energy Sources
RfG	Requirements for Generators
RTE	Round Trip Efficiency
R&I	Research and Innovation
SPM	Storage Park Module
TSO	Transmission System Operator
VLAIO	Flemish (Vlaamse) Agency for Innovation and Entrepreneurship
VREG	Flemish (Vlaamse) Regulation Entity for the Electricity and Gas

1 Introduction

1.1 White Paper Objective

Belgium is about to take some important decisions about the future of its electricity system. The so-called Energy Pact, which is currently being drafted by regional and federal administrations, will set out the long-term future of a sector that is undergoing rapid and fundamental changes in a transnational context.

The purpose of this paper is to discuss the current and future opportunities in Belgium regarding energy storage development. More specifically, the paper examines the institutional and regulatory framework for the development and participation of energy storage units in the electricity markets and power mechanism in Belgium, with a focus on Battery Energy Storage Systems (BESS). Unless highlighted otherwise, the terms 'BESS', 'energy storage', battery storage', and 'storage' are used interchangeably with the same meaning in the paper.

1.2 Background

Battery storage in recent years has faced an extremely high level of multidimensional development, which spans across all levels of the electrical system (production, transmission, distribution, and final use), in sizes ranging from kW to GW and for uses covering a wide range of technical services and market operations. The battery storage technology is a convincing response to several issues that global electricity markets have to deal with, with some of its key benefits being:

- It is an important tool to assist the further integration of Renewable Energy Sources (RES) and enhancing grid stability, the decongestion of saturated grids, the promotion of self-consumption, and overall, the energy transition to a cleaner energy future.

- It is capable of both reducing peak demand and providing flexibility to the network operator, by balancing real-time differences between forecast and actual supply and demand, as it allows any surplus electricity to be temporarily stored, in order to be made available again as electricity when needed. The industry has clearly picked up on this opportunity: the European energy storage market is expanding rapidly, having grown from 0,6GWh in 2015 in 8,3GWh in 2021[1], a tremendous 14 times up increase in just 6 years [2].

- It is highly versatile and scalable and can be used for both residential and utility-scale short-duration storage applications in distributed or centralized setups. With the drop in the cost of lithium-ion batteries, there has been an increased demand for battery storage. In particular, the co-location of BESS with PV (Figure 1) or wind farm power plants is a growing global trend nowadays.

[1] These figures are applicable to stationary electrical, electrochemical, and mechanical storage (with the exception of pumped hydro storage).

- Even large-scale BESS plants have minimum space and environmental requirements (Figure 2) and can be installed in a relatively short period of time which makes them ideal suited for implementation in a very fast-moving energy market like todays.

Figure 1: A 20MW/10MWh containerized BESS combined with 570MW of solar PV (source: ccj-online.com)

Figure 2: Artist's impression of the proposed 320MW/640MWh Gateway BESS site, one of the world's largest battery projects (source: intergen.com)

Energy storage can undoubtedly provide Belgium's power system with cleaner energy, ensuring safety, flexibility, and stability, while also enabling the reduction of electricity prices for the benefit of the end consumers. However, to enable new services and ensure the security of the power network, the Belgian electricity market design, and the legal and regulatory framework for the deployment of battery storage will need to adapt and reflect the flexibility that this technology can offer.

2 Energy Storage Overview in Belgium

Energy storage will play a key role in enabling the EU to develop a low-carbon electricity system. Energy storage can supply more flexibility and balancing to the grid, providing a back-up to intermittent renewable energy. Locally, it can improve the management of distribution networks, reducing costs and improving efficiency. In this way, it can ease the market introduction of renewables, accelerate the decarbonisation of the electricity grid, improve the security and efficiency of electricity transmission and distribution (reduce unplanned loop flows [2], grid congestion, voltage regulation, and frequency variations), stabilize market prices for electricity, while also ensuring a higher security of energy supply.

2.1 Energy storage technologies

Batteries are a key storage technology; the various energy storage technologies are listed in Figure 3 below. Among them, lithium-ion and lead acid are the best-known battery types. It should be noted that batteries are increasingly becoming a more efficient and cost-effective method of storage. Undoubtedly, they are a significant area of focus due to their flexibility of use, fast response times, and co-location and demand reduction opportunities.

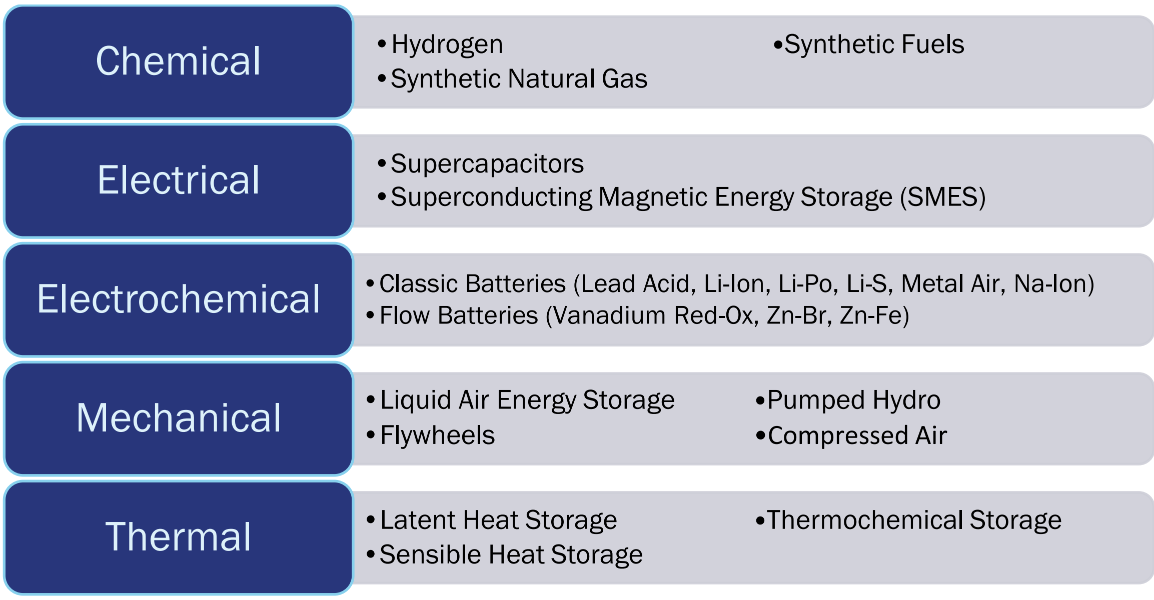

Figure 3: Energy storage technologies (source: The European Association for Storage of Energy

Development of electrochemical cells is not new. Lead-acid battery is the first rechargeable electrochemical cell invented in 1859. Since then, a big number of other electrochemical

[2] Physical power flows in one bidding zone of the European interconnected power system caused by internal commercial energy transactions within another bidding zone

combinations has been developed, resulting in a big number of battery types commercially available, each offering unique combination of characteristics. Energy storage systems operate within a range of services, each of which favours specific characteristics from the battery type used. The feasibility assessment of a battery type for a specific service or bundle of services is the most important task in the development of a new BESS project. Below a list of the most established categories of rechargeable battery technologies is presented:

- Lead-acid batteries
- Nickel based batteries
- Metal-Air batteries
- Molten salt batteries
- Li-ion based batteries
- Na-ion based batteries
- Al-ion based batteries
- Redox Flow batteries

Nevertheless, Li-ion batteries represent one of the most dominant technologies. According to a BloombergNEF study [3], the cost of lithium-ion battery packs has dropped by over 90%, and typical costs are expected to reach close to 100 $/kWh by 2023. The decrease is due to growing order sizes and battery electric vehicle sales growth, which has resulted in economies of scale for battery suppliers, as well as the lower cost of cathode materials since 2018, which has improved profit margins for developers.

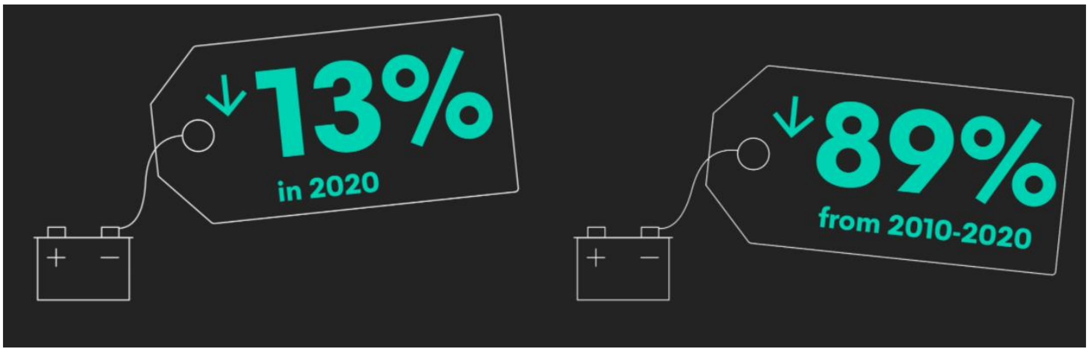

Figure 4: Lithium-ion batteries price drop (source: BloombergNEF)

Continuous development of Li-ion batteries has resulted in several types, each offering a unique combination of characteristics. Depending on the application, careful assessment of the feasibility of a specific type should be conducted. Types of Li-ion batteries commercially available today are:

- LCO – Lithium Cobalt Oxide
- NCA – Lithium Nickel Cobalt Aluminum Oxide

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[3] https://about.newenergyfinance.com/electric-vehicle-outlook/

- NMC – Lithium Nickel Manganese Cobalt Oxide
- LMO – Lithium Manganese Oxide
- LFP – Lithium Iron Phosphate
- LTO – Lithium Titanate Oxide
- LiPo – Lithium-ion Polymer
- Solid state Lithium

BESS is a multi-purpose technology, as it can serve a wide variety of applications. Generally, energy storage systems benefit when operate within a range of services in order to stack revenue streams and enhance their feasibility. However, value-stacking introduces a “revenue interface risk”, i.e., a series of technical and commercial challenges that result from accessing multiple revenue streams. The impact of this revenue interface risk can be very big as the BESS project might be left unable to deliver the services targeted, and so fail to secure the promised revenues. Relationship pressures can stem from various issues, including:

- Technical requirements: This is about the ability of the storage project to meet the requirement of delivering multiple services, given differences in technical service specifications. For instance, frequency response services require symmetrical operation (i.e., both upwards and downwards support), whereas other services are one-way, bringing complexity in managing state of charge.

- Commercial prioritisation: This is about the BESS ability to meet commercial obligations, such as when to target Revenue 1, and when to target Revenue 2. The answer can be contractually complex: some ancillary services bring heavy penalties for non-performance, and/or place compliance restrictions on value-stacking; the counterparties may differ too.

Considering the big amount of commercially available battery types, it becomes evident that the assessment of the feasibility and suitability of a specific battery type for a specific storage application is a challenging task, since each application requires specific technical characteristic to be fulfilled from the battery in order to perform optimally. Battery applications can often be classified as energy or power intensive. Energy intensive applications are characterized by long cycles while power intensive applications are characterized by short cycles. In order to illustrate the complexity of the optimum battery selection for a specific application, an example of a battery performance characteristic is presented below by focusing on the C-rate capability of batteries. The charging and discharging maximum C-rate of a battery defines how quickly a battery can deliver its energy content or in other words defines the power density of the battery and therefore the maximum delivered power of a configuration. Below, the maximum C-rates of 4 commercially available Li-ion batteries is presented.

	LTO	LCO	NMC	LFP
Voltages	2.4 volts	3.60 volts	3.6 volts	3.2 volts
C-Rate	10C	1C	2C	20C

LFP and LTO types offer considerably higher C-rate making them a better choice for a power intensive application such as frequency response service, compared to LCO and NMC which would fit better an energy intensive application such us energy arbitrage.

Apart from C-rates, there are many other battery specifications the have to be considered on specific applications, with round-trip efficiency, life cycles, calendar life and maximum depth of discharge (DOD) among others. When assessing projects with stacked revenues, the designer has to be prepared to identify and quantify trade-offs arising from the different requirements of different applications. The complexities arising from the different requirements of specific applications along with the big amount of commercially available battery types highlight the necessity of an independent expert advice when selecting the best battery technology and sizing the system. Pulsar Power is committed in offering the expertise required to perform this evaluation by considering existing proven technologies but also by closely following all recent battery developments.

2.2 Why energy storage?

Energy storage offers a range of opportunities for standalone developers, generators, network operators and consumers (ranging from large energy users to domestic consumers) and other electricity sector participants. Storage is an increasing focus due to the range of benefits the various technologies can provide. The flexibility of energy storage is demonstrated by its applications as displayed in Figure 5 below.

When looking at the energy transition and the decarbonisation of the EU economy, BESS will play a pivotal role in a renewable-based power system. By providing flexibility and fast balancing services, BESS technologies provide all the conditions that are vital for maximizing the integration of high shares of variable RES, as well as the grid integration of electric transport.

From a power system perspective, BESS technologies bring significant benefits, including:

- Injecting and absorbing electricity extremely fast (<50ms), with higher accuracy than conventional generators, to provide power system reliability services.
- Improving short-term variability, fostering the penetration of higher shares of renewables in the power system.
- Eliminating production and load peaks, reducing network costs and investments needs.
- Making solar fully dispatchable, optimizing the supply of solar energy in line with the power system needs.
- Storing solar electricity when prices are low, using it when prices are high, allowing energy prices to stabilize.
- Rebooting grid operations in the event of power outage.

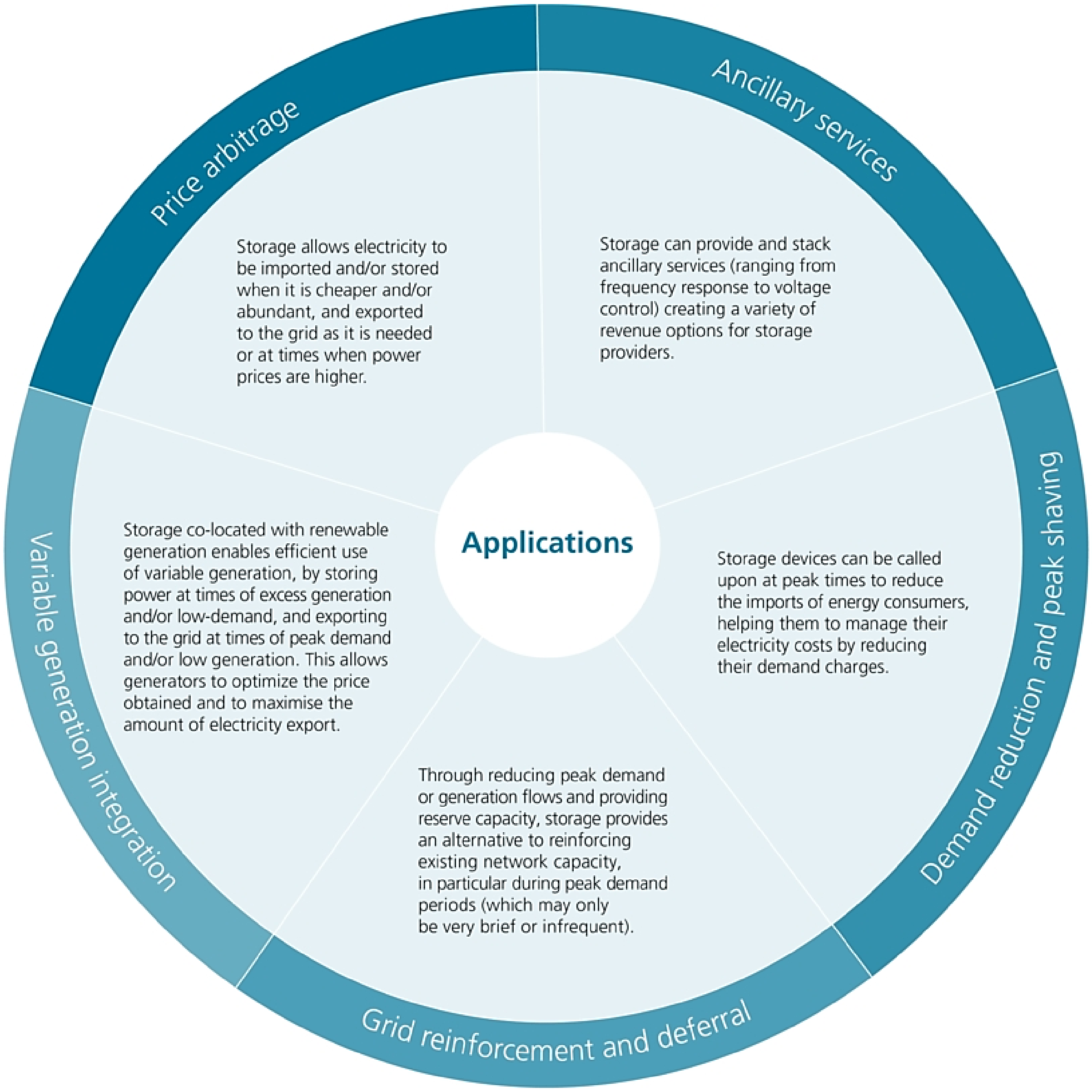

Figure 5: Energy storage applications. (Source: cms.law)

The provisions included in the EU Clean Energy Package[4], specifically in the Market Design Regulation 2019/943 and Market Design Directive 2019/944, constitute a solid basis for BESS. Opening up new markets for storage – such as frequency response, energy shifting, reactive power, balancing – strongly support its business case, especially if properly matched with the possibility of stacking several services and removing financial disincentives to simultaneously store renewable energy and provide flexibility services to the grid. On top of setting up a strong legislative framework enabling BESS technologies to deploy their full potential, there are additional measures that can

[4] https://ec.europa.eu/energy/topics/energy-strategy/clean-energy-all-europeans_en

be taken by policymakers to speed up their uptake and enhance renewable deployment while creating a more flexible and reliable grid. Some characteristic examples regarding Belgium are discussed in the rest of this paper.

2.3 Current Situation

According to Elia, in 2020 renewables accounted for over 50% of Belgium's electricity consumption on 119 days, a record for the country. Solar power and wind energy complement each other, as there is relatively high level of solar energy generated in summer and higher wind generation during winter. According to Eurostat data, as summarized in Table 1 and Table 2, during the 2010-2019 period solar energy production in Belgium was increased by over 360 %, and wind energy production by approximately 324%.

Table 1: Solar production capacity in Belgium (source: Eurostat)

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Production [MW]	1.007	1.979	2.647	2.902	3.015	3.132	3.329	3.621	4.000	4.637

Table 2: Wind energy production capacity in Belgium (source: Eurostat)

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Production [MW]	912	1.069	1.370	1.780	1.944	2.177	2.370	2.788	3.268	3.863

Currently debates are taking place at federal and regional levels, with the aim of defining Belgium's long-term energy vision, with a focus on the future energy mix and market design. This is of particular importance given the decision to phase out nuclear generation by 2025, and Belgium's commitment to the COP21 Paris Agreement. To achieve full decarbonisation until 2050, many changes need to be made, with an emphasis to the sustainability and reliability of the grid. [1]

With respect to energy storage, in Belgium the situation is somewhat different compared to other European member states. The Belgian legislation allows the Transmission System Operator (TSO) to undertake storage activities, something that the Distribution Network Operator (DNO) is not allowed to do. The Flemish (Vlaamse) Regulation Entity for the Electricity and Gas (VREG) has proposed that the legislation be amended so that the DNO may also undertake storage activities. However, this does not mean that the DNO/TSO may actually physically own storage units, but they would need to purchase this service through commercial markets. An exception to this commercialization is when the storage unit is used for the core activity and the DNO can demonstrate through a cost-benefit analysis that purchasing this service would be too expensive.

Due to the Belgian federal state structure, the regional governments of Flanders, Wallonia and Brussels Capital are principally responsible for designing and implementing policies for energy efficiency, renewables, non-nuclear energy research and development and market regulation.

In particular, Belgium has four energy regulators:

- the Federal regulator, the Commission for Electricity and Gas Regulation (CREG)
- the Flemish regulator, VREG
- the Walloon regulator, the Walloon Energy Commission (CWaPE) and
- the Brussels regulator, Brussels Gas Electricity (BRUGEL).

The federal authorities are responsible for “matters which, on account of their technical and economic indivisibility, must be dealt with on an equal basis at national level”, i.e., matters that need a coordinated approach at national level.

With regard to the electricity grid in Belgium, the 150kV to 380kV high-voltage transmission network is operated by Elia, the TSO. Elia has a legal monopoly as Belgium’s sole electricity TSO; its license is valid for 20 years and can be renewed. The Flemish, Walloon and Brussels-Capital Region are responsible for distributing electricity with a nominal voltage of 70kV or less. A distinction is made between operating systems with a voltage of 70kV and those with a lower voltage. The networks with a voltage of 70kV, operated by Elia, are the local transmission network in Wallonia; the local transmission network in Flanders; and the regional transmission network in the Brussels-Capital Region.

Those with a lower voltage are the distribution networks, which are operated by the distribution system operators (DSOs). The three Regions are also responsible for renewable energy generation (excluding federally governed electricity generation from offshore renewable sources in the North Sea) and the rational use of energy. The Belgian Electricity Law sets out some exemptions at the federal level for tariffs on storage batteries. However, this legislation still needs to be fully established at the regional level.

2.4 Future Challenges & Opportunities

It is obvious that there is a transition towards a renewables-based system in Belgium, with increasing amounts of renewables steadily displacing conventional generation. This transition is facilitated by the reduction in total costs (investments, maintenance) of renewables which has been made possible by technological progress. Wind and solar are progressively emerging as the “winning” technologies to decarbonise the system.

Given that the country has low potential in primary fuels (such as coal, gas, oil, uranium, etc.), the transition towards more renewables represents an opportunity both in sustainability and in energy independency. But it also brings many challenges, in particular about how to maintain a competitive economy and social welfare in the next decades. The magnitude and speed of the challenges affecting the energy system will only increase in the years to come. However, changes also mean that there is a chance to seize opportunities that arise with the right choices in terms of vision and steps to make it happen. Hydrogen, energy storage, district heating and geothermal energy are expected to be the biggest game changers in the coming years in Belgium.

Energy storage is increasingly contributing to the management of the daily variability of renewables and the balancing of the Belgian system but is not yet mature technology (in the short to medium-term) to manage the weekly or seasonal variability. The development of energy storage applications necessitates the settlement of licensing issues, network accessibility, effective integration in the markets and possibly the establishment of support mechanisms that will cover the financing gaps of projects. At all four levels, the current institutional and regulatory framework in Belgium has either significant gaps or does not exist.

The main obstacle for development of renewable energy in a very densely populated country such as Belgium is local opposition when applying for an integrated permit. This is particularly true for wind turbines in mixed-use areas in the Flemish and the Walloon regions. Such appeals/protests can delay or entirely terminate wind projects. There are also very lengthy administrative permitting procedures to be followed when developing a large renewable energy project, both onshore and offshore, which affects timing. The current imbalance of the electricity market due to intermittent over- or under-production also affects the need and support for renewable energy. Furthermore, multiple regulatory hurdles exist as to development of further local off-take for renewable energy production. The policy in some regions is still strict in relation to direct lines, tariffing benefits and local energy community and local sharing legislation.

CREG and the regional regulators (VREG, CWAPE and BRUGEL) play an important role in identifying and assessing the feasibility for the development of energy storage projects, and in issuing recommendations to their respective governments to adopt the necessary legislative and regulatory improvements. In this context, CREG issued a report on the profitability of energy storage in Belgium in April 2015. This report identified the following challenges and barriers for the development of energy storage in Belgium:

- Tariffs, taxes, etc. – storage facilities with direct connection to the grid face high tariffs, taxes and obligations that prevent their development. Conversely, storage facilities directly connected to production capacities and/or self-producers are able to avoid such tariffs.
- Compatibility with ancillary services and Belgian Power Exchange (BELPEX) markets – due to the limited capacity of storage facilities, the range of services to be offered in the context of ancillary services on the BELPEX market remains limited.
- Competitiveness with other ancillary services – storage facilities face additional costs as they are subject to taxes and tariffs in the context of their “consumption” of electricity and therefore find it difficult to compete with more conventional providers of ancillary services.

The CREG report includes several recommendations to the federal and regional governments in order to tackle these challenges and barriers. However, none of these recommendations have been implemented so far.

To build the path allowing Belgium to achieve its ambitions, it is important to consider the strengths and challenges of the Belgian electricity grid, as summarized in Figure 6 below. Batteries are and will continue to help the system in terms of flexibility towards this direction.

Strengths

- Located at the centre of Europe, Belgium is at the crossroads of important renewable generation hubs - major wind hubs in the North and solar hubs in the South - and close to the main load centres.
- In this central position, Belgium is surrounded by large countries with different strategies from the energy point of view, which gives Belgium access to the best of their choices.
- As part of its energy strategy, Belgium has built and maintained a robust and interconnected energy infrastructure, as well as a leading position in market design and integration. This constitutes the biggest strength on which Belgium should leverage.

Challenges

- Given Belgium's small territory, only a part of the country's demand could be met by domestic renewable capacity. It is therefore not possible to rely only on domestic renewable generation to achieve a full decarbonisation.
- In the current market design with higher amounts of renewables in the system, concerns have been raised about the profitability of conventional units.
- Maintaining security of supply becomes increasingly challenging given the plans to phase out nuclear power.

Figure 6: Strengths and challenges of the Belgian electricity grid.

3 Grid Connection Considerations

3.1 General

The declared export and import power capacities will define the way to connect the energy storage stations to the network, as well as the necessary enabling works to strengthen the relevant network. These capacities typically depend on:

- The production and demand profile of the installation,
- How the storage facility will be managed commercially and the market remuneration mechanisms the BESS will participate in, and
- The characteristics/specifications of the storage equipment.

Regarding grid connection costs, energy storage stations will be charged the full cost of both the expansion works required to connect them to the grid and the associated reinforcement works, based on the same practice applied to all power generation stations.

3.2 Technical Requirements

For each storage station connected to the electrical system, a set of technical requirements need to be fulfilled, which comprise the terms of its connection agreement, and which the storage station commits to satisfy during its connection and throughout its operation.

Energy storage plants will replace conventional generation units during the operation of the system, similarly to RES plants, and their integration should be realised on the basis of similar technical requirements so that the system security is not compromised, particularly during periods of very high-RES penetration. At European level, no specific technical requirements have yet been developed for energy storage stations, similar to those existing for other generation units as per RfG, but in Belgium the situation is different. Elia has published a set of technical requirements for energy storage stations, which particularizes the EU Regulation 2016/631 and the “Requirements for Generators” (RfG) [3].

In general, the possible technical capabilities of a Storage Park Module (SPM) are similar to the ones of Power Park Modules (PPM) as they share similar technical aspects as modules connected to electricity networks through power electronics acting as inverter and rectifier for the case of SPM. Therefore, the proposed technical capabilities are aligned as much as possible with the PPM’s exhaustive and non-exhaustive requirements defined in the RfG Network Code. These cover issues of participation in frequency and voltage regulation, ability to monitor active power commands from the network operators, fault-ride through capability, etc., and their content is determined by the maximum capacity of the power station, the voltage level of its connection point and the technology of the generating units according to a Type classification mechanism.

3.3 Storage Park Modules Type Classification

According to the "Proposal for Storage Connection Requirements", prepared by Elia in 2018 [3], a SPM is an electric system composed of a single or multiple electrical storage units capable of storing and delivering energy into a single electrical point of connection. The current connection requirements, as listed in Table 3 below, are applicable to new installations and existing installations to which substantial modifications will be made.

Figure 7 illustrates possible connection of a SPM and the Point of Common Coupling (also referred in this paper as the connection point) to the transmission grid. The same facility could include other Power Generation Modules (PGMs) or demand units as auxiliary supply.

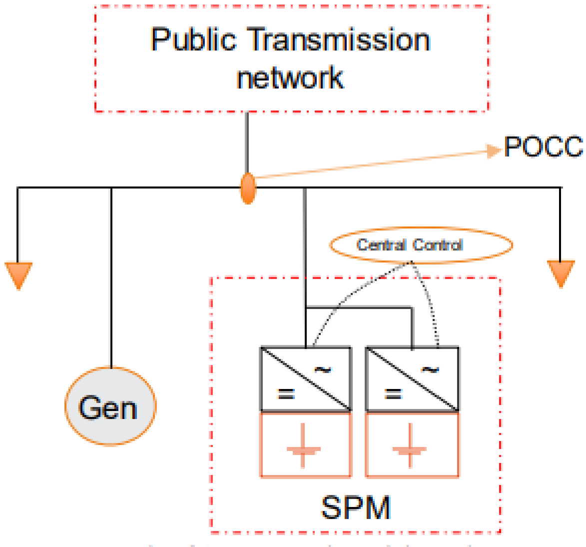

Figure 7: Example of SPM grid connection

The present technical requirements are defined per each of the following categories taking into consideration the maximum active power that the SPM is technically designed to deliver or absorb at the connection point (P_{max}).

Table 3: SPM type classification (source: Elia's proposal [3], 2018)

Types	Active Power limits
A	0,8 kW $\leq P_{max} <$ 1 MW
B	1 MW $\leq P_{max} <$ 25 MW
C	25 MW $\leq P_{max} <$ 75 MW
D	75 MW $\leq P_{max}$

Many parameters such as frequency and voltage ranges, rates of change of active power output etc. are described in detail by Elia in its proposal. The requirements on fault-ride through for symmetrical and asymmetrical faults are also analyzed, as well as the required reactive power capabilities for each type. A discussion of all these requirements exceeds the purpose of this paper.

3.4 Access of Energy Storage Stations to Congested Networks

Belgium has a well-developed and meshed high voltage grid, connecting the main load and generation centres. Therefore, grid congestion and congestion management were never a pressing issue for the Belgian TSO in the past. However, this has changed due to the deployment of offshore wind power in the Belgian North Sea.

The operating profile of the energy storage stations participating in the electricity markets typically leads to energy absorption during low electricity price clearance times, which generally coincides with periods of high-RES production, and energy export during the hours of high clearance values, when production of RES is generally limited. This correlation, which becomes more and more pronounced as the penetration of RES increases, allows energy storage stations to contribute to the decongestion of networks supporting high levels of RES generation, by increasing the available electrical capacity in these areas to accommodate additional RES capacity.

It is therefore reasonable that energy storage stations should not be subject to the same treatment with RES plants for connecting into the grid regarding the allocation of electrical capacity and the order of assessment of the relevant connection requests. Although this general observation is fundamentally justified, situations of counteracting operation, where storage facilities inject energy simultaneously with high local RES generation or absorb energy simultaneously with high local demand, cannot be excluded either.

To ensure that the connection of energy storage plants does not exacerbate the problem of grid congestion, thereby justifying the prioritisation of their connection over renewables, it is necessary to impose restrictions on the operation of these plants in predefined time zones of the 24-hour period, possibly with a seasonal variation, which will ensure that storage plants do not inject energy during periods of high local production. Similarly, if grid connection is due to high demand, the storage stations should not absorb energy during periods of high demand on the local network.

The implementation of the required restrictions shall be the responsibility of the operator of the storage plant, which shall be considered when the plant is active on the electricity markets. To this effect, it is necessary to introduce an obligation for the participant to establish a market programme compatible with the restrictions imposed (e.g., no injection of energy at midday in areas with congestion due to PV generation), so that their fulfilment is not a product of generation redispatch in the balancing market with additional costs for the system. Compliance with the constraints should be monitored on an accounting basis and any non-compliances should be addressed by imposing discouraging penalties.

Provided that the energy storage stations commit to satisfy the aforementioned operational constraints that ensure they do not exacerbate network congestion, it is recommended that they should take precedence over renewable energy plants when being considered for connection offers. Not only because they do not occupy electrical capacity, but also because these are resources which, assuming a rational market intervention or the introduction of a framework of decongestion services, can contribute to remove grid congestion and increase the electrical capacity available for integration of additional RES. However, this prioritisation of storage is not applicable to where the congestion of the local grid is associated with the limit of the short-circuit level, as in these cases the connection of storage facilities, as well as RES plants, exacerbates the problem.

On the other hand, in case of non-compliance of the energy storage stations with the operational restrictions, the priority of access over RES shall obviously not be applicable. In such cases where the storage plant does not undertake operational commitments, the connection offer will be prepared assuming the extreme scenarios of simultaneous injection from RES and storage plants and simultaneous occurrence of maximum local demand and absorption of the plants. In extreme occasions, consideration shall also be given to access restriction to the congested networks for such storage facilities.

4 BESS Participation in Electricity Markets

Due to the high initial cost of a BESS, the optimal commercial operation of this asset is essential, and this can only be achieved by developing a viable platform for BESS participation in different electricity markets. This section discusses the BESS prospects in the Belgian electricity market.

4.1 Spot Markets

To ensure a continuous balance between electricity generation and consumption, different wholesale markets are established in Belgium across different time horizons in advance of the actual moment of energy delivery. An important revenue stream for BESS plants can come from their participation in the Belgian spot markets managed by EPEX Spot Belgium, and more specifically the Day-Ahead Market (DAM), and the Continuous Intra-day Market (CIM). The minimum quantity that can be traded in both markets is 0,1MWh.

The CIM is the auction for continuous daily trading of electricity during the same day. When rapidly changing weather forecasts result in an unforeseen deficit or surplus of electricity from solar or wind power plants, intraday trading is a critical component for direct marketing of RES power. Greater price volatility is expected at the opening of the intraday trading slot because there is less certainty regarding weather conditions, for example, due to fewer hours of sunshine or lower wind than forecasted, as well as what other parties are trading and other market circumstances. Traders have better information about their position and prices closer to the delivery moment. Therefore, in the CIM, participants adjust their market trading schedule, considering the data of the system and their installations, closer to real time, typically 5 minutes and up to 8 hours ahead of the delivery moment.

The DAM is the auction for the following day's trade of energy. Buyers and sellers provide volume and price hour by hour, while supply and demand set the hourly Day-Ahead (DA) price. DA trading is anonymous and takes place on all days, including public holidays. The DAM is the most liquid market, with the prices on it reflecting to a greater extent the variables that shape the short-term value of electricity, thus providing the most representative price signals for investments in the electricity sector. The possibility of effective participation of energy storage stations in this market is critical to gain the expected benefits from their operation, as well as for the sustainability of these investments.

Participation of BESS plants in the spot markets means they can generate income by capturing the price spread in the electricity market and therefore benefit from price volatility, i.e., relative differences in market prices. The expected CIM income varies between 16.000-19.000 €/MW/year, while the expected DAM revenue varies between 14.000-18.000 €/MW/year. The sustainability of energy storage projects and the expected benefits of their operation in these markets presuppose the capability of constantly adjusting their market trading schedule, which would in turn necessitate the use of an Internet of Things (IoT) based data analytics platform.

4.2 Ancillary Services

4.2.1 Overview

Elia purchases flexible power capacity and reserves from consumers and generators connected to its network, as it does not have assets to maintain the frequency of the power grid. These services provided by consumers and generators are called ancillary services and are vital to support the power system's operation. Innovative ancillary services can address the variability and uncertainty of the variable RES. For maintaining the real-time power balance of the Belgium electricity grid, Elia mainly uses the following ancillary services:

a) Frequency Containment Reserve (FCR),

b) automatic Frequency Restoration Reserves (aFRR), and

c) Manual Frequency Restoration Reserves (mFRR).

Service suppliers often work with their own controller (combining energy and power management) to realize their schedule obligations by measuring the grid frequency independently at the location of power consumption or generation and responding immediately to frequency changes. For aFRR in particular, a reliable high-speed data connection between the provider and Elia is necessary to receive the desired setpoints in real-time. Table 4 provides an overview of these ancillary services.

Table 4: Overview of the ancillary services in Belgium (source: Elia[5] [6] [7])

Previous terminology	New terminology	Activation frequency	Activation energy	Procurement
Primary Reserve (R1)	FCR	High	Low	Daily as of July 2020
Secondary reserve (R2)	aFRR	High	High	Daily as of October 2020
Tertiary reserve (R3)	mFRR	Low	High	Daily as of February 2020

4.2.2 Procurement and Remuneration

The purpose of FCR is to provide an immediate initial response to frequency deviations across Europe. The FCR capacity is purchased daily by Elia via the international Regelleistung market in coordination with other TSOs of neighbouring countries (the so-called "Common Auction"). Any BESS offered by a supplier to deliver FCR service must reserve a capacity band (MW) equivalent to

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[5] Terms and Conditions for balancing service providers for automatic Frequency Restoration Reserve (aFRR)

[6] Terms and Conditions for balancing service providers for automatic Frequency Restoration Reserve (mFRR)

[7] FCR service design note

their contractual obligation for the unique usage of primary control reaction at all times during the delivery period. An FCR provider using battery assets with limited energy capacity must always have established a suitable charging strategy, e.g., using other assets in their portfolio for day-ahead and intraday electricity market transactions, to be able to meet this obligation, otherwise Elia will automatically apply strict penalties on the missing volume. Therefore, it is crucial that a correct sizing of BESS assets is undertaken by the supplier before registering the plant for the FCR service, considering the optimum energy management strategy.

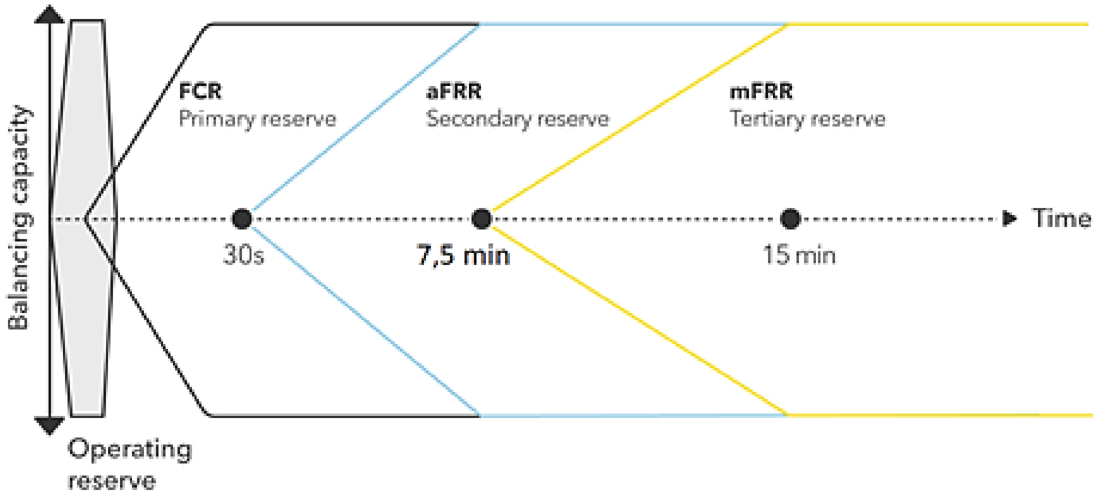

Figure 8: Ancillary services procured by Elia (source: Next Kraftwerke)

The aFRR service aims to offset any national day-to-day system imbalances in both directions between generation and consumption in support of FCR, while mFRR service is supporting the system in the event of major system imbalances between generation and consumption, relieving the saturated aFRR reserve. Consequently, the activation (dispatching) of aFRR and mFRR bids for balancing takes place in real-time operations. According to aFRR product, the generation assets are activated automatically in less than 7,5 minutes after a frequency imbalance incident occurs. Upon activation, Elia delivers a new setpoint every 4 seconds, which must be followed within a tight accuracy band. The aFRR service is characterised by the high frequency of activations and a large amount of activated balancing capacity. It is considered as the most complex but the same time most important product to manage day-to-day imbalances in the Belgian grid and has positive values (supply to Elia network; upward control) and negative values (draw from Elia network; downward control). The mFRR product is typically activated as a supplement to aFRR. It is manually controlled by Elia and the requested energy must be available by the registered plants within 15 minutes.

Both aFRR and mFRR require capacity which can deliver 4 hours of energy continuously, which means a BESS should have a storage depth of at least 4 hours. The aFRR capacity is procured daily, with 12 simultaneous auctions taking place on day D-1 for delivery during a specific contracted period of 4 hours on day D, i.e., 6 for upward aFRR and 6 for downward aFRR. The mFRR capacity is also procured daily with 6 simultaneous auctions on day D-1 for delivery during a specific contracted period of 4 hours on day D.

The remuneration of FCR service comprises only the remuneration of reserving the contracted primary control capacity. For aFRR and mFRR products, in addition to capacity payments participants are also being reimbursed at energy cost for actual activations based on the merit order principle. The number of activations depends on energy price offered, and for aFRR it can range from several activations per hour to a few activations per week. Some useful financial data based on the most recent details published by Elia are provided in the figures below.

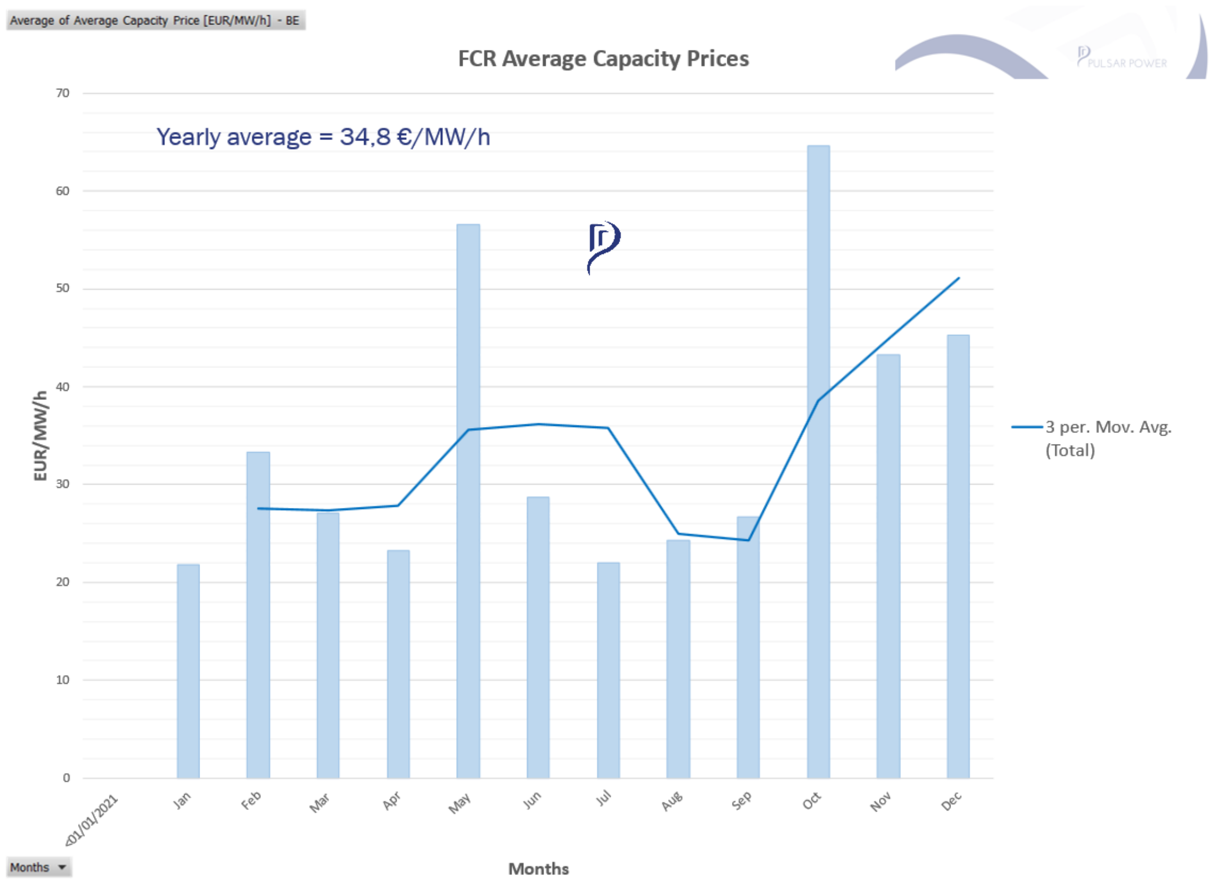

Figure 9: FCR – 2021 Capacity Prices Overview

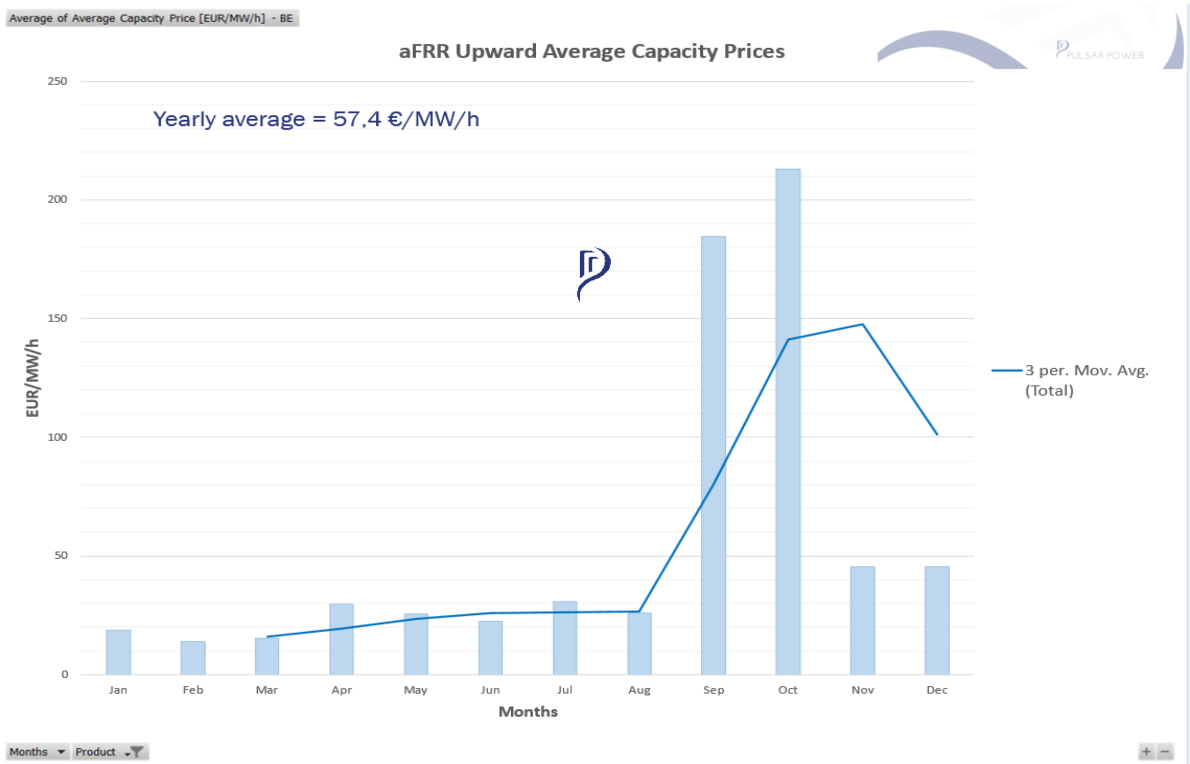

Figure 10: aFRR - 2021 Upward Capacity Prices Overview

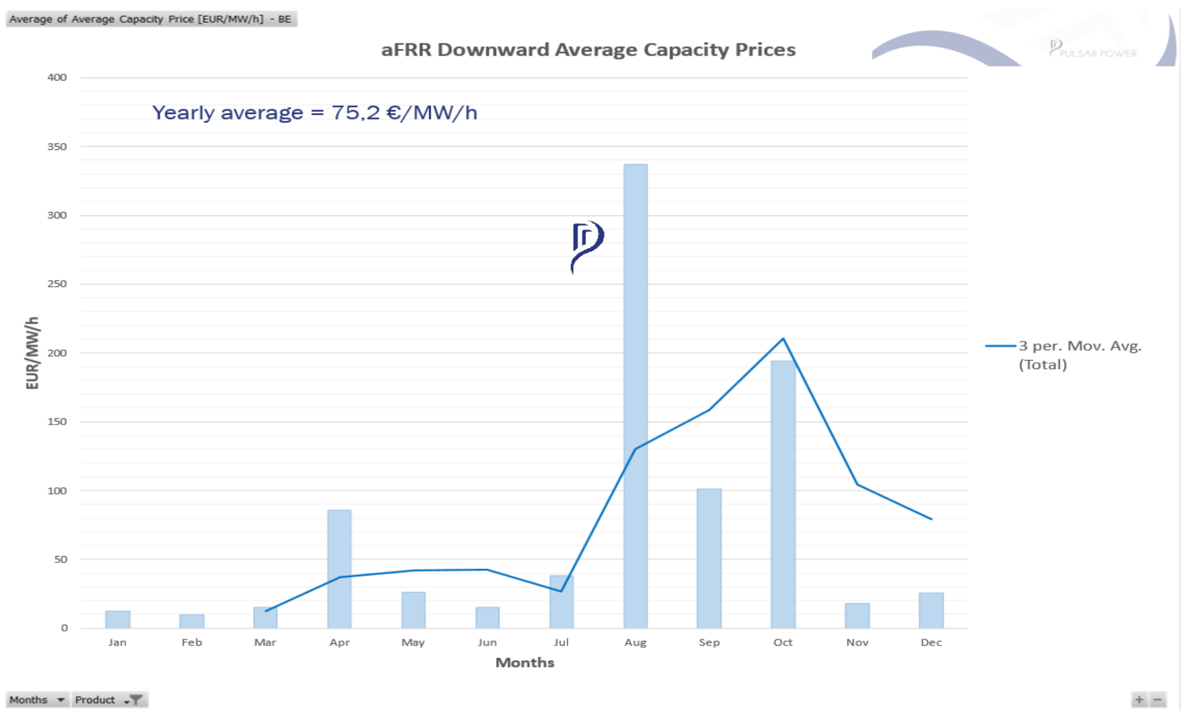

Figure 11: aFRR - 2021 Downward Capacity Prices Overview

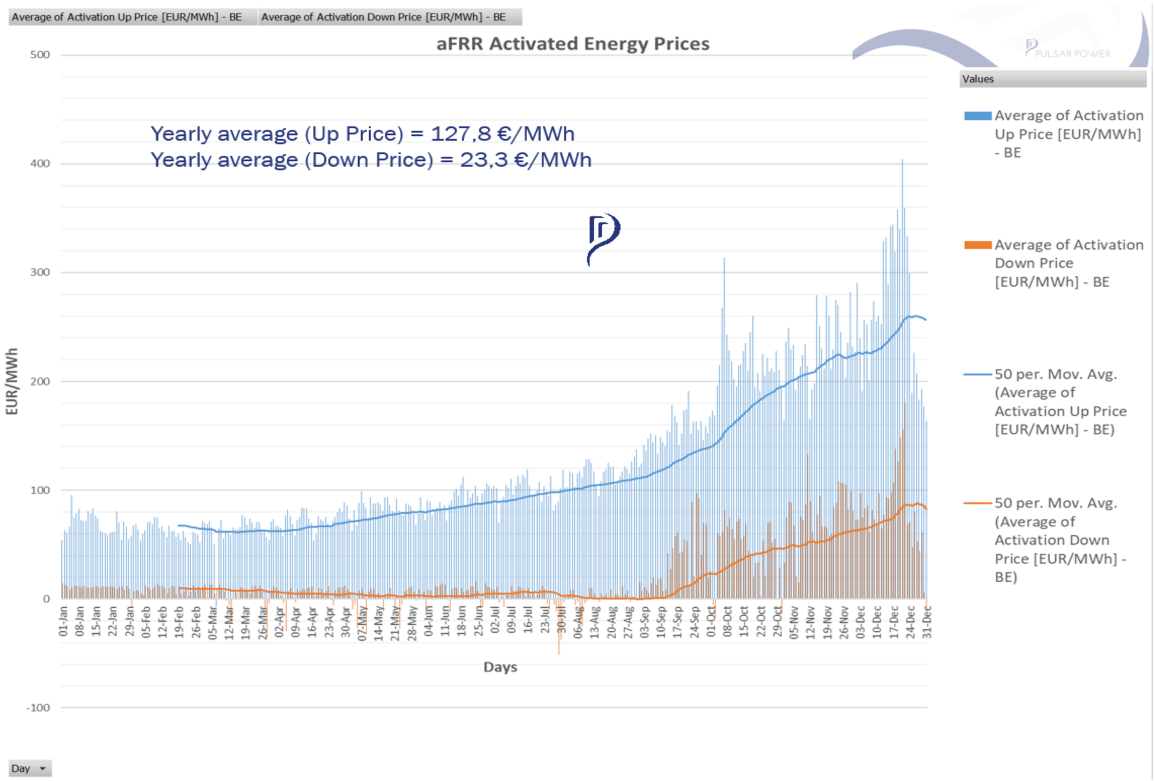

Figure 12: aFRR - 2021 Activation Prices Overview

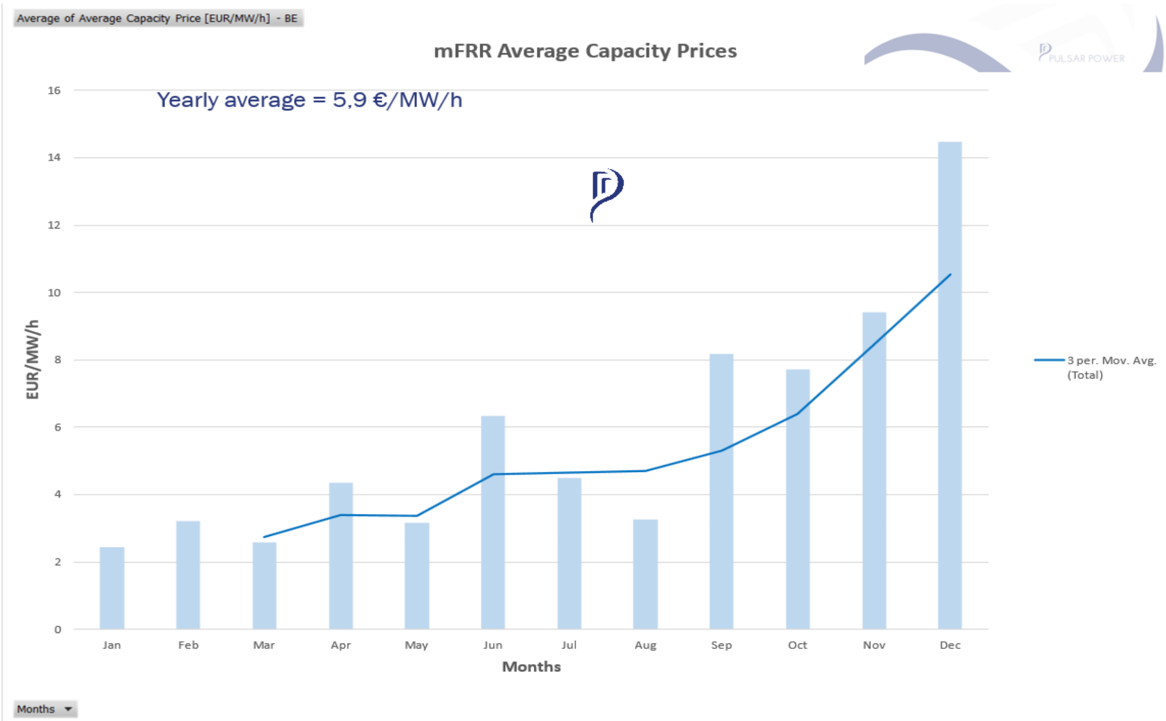

Figure 13: mFRR - 2021 Capacity Prices Overview

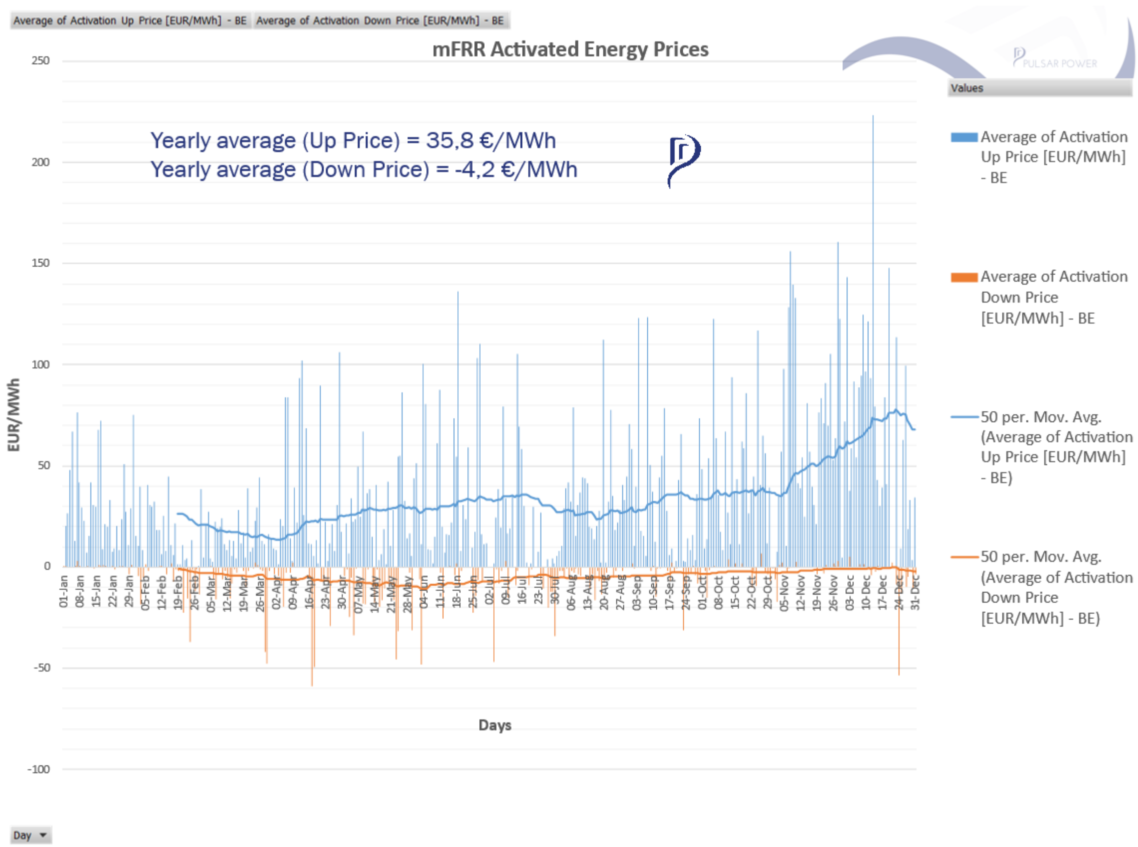

Figure 14: mFRR - 2021 Activation Prices Overview

The replacement of nuclear power plants with flexible generation capacity and the further integration of European ancillary service markets is expected to increase FCR market competitiveness and lower prices in the future. Furthermore, as battery prices fall, the number of new BESS projects participating in the ancillary services auction is expected to rise, resulting in a further reduction of competition between Belgian providers.

4.2.3 aFRR –Revenue Calculation Example

The following revenue calculation example for the aFRR service is based on information gathered from the financial graphs in section 4.2.2. Assuming the yearly average of 2021 upward and downward capacity prices, i.e., 66,3 €/MW/h, a value that is derived from the respective average prices depicted in Figure 10 and Figure 11, as well as a 50% success factor in the daily procurements and 97% yearly plant availability, the yearly calculated capacity remuneration is estimated to be approximately 280.000 €/MW. For a 10 MW BESS this mean approximately 2.8 M€ per year.

On top of that, additional activation payments are anticipated. Assuming the 2021 yearly average upward price of 127,8 €/MWh and downward price of 23,3 €/MWh (Figure 12), the total yearly revenue from activation payments can be estimated with the following formula:

Activation Revenue = $\sum_{k=1}^{Nup}(Ek * 127,8) + \sum_{j=1}^{Ndown}(Ej * 23,3)$

where Ek and Ej are the amounts of energy activated each time for upward and downward frequency control respectively, and N_{up} and N_{down} the total number of activations in a year

5 Investment Support Schemes

5.1 Background

Despite the benefits they can bring, BESS facilities globally are struggling to obtain sufficient revenue streams from their participation in competitive markets to ensure the sustainability of their associated investments. Some changes are required to ensure the economic feasibility of large-scale energy storage projects, such as:

- Exemption from federal taxes and additional costs,
- Adoption of a tailor-made tariff regime,
- Modification of the grid losses compensation mechanism, and
- Exemption from the green certificate's obligation for the offtake of electricity.

Electricity generators and suppliers are important players as they have direct operational and commercial interests in energy storage projects. Other players, such as public finance structures, will also be part of such projects.

In the few cases internationally where BESS development was possible in the modern market environment without subsidy schemes, this was because high-value energy storage services were identified and competitive procedures were established by network operators for the supply of these services, with adequate remuneration for the sustainability of the participating storage stations. Recognizing and rewarding the added value of specific services that storage facilities are able to provide would contribute to revenue stacking, which in turn would reduce the funding gap and ultimately achieve project sustainability.

A solution for the timely development of large-scale storage projects could be provided by the introduction of storage investment support schemes, which would compensate for the uncertainties of market revenues and fill the financing gap of the projects to make the relevant investments sustainable and fundable. The support may be provided in the form of capital subsidies or through tax exemptions and other investment incentives. An overview of such support schemes established in Belgium is provided in the following sections.

5.2 Capacity Remuneration Mechanism

Belgium must not only deal with the transition to renewable energy, but also with the entire phase-out of nuclear power by 2025. Elia studied the need of adequate and flexible energy sources and suggested a Capacity Remuneration Mechanism (CRM), an organized competitive bidding procedure, which is market-wide and technology neutral, to incentivize investments in generation capacity to ensure Belgium's supply security at the lowest feasible cost. All awarded capacity providers get cash compensation for the availability of their generating capacity in the Belgian energy market. On April 4, 2019, the Belgian federal parliament passed a measure to amend the Belgian energy laws and enabled the implementation of a CRM to promote investment.

The European Commission has already approved six electricity capacity mechanisms, under EU State aid rules, to ensure security of supply. The CRM will have a significant impact on the electricity market in Belgium, since it foresees a subsidy mechanism to ensure the requested level of security of supply, which will be crucial in relation to Belgium's phasing out of nuclear energy. The mechanism authorised in the case of Belgium is related to strategic reserves, namely keeping certain generation capacities outside the electricity market for operation only in emergencies. They can be used to ensure the supply of electricity during unavailability of electricity markets discussed in Section 4.

Looking at some specific characteristics of the CRM in Belgium, Elia has proposed a methodology on how to calculate derating factors of the CRM, which apply on the CRM registered capacity of each participating plant. These factors for a BESS are calculated after the optimal power dispatch (Monte-Carlo simulation) is conducted as to provide technology utilization factors relative to near-scarcity hours of the market and specifically for BESS by considering their financial optimization during operation in spot market prices. Detailed information is provided in 'CRM Design Note: Derating factors'[8]. The minimum quantity that can qualify is 1MW of derated capacity and is called Capacity Market Unit (CMU). The table below summarizes the 2021 derated factors for BESS, based on the daily hours of service.

Table 5: Derating Factor as published (30/04/2021) for the Y-4 Auction 2021

Sub-Category	Derating Factor [%]
1	11
2	19
3	28
4	36
5-6	52
7-8	65

According to Elia's recent adequacy and flexibility analysis, new capacity of 3,9GW would be required starting in 2025 to provide supply security following the complete phase-out of nuclear power. Auction Y-4 takes place 4 years in advance of the corresponding delivery period. The first auction (auction Y-4, 2025) took place in October 2021 and corresponds to a delivery period commencing in November 2025. A Y-1 auction takes place 1 year in advance of the corresponding delivery period, therefore Y-1 auction for the first CRM delivery period of 2025-2026 will take place in 2024. The same annual process is maintained for delivery periods following 2025. Because of the European Commission's technological neutrality requirement, capacity auctions do not exclude any type of technology. The auction is open to all capacity providers, including storage stations, who can contribute to supply security.

[8] Formal public consultation on the CRM design notes

Capacities may participate in CRM as individual CMUs or as aggregated CMUs of different delivery points. Participation eligibility criteria include the refusal of other variable subsidies during the delivery period. Typically, in the annual schedule of actions, an actor may submit the pre-qualification application to Elia roughly by end of Q2 in order to participate in the auction of Q4. Each bid is considered with its volume in MW, price in €/MW/year and capacity contract duration for a given number of delivery periods, which can be 1, 3, 8 or 15 years. Bid prices are limited by price cap determined by the ministry. After the auction algorithm clears the bids by applying a pay-as-bid auction clearing mechanism, the results are validated by CREG and a contract for the awarded capacities is signed with Elia. This leads to a new timeframe, the pre-delivery period in which the CRM gathers information on the ability of the asset to deliver the service. Penalties are due in case of delays or missing capacities.

The most suitable storage technology for participating in the Belgian CRM auction is Li-ion Battery Energy Storage. This technology has favourable characteristics such as short response time, high power and energy density, high round-trip efficiency (RTE), and low costs. Competing non-battery storage technologies are large-scale Pumped Hydroelectric Energy Storage and Compressed Air Energy Storage stations, however, both are not suitable in Belgium due to geographical restrictions.

Among 40 CMUs that received long-term contracts for 4.448MW of capacity through the Y-4 Auction, at least four were BESS projects, with 130MW / 540MWh output and storage capacity. The fact that three of those projects are 4-hour discharge duration systems is particularly interesting and shows that in Belgium it is suitable to have more than 2 hours duration BESS. This is due to the high secondary reserve prices, as well as the less aggressive cycling due to the longer discharge. The following table provides some interesting information on the results of the latest CRM auction.

Table 6: Y-4 CRM auction results for 2025-2026 delivery period

Auction and Delivery Period	Y-4 Auction organized in October 2021, for 2025-2026 Delivery Period
Weighted average Bid Price (in EUR/MW/year)	31.671,57
Highest Bid Price (in EUR/MW/year)	49.993,18
Total selected capacity (in MW)	4.447,7
Number of selected CMUs	40

Based on the above average price and derating factor of 36%, a 11.400 €/MW annual revenue can be estimated for a BESS plant participating in CRM.

Finally, in the following graph, the 'Energy-limited 4h' CMU corresponds to large scale battery storage; 30,48MW in total were submitted with a 100% success in selection. This shows that battery storage is a mature and competitive technology for participation in CRM. Smaller battery storage systems were also selected within portfolios of aggregated technologies (SLA CMUs).

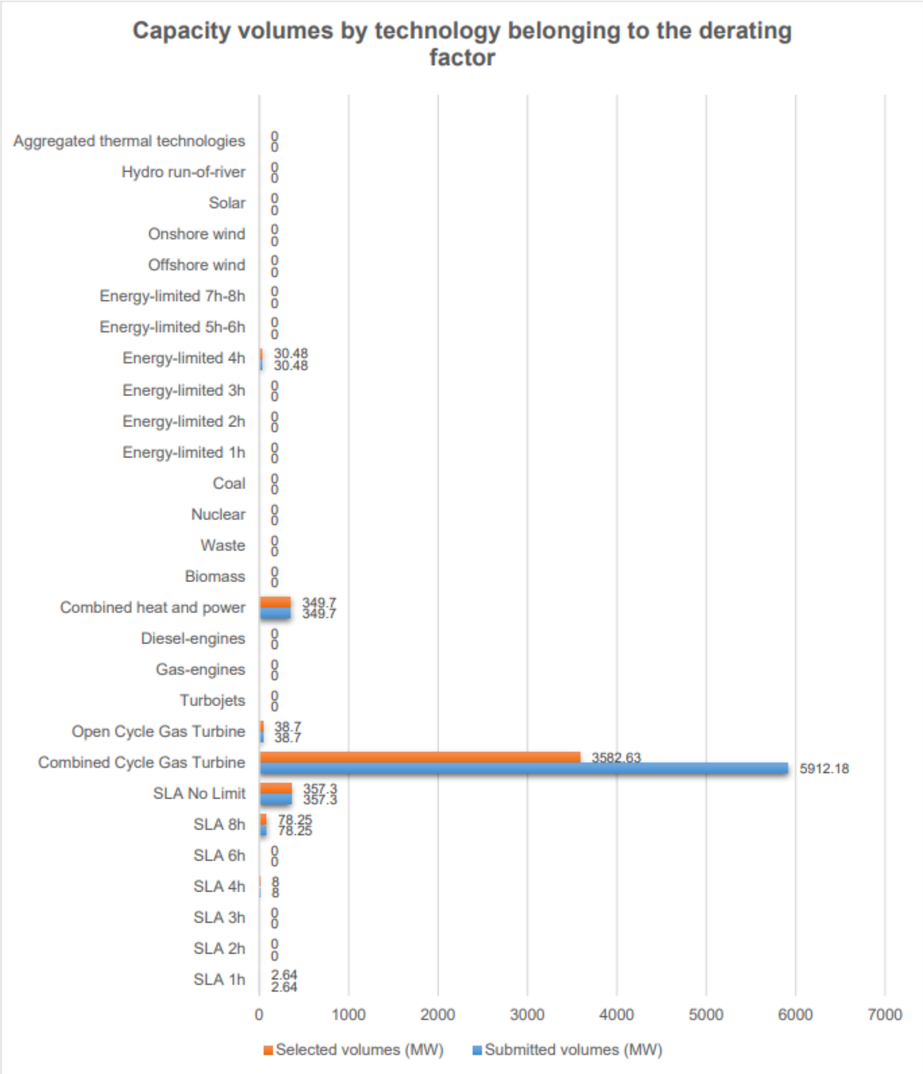

Figure 15: CRM awarded capacity summary for 2025-2026 delivery period (source: Elia)

5.3 Federal Government support

In view of its responsibility for security of supply, the Federal Government will consult with the Regions to identify the most flexible system available and ensure the stability of the system. The focus is on large-scale, long-term storage to bridge seasonal differences and provide a solution for long periods during which the supply of solar and wind energy is not sufficient. To bolster (energy) infrastructure, the legal certainty and investment security of projects must be supported by a simplified permit application procedure and by optimizing existing legislation on urban planning and the environment.

The Regions are furthermore working on a clear regulatory framework with a view to placing storage behind the meter or at the neighbourhood level and to delivering demand management across the distribution network. Furthermore, the development of energy storage is encouraged at different levels. The Federal Government manages the Energy Transition Fund, issuing a call for Research and Innovation (R&I) projects linked to areas under the federal government's responsibility (nuclear energy, transport networks, energy storage, offshore energy, etc.) every year. The scope of projects eligible for the fund will be extended to include regional competences. The fund is supported by an annual fee of 20 million € paid by the owner of the Doel nuclear power plant to the Federal Government in return for the extension of its operating licenses, until 15 February 2025 for Doel 1 and 1 December 2025 for Doel 2.

5.4 National Investment Pact

In September 2016, the Belgian Prime Minister launched a proposal for a National Investment Pact with the private sector to create public-private partnerships between now and 2030. The report was published on 11 September 2018; six 'strategic' sectors were identified, energy being one of them. The investment pact mentioned the development of storage facilities for heat and electricity as one of the investments required to enable the energy transition. These energy-related projects represent a total investment of 60 billion € between 2018 and 2030 (versus 150 billion € for the six strategic sectors). In general, the private sector will provide around 55% of the capital funding, with some of this funding to be spent on innovation, research, and development. [4]

In Flanders, the Flemish (Vlaamse) Agency for Innovation and Entrepreneurship (VLAIO) offers grants for Research & Development (R&D) projects, including support for development projects at an advanced stage of the innovation process (pilot phase). In addition, VLAIO also provides support through advice and training and by stimulating coordination and networking. VLAIO's grants cover the entire spectrum of R&I projects, including energy and climate (energy efficiency, renewable energy technologies, energy systems, energy storage, carbon capture, use and storage (CCUS), etc.), and are awarded following an evaluation based on the precise innovation involved and the economic added value created for Flanders.

Energy research is also a core part of Wallonia's energy commitments and regional expertise. The following energy storage technologies are one of the main fields of research: a) storage (daily and inter-seasonal), including batteries (and their recycling) and emergency power supplies, b) phase-change materials, c) compressed air storage, d) accumulators, e) hybrid batteries (lithium, redox-flow, etc.), and f) storage management tools.

6 Conclusions

Belgium is facing numerous challenges to its electricity system, today and even more so in the future when its nuclear capacities will be gradually phased out. All parties, such as the government, the regulators, the TSO and DSOs and other market parties are committed to strive for an even better functioning network. Towards this direction and with the rising penetration of RES, reliable and cheap energy storage will play a critical role to support and stabilize the network. While the EU has set high renewable energy objectives, it is also a firm believer that grid flexibility can and should be accomplished in a variety of ways, with energy storage being one of numerous viable options. In order to reach the European targets and maintain a stable grid, the Belgian electricity system will require using the full potential of RES, and their combination with BESS will be of high importance.

Because of the high initial cost of a BESS, its optimal functioning is critical, and this can only be accomplished by creating a sustainable platform for BESS participation in various electricity markets. Additionally, to fully realize the potential of energy storage, technological advancements must be accompanied by coherent policies that recognize the value of services provided by energy storage, particularly ancillary services. The extent to which energy storage can participate in the different electricity markets and services in a sustainable manner depends on the regulatory framework within which market design and tariffs play an equally important part. To generate steady revenue streams, creative ideas are necessary, as are answers to the uncertainties in legislation, rules, and prices.

In line with other European countries, Belgium has recently launched a capacity mechanism (CRM – refer to section 5.2) to economically support BESS investments. The CRM can provide a guaranteed multi-year annual revenue for a part of the BESS assets (considering the derating factors) that can be used for some financing, but a correct sizing of BESS assets must be undertaken by a prospective supplier before registering the plant for ancillary services or CRM, since Elia will automatically apply strict penalties on any missing volume compared to the one agreed upon.

On top of that, any BESS plants with at least 1MW of (aggregated) power can participate in the various available balancing products, such as FCR and aFRR, and gain significant revenues once they have demonstrated compliance with the respective technical requirements. Furthermore, participation of BESS plants in the spot markets means they can generate significant income by capturing the price spread in the electricity market and therefore benefit from price volatility, i.e., relative differences in market prices. It should be noted that for optimum revenue stacking of ancillary services and CRM with the spot markets, a sophisticated BESS plant controller (combining energy and power management) is necessary, coupled with a real-time optimization software.

From the discussion points this paper, the following conclusion can be derived: the optimal development of renewables goes hand in hand with a comparatively higher existence of BESS to fulfill the following network requirements:

- Stabilize and decongest the grid,
- Ensure security of energy supply, and
- Promote the energy transition to a cleaner energy future.

Finally, it is worth noting that the use of large-scale RES and storage stations highlight the challenges of setting high decarbonization targets for the country and Europe. The cost of the mechanism to unlock the necessary investments – if adequately designed – would gradually decrease as the energy transition evolves.

Pulsar Power has an extensive network of BESS specialists worldwide, who can provide independent technical advisory services in relation to asset optimization and development, project finance, technology selection, design and engineering, due-diligence, and construction management.

7 References

[1] – Elia's view on Belgium's Energy Vision for 2050, Elia, June 2017

[2] – European Market Monitor on Energy Storage, Delta-ee, March 2021, edition 5.0

[3] – Proposal for Storage Connection Requirements, Elia, 17 May 2018

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