DNV

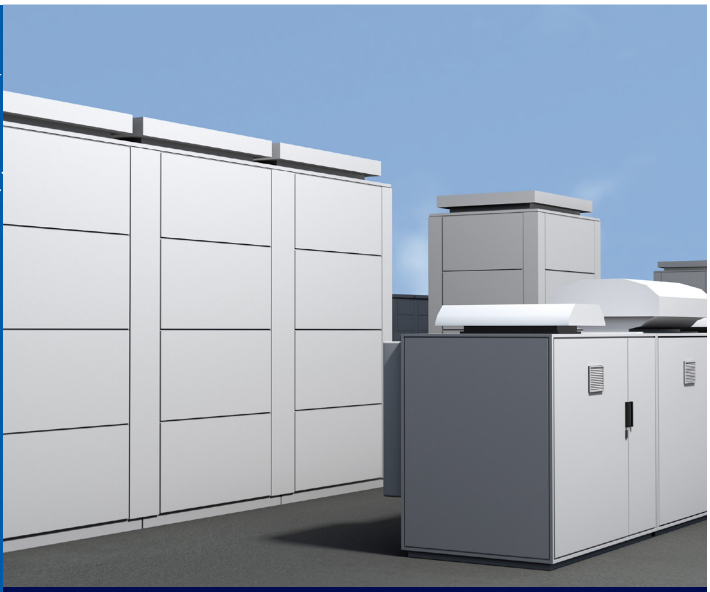
WHEN TRUST MATTERS

BATTERY ENERGY STORAGE SYSTEMS IN THE NETHERLANDS

Market opportunities & financing challenges

A joint publication with INVEST-NL

WHITE PAPER



Content

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

PURPOSE AND CONTEXT OF THIS WHITE PAPER

- The rise of power generation from weather-dependent renewables (solar and wind), combined with a major shift in demand towards increasing electrification, leads to new challenges in continuously balancing out demand and supply of electricity while maintaining overall system adequacy. An important solution for any mismatch, is the use of available “flexibility[1]“ to retain reliable and cost-efficient operation of the power system.
- Flexibility can come from different sources, like demand response (industrial and residential flexibility), increasing system integration (converting electricity to other energy carriers, such as heat and gasses) and more interconnection capacity that allows for more cross-border exchanges of electricity[2,3]. Additionally, an important direct source of flexibility for the electricity market, are battery energy storage systems (BESS) that can store and supply power to the grid almost instantaneously. The nature of BESS makes it interesting as flexibility source, as it facilitates near-real time system balancing.
- Hence, BESS can be deployed in a multitude of ways – grid-level or customer-sided (behind-the-meter). In the latter case, it may be for a large industrial site, or at household level. The economic potential (business case) of each storage system relies on the potential stacking of several/available revenue streams. Common revenue streams for all utility scale BESS are the wholesale and ancillary services markets. Developments on these markets and their opportunities for BESS are the focus of this white paper.
- Experiences with utility-scale BESS in the Netherlands, have so far shown that market revenues need to be combined with other sources of income for BESS-business cases to be successful. Such other revenues should mainly come from contracts to provide local grid (congestion) management services to network operators and/ or portfolio optimization services (e.g. through ‘peak-shaving’) for balance responsible parties.

  - Next to bilateral contracting for congestion management, Dutch network operators have developed a separate market platform for congestion management: GOPACS. GOPACS works in a way that is consistent with key European directives that relate to market-based mitigation of grid congestion and offers large and small market parties an additional way to generate revenues with their available flexibility and contribute to solving congestion situations. For GOPACS the grid operators collaborate with the ID market platform of ETPA. They are currently having talks with other market platforms to connect these to GOPACS as well[4].
  - GOPACS and its further development are not part of the scope of this whitepaper. But BESS developers should note that this platform and other opportunities for offering (local) grid and portfolio management services, are important sources of additional revenue streams for BESS.

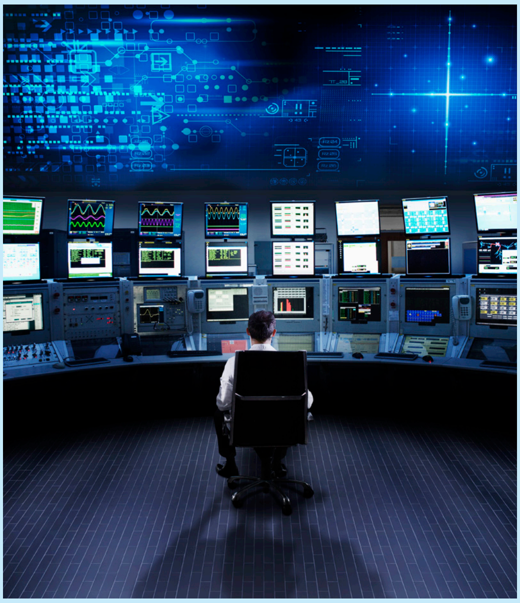
- According to ENTSO-E’s most recent Ten-year network development plan (TYNDP 2020), 750 MW of BESS is forecasted to be available in the Netherlands in 2030.
- In this context, DNV has been commissioned by Invest-NL to examine the Dutch wholesale and balancing market developments and the opportunities for BESS. This whitepaper highlights the current and (possible) future developments in electricity wholesale and balancing markets and the interactions between them. These insights are used to conclude on the most promising market opportunities for BESS.
- Finally, the paper presents some practical insights regarding improvements that developers can make in attracting investments.

[1] ‘Flexibility’ is defined in this paper as the short-term system response required to balance out the variability of demand and supply.
[2] ‘De mogelijke bijdrage van Industriele vraagrespons aan leveringszekerheid’, DNV, November 2020.
[3] ‘Flexibiliteit in de gebouwde omgeving: een wegwijzer voor ondernemers’, DNV & TNO, February 2021.
[4] Source: GOPACS website - About GOPACS - GOPACS

THE OPPORTUNITIES FOR BESS IN THE FUTURE DUTCH POWER MARKETS

- FCR and passive balancing currently offer the most interesting market opportunities for a BESS, given the short bidding blocks, fast response times and (sometimes) high price levels.
- Another promising market for BESS is FRR due to the relatively high income potential, albeit dependent upon actual activation. A risk for a BESS is that the activation is too long, requiring power beyond the energy content of the BESS.
- The ID market also offers some attractive potential for deployment of a BESS, especially as the trade volumes on this market can be expected to increase due to the increasing weather-dependency of power supply. Coupling with a market-based approach to solve congestions (GOPACS on ETPA) is an interesting development as it increases transparency about (resolving) congestions in the Dutch grid.
- Experiences with utility-scale BESS in the Netherlands, have so far shown that market revenues need to be combined with other sources of income for BESS-business cases to be successful. These income streams can come from (local) grid or portfolio optimization services. This will continue to be the case and optimizing a combination of these various revenue streams will help to improve the bankability of a BESS.
- Making the most of the price peaks on various markets and 'stack' value creation from different markets and services, requires a very smart bidding approach by the owner/ operator of the BESS to optimize its revenues, and meet all the obligations connected to different bids.

MESSAGE TO DEVELOPERS



- Consider business models that involve peak-shaving for renewable generation and/or congestion management services for network companies, besides looking for earning potential on wholesale and balancing markets. Potential to provide these types of services are closely tied to the physical location of the BESS.
    - Peak-shaving could help save grid connection costs and hence enable business cases for renewables that are sometimes limited by their connection capacity.
    - Congestion management is a temporary solution for grid operators that struggle to increase grid capacities but can yield interesting revenues for a BESS. Grid operators in the Netherlands have developed a platform (GOPACS) that offers a marketplace for congestion management services[5].
    - A further assessment of peak-shaving and congestion management (including the GOPACS marketplace) potentials for BESS are not within the scope of this white paper.
- Be alert to changes in the regulatory framework and/or the competitive environment, and (be ready to) act accordingly. It creates resilience in a business (offering short-term flexibility to the power sector) that currently offers attractive niche market revenue potentials. This is due to the limited volumes in the most attractive markets, and growing competition in the long run.
- Next to the 'stacking' of revenues in the Dutch marketplace, owner/ operators should also keep their eyes open for opportunities across country borders. While this whitepaper only focusses on opportunities on Dutch power markets, the supply of power or balancing services to other European countries is also possible. For example, FCR, ID and DA trade take place in international marketplaces.
- Develop smart trading algorithms and approaches to optimize 'value stacking' across markets, services and the obligations that come with them.

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[5] See: [About GOPACS - GOPACS]

OVERCOMING FINANCING CHALLENGES

Based on practical experiences with various BESS development projects, Invest-NL and DNV have developed the following (non-exhaustive) list of actions developers can undertake to increase their chances of successfully attracting investments.

- To build confidence and attract investments, it is important that investors are informed to (better) understand the potential revenue streams for the assets they are considering investing in.
- Developers that want to attract investments should develop a probabilistic approach to their business cases to help investors better understand uncertainties and their possible impacts in these cases.
- Help investors understand what the basic, ensured revenue streams will be, e.g. from bilateral arrangements or other (long-term) contracts that help to reduce business case uncertainties.
- Related to the previous point: Certain locations can offer additional revenue and/ or cost savings potential. It is important to consider and incorporate any such benefits into a business case.
- Ensure the availability of sufficient expertise for development and operation. With more experience and capabilities on the team, especially in determining dispatch and trading, an investor will have more confidence that a developer will reach targets and be able to develop a successful project.

MESSAGE TO INVESTORS

- BESS are flexible assets that can fullfil various roles in the developing power system. Consequently, they have different earning opportunities (please refer to the ‘Message to developers’ above) that will likely evolve throughout the lifetime of the BESS. To ensure sustainable revenue streams, it is important that owners/ operators are aware of these wide-ranging opportunities and are knowledgeable and flexible enough to maximize their income across a multitude of options.
- Thorough understanding is needed of the business case for each BESS, accounting for potential (balancing) market developments based on probabilistic analyses. Potential additional upside might reside in policy changes regarding current double taxation of the electricity stored and sold.

MESSAGE TO ALL READERS

This paper aims to provide the most up-to-date market insights and reflects on what they (could) mean for BESS. However, European wholesale and balancing markets are undergoing significant and rapid changes. This results in market evolutions such as the increased coupling of European wholesale and balancing markets, the harmonization of balancing arrangements across Europe, and allowing new technologies and business models onto these markets. Qualitative and quantitative insights about e.g. future price developments are therefore required to be updated regularly.

1 Introduction

This paper aims to contribute to building a better understanding of potential revenue streams for a Battery Energy Storage System (BESS) on the Dutch market. It should help developers to build better substantiated business case propositions and build confidence in these cases among potential investors.

SCOPE

Focus here, is on the more market-based revenue streams that can come from the provision of balancing services (FCR, FRR, voluntary balancing), and from wholesale market trade on the Day-Ahead (DA) or Intraday (ID) market.

BESS business cases in the Netherlands depend (at least partially) upon revenues from ancillary services for the system operator (e.g. congestion management or reactive power provision to manage grid capacity or voltage levels) or from peak-shaving (e.g. to reduce connection or imbalance costs) for portfolio optimization. As these revenue streams are often dependent upon the location of the BESS in the grid or the specific portfolio to which the BESS is linked, these revenue potentials vary per project and asset. Therefore, these are left outside of this paper's scope.

An important point to mention here is the fact that a market-place for congestion management has recently been developed: GOPACS on the ETPA marketplace. This offers a market-based approach to resolve congestion management challenges in the Dutch grid, linked to an ID trading platform. Although this has not been analysed in-depth for the purposes of this paper, it is an important development that can enable further market-based revenue streams for a BESS.

The figure below illustrates which potential revenue streams for a BESS are in and out of scope here.

OVERALL VIEWS ON BESS ON THE DUTCH MARKET AND BUSINESS CASE POTENTIAL

According to ENTSO-E's most recent Ten-year network development plan (TYNDP 2020), 750 MW of BESS is forecasted to be available in the Netherlands in 2030. These batteries are able to supply the different power markets in the Netherlands with fast-response capabilities to (sudden) variations in available power. The quick response times of these assets can particularly provide (part of) the short-term balancing[6] contributions required to keep the system going on the short-term (within an hour of real-time).

Appendix 1 further describes DNV's outlook on the development of flexibility needs on different timescales in the Dutch power system.

BESS may very well contribute to trade and balancing services on especially the ID and balancing markets. To evaluate the economic potential of these markets, DNV has conducted a study on the historical developments in terms of market changes, volumes and prices of the DA, ID and balancing markets. Next to current economic arbitrage opportunities for BESS, we foresee continued future opportunities in delivering services such as grid congestion management or peak-shaving for portfolio optimization. Further views and direction on different ways of using BESS in the Dutch energy system, are also provided in the report on 'Smart Grid Ready Energy Storage', drafted by TKI Urban Energy[7].

Choice of location can be crucial for a BESS: apart from the fact that certain locations will offer greater opportunities for revenue streams from services like congestion management and peak-shaving, installation and grid connection costs may be reduced by installing a BESS on, or close by, already existing connection points. E.g. on the location of a (soon to be de-commissioned) power plant. In such a case, the already available infrastructure could be embraced and leveraged.

Besides any market and regulatory opportunities and risks, and the possible up-sides of choosing a certain location, the success of any business case for BESS in an environment with growing competition will strongly depend upon the capabilities of the people operating the asset and trading its capacity and energy across different markets and services.

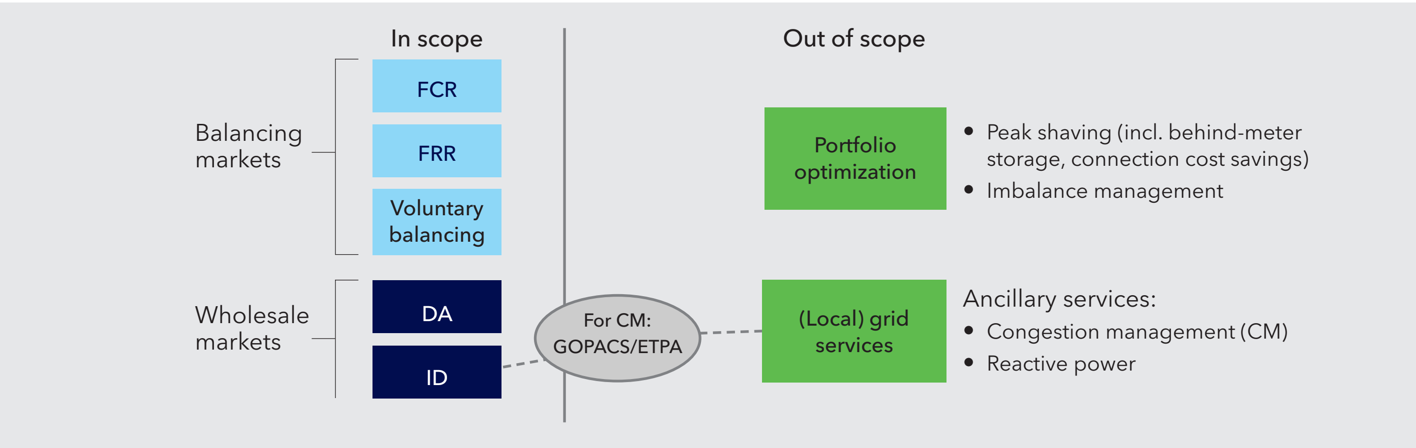

Figure 1: Markets in and out of scope in this white paper

[6] In this case, the term 'balancing' refers to the short-term balancing capacity and energy, as required by the TSO. This relates to the short-term imbalances in the market which are typically solved by (passive) balancing, FCR and FRR.

[7] 'Smart Grid Ready Energy Storage', TKI Urban Energy, February 2020.

2 Wholesale markets

Electricity is traded on wholesale markets as well as bilaterally. The wholesale market consists of the DA market and the ID market. The volume traded on the ID market is increasing, most likely because of additional forecast errors due to increasing generation with weather-dependent renewable technologies.
This chapter discusses the main features of wholesale markets and their outlook.

2.1 History and main features

In this section, the main features of the DA market, the ID market and the passive balancing market will be provided.

2.1.1 Day-ahead market

In the Netherlands, electricity is traded on the DA market in hourly blocks. Based on predictions of expected demand, suppliers provide demand curves to the exchange daily. Based on their generation portfolio, producers provide a supply curve, which can include a prediction of expected renewable generation. The market price and volume are automatically determined by matching the demand and supply curves, after which all parties that are matched will receive the same hourly clearing price.

The historical developments of the DA baseload[8] prices in the Netherlands present an increase in the period of 2017-2018 driven by an increment in commodity prices and emission costs. In 2019, the prices decreased with respect to previous years, and the same is seen in the period until October 2020. The decrease in prices is affected by the higher availability of RES generation, lower fuel prices and the effect of COVID-19 in the year 2020, which resulted in lower demand. BESS can profit from the DA market by capturing the hourly spreads. In this regard, Figure 2 shows the volatility of the Dutch DA market. 5% Of prices were above ~ 80€/MWh in 2018. From that moment onwards, price levels have dropped, with 5% of the hours (until October 2020) having a price higher than 50 €/MWh in 2020.

2.1.2 Intraday market

The ID market enables the trading of electricity up to minutes before the moment of actual delivery. This has been developed to facilitate ongoing trade to avoid imbalances that could be derived from just the DA trades. In the Netherlands, the trading procedure of the ID market, and therefore the ID price, is organized in a continuous trading, procuring trades up to 5 minutes before delivery[9]. Various platforms offer the possibility to trade ID products: Nord Pool (only for ID cross-border trading with Norway) and EPEX Spot have been around for a while. This year (2021) these were joined by the recently developed marketplace ETPA[10], which aims to be the go-to marketplace for both large- and small-scale actors on the (Dutch) power market. Additionally, ETPA's ID trade platform is collaborating with Dutch grid operators to run the GOPACS marketplace for congestion management[11].

The ID market volumes of the Netherlands have been increasing over the past years (2016-2019), with 57% more volume traded in 2019 than in 2018. Regarding ID prices, 2016 and 2017 showed ID (ID) prices mostly higher than DA (DA) values, i.e. more hours of the year with higher ID prices than DA prices. However, this trend has shifted in 2018 and 2019. In those years higher DA than ID prices were experienced more frequently. Moreover, 2019 presented smaller difference between DA and ID prices than 2018, with an increased number of hours with low price differences[12].

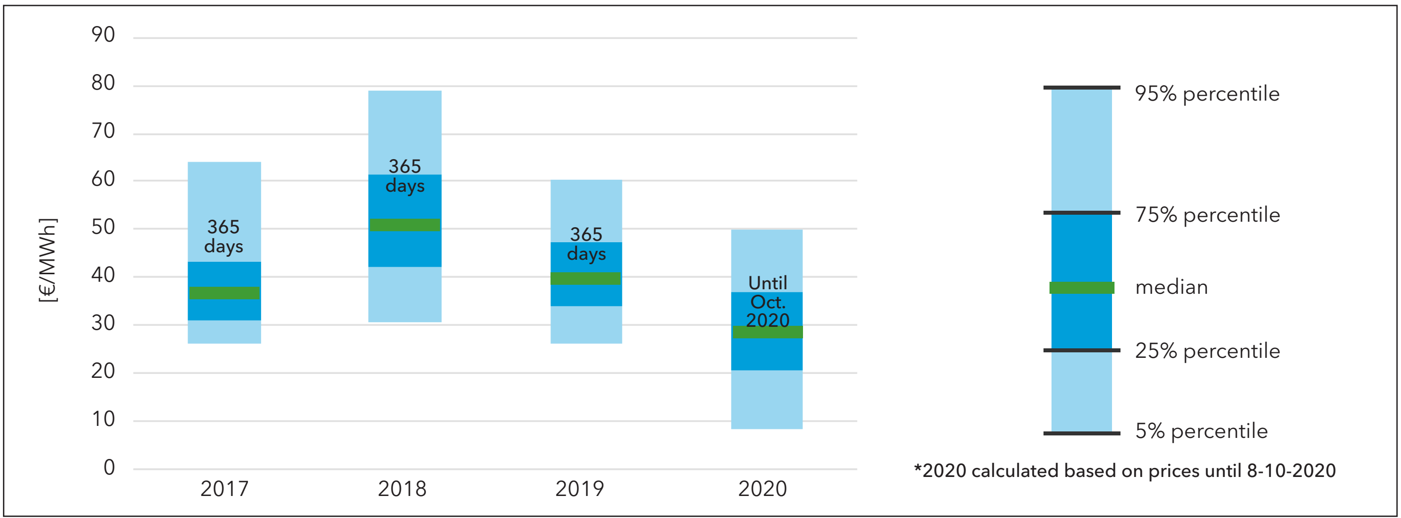

Figure 2: Historical annual price range on the DA market in the Netherlands
Columns in this graph are based on all the DA-prices that have occurred in a year and the price distribution is therefore based on 8760 hourly values (apart from 2020, which only incorporates values until October of that year).

8 The term 'baseload price' represents the average of all spot market prices in a year.
9 Trading on EPEX Spot, EPEX Spot, 2020.
10 See: Home (etpa.nl)
11 GOPACS and congestion management are not within the scope of this white paper, but the linking of marketplaces for ID trade and congestion management can be important for BESS.
12 Annual Market Update, TenneT, 2019. More recent detailed insights on ID prices in the Netherlands are not publicly available. They need to be purchased from EPEX.

The number of trades is higher during evening hours when electricity consumption increases. The amount of trades doubled in 2019 (for all delivery hours) with respect to 2018. However, the average traded volume increased by only 57%, which indicates that lower volumes per trade were made.

The ID market represents the opportunity for balancing service providers (BSPs) to use BESS to optimize/balance out portfolios closer to real-time.

2.2 Market outlook

In this section, we present a market outlook for the DA and ID wholesale market until 2030.

2.2.1 Day-ahead and Intraday market

DNV's Power Price Forecast for the Netherlands shows an increase in the average power price from 2021 until 2025. There is a reduction of average prices in 2020 and 2021 in comparison to 2019, due to a decrease in electricity demand and commodity prices as an effect of COVID-19. Gas-fired generation is dominant price-setter in the period 2025 – 2030. From 2025 onwards, the increase in renewables combined with a decrease in thermal generation capacity leads to a decrease in baseload power prices and an increase in price volatility (both hourly and monthly variations).
Yet in the period between 2025 and 2030, the forecasted baseload power price shows only a small decline from about 46 to 43 €/MWh: gas-fired power plants still dominate the price-setting until 2030, regularly being the marginal generators in the system. Monthly average prices start showing a subtle seasonal impact of renewable generation starting from 2030, as RES installed capacity increases and the (pricing) impact of RES gradually increases.

Average power prices are, however, not relevant for a BESS when it comes to market trades. The key for a BESS's revenue potential is in the difference between high and low prices within a certain timeframe. Figure 3 below shows the evolution of maximum daily price variation as calculated by DNV based upon detailed market simulations of an evolving European power system[13].

A higher frequency of hours with high and low prices is observed from 2025 onwards. This increment in price variability is influenced by the increase of renewable generation in the Netherlands and its neighbouring countries, together with a decrease in controllable supply, which introduces a more intermittent generation pattern and fewer (controllable) sources to balance out supply and demand.

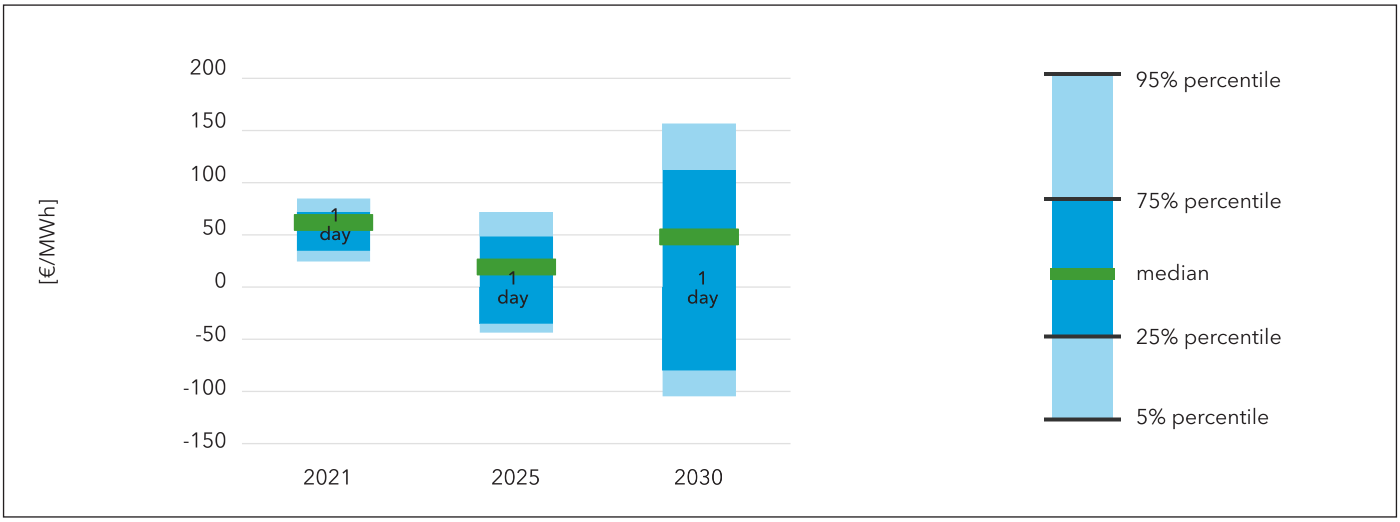

Figure 3: Maximum daily price range on DA markets in the Netherlands (2021-2030) as forecasted by DNV using her European Power Market Model. Each column represents the day in the year that shows the highest difference between minimum and maximum price levels.

[13] These simulations are performed using DNV's European Power Market Model that optimizes future power supply on an hour-by-hour basis accounting for the evolving European power supply. This means the model incorporates the foreseen system development and the effects of increasing system dynamics (weather profiles, demand response, interconnections, et cetera) based upon leading national (governments, TSOs, research institutes) and European (e.g. ENTSO-E) sources.

The growing penetration of renewables will likely result in larger ID trading volumes as the weather dependency and the resulting uncertainty related to these generation sources will make it necessary to trade more in shorter term. Additionally, more participants are expected in the ID market as regulatory efforts are being made to enable the entry of new flexibility solutions and business models into the wholesale market. These include for example smart charging, small-scale (households) and large-scale (industry) demand response[14] participation and potentially vehicle-to-grid technology[15].

As dictated by the Directive (EU) 2019/944 all member states should enable their regulatory frameworks to allow independent aggregators in all markets and other new business models, such as energy communities. The new ETPA marketplace is aimed at enabling this, including the enablement of market participation by owners of relatively small-sized assets that can supply flexibility. These kinds of developments will unlock more energy sources, including demand response capacity from the residential and industrial sector. This growth in participants and technologies on the wholesale market(s) will increase competition and liquidity in both the DA and ID market.

Regarding price differences between DA and ID prices, following the historical trend, higher DA prices than ID prices are experienced more frequently. DA trades might account for the risk of using less accurate predictions, which could imply higher (imbalance) risk premiums in pricing. The increase of renewables in the generation portfolio places more focus on the importance of generation forecasts of such assets, to deliver the DA trades and reduce imbalance risks. Therefore, better RES and load forecasts are expected in the future, resulting from further improvements of weather predictions and more detail in renewable generation forecasts: through more detail in wind farm generation assessments for example, e.g. through wind power forecasting on a scale of 1 km^2 rather than 30 km^2 and more use of actual measurements from the wind farms themselves. This increasing accuracy and importance of predictability can result in further convergence between DA and ID prices. However, the ID market will continue to provide a more accurate, short term answer to system needs.

[14] Also see: 'De mogelijke bijdrage van industriële vraagrespons aan leveringszekerheid', DNV, November 2020.
[15] An overview of the Vehicle-to-grid landscape by DNV, is available for download on: https://www.dnv.com/Publications/v2g-a-market-overview-165866

3 Balancing services

The transmission system operator (TSO), makes use of ancillary services offered by market parties to fulfil her main task of operating and continuously balancing the power grid. The ancillary services are divided into five services, which can be used by the TSOs according to their obligations and regulated tasks.

In figure 4, an overview of the various ancillary services is provided. The focus of this study is on balancing reserves, which are required in case real-time power frequency imbalance occurs. Thus, balancing reserves are responsible to provide a constant power flow with a stable frequency of 50mHz that results in a balanced state of the grid.

This Chapter provides an overview of these balancing reserves by describing the history and their main features. Also, an outlook is provided on the development of both types of balancing reserves depicted in figure 4: Frequency Containment Reserve (FCR) and Frequency Restoration Reserve (FRR). Next to these balancing reserves, the Netherlands has the so-called voluntary or passive balancing scheme. This form of balancing is also analyzed and presented in the next pages.

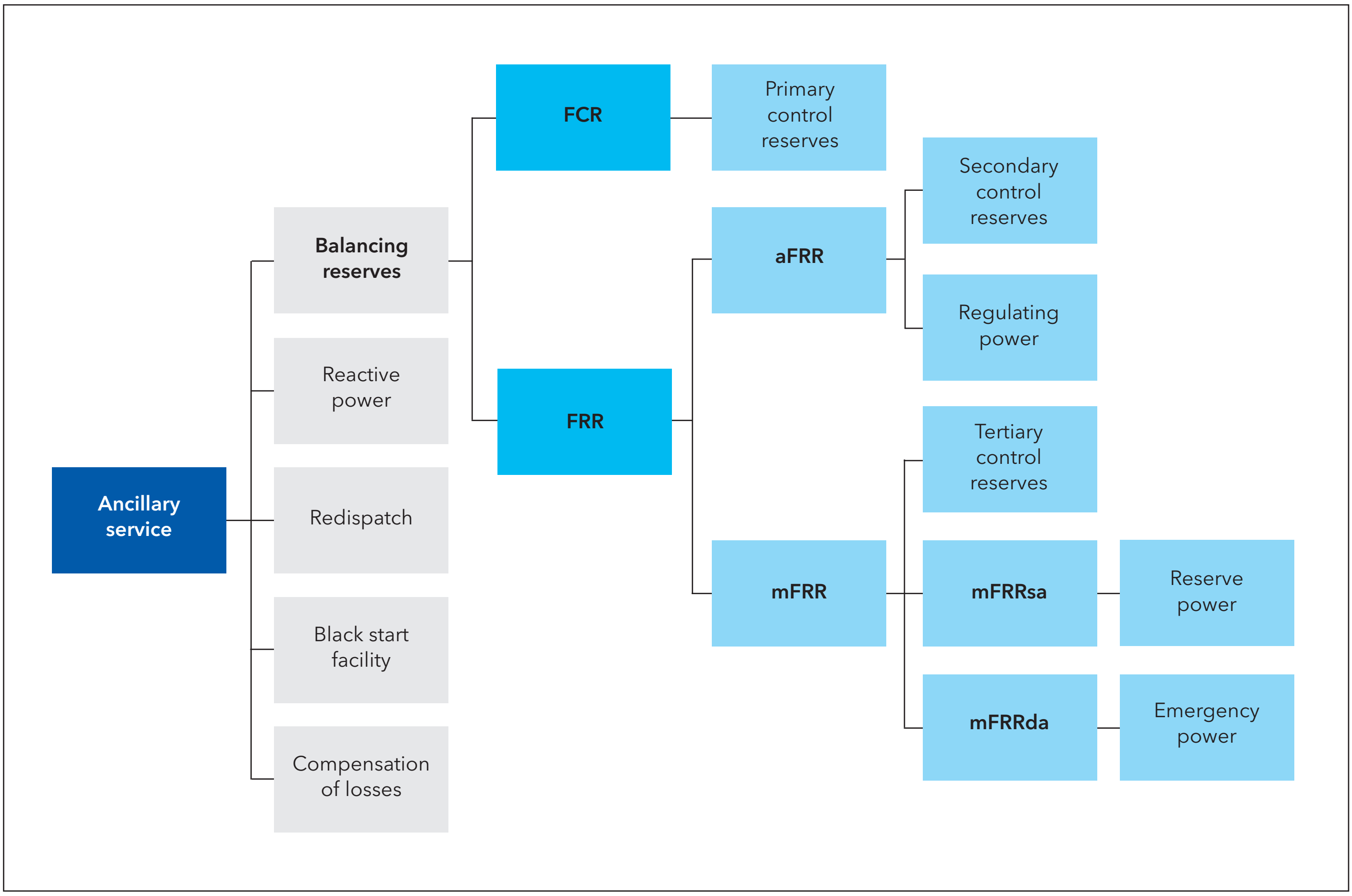

Figure 4: Overview ancillary services with a focus on the balancing reserves

3.1 History and main features

The different forms of balancing applied in the Netherlands, are presented in more detail here.

3.1.1 Frequency containment reserve (FCR)

Frequency containment reserve (FCR) represents primary regulation control which automatically ensures a constant ratio between frequency change and power change within a maximum time period of 30 seconds. The aim of FCR is to stabilise frequency deviations in the interconnected (European) high-voltage grid, regardless of the cause and location of the disturbance. Primary control of the balancing services is procured internationally, but each participating country contributes its own share of FCR volume. For the Netherlands, the FCR capacity contribution towards the total continental Europe synchronous area resulted in around 3.8% of the total demand in 2020 which equals 113 MW[16].

TSOs of the interconnected FCR scheduling area organise daily "common public auctions" in 4-hour blocks, with gate closure at 3pm on the day before (D-1). Although procured internationally, a minimum of 30% must come from suppliers (referred to as Balancing service Providers or BSPs) with connections to the countries Load Frequency Control (LFC) area[12]. Reimbursement is based on marginal pricing and thus, depending on the highest awarded bid[17]. The minimum bid size is 1 MW whereby the volume can either be delivered from a "single" reserve providing unit (RPU) or from a "pool" reserve providing group (RPG) that combines units. This can be beneficial for a pool of small-scale batteries or a large battery with limited maximum delivery capacity. The FCR offers require a full activation time of 30 seconds for the allocated volume. Further, the BSP portfolio must be able to respond with 100% of its bid capacity for at least 15 minutes in case of a frequency deviation of 200 mHz, referred to as full activation deviation (FAD). Energy-limited resources (e.g. batteries) demand for some special requirements, such as clear documentation of charging limits, self-discharging, ageing and the fact that the contracted capacity must be fully available no later than two hours after reaching the insensitive range again.

Recent changes in FCR systematics:

- Due to the daily auction per July 2019 and replacing pay-as-bid with marginal pricing, prices became much more variable. On average however FCR prices decrease.
- Per July 2020, a 4-hour bidding block was introduced. This again increased the price volatility, but average prices keep declining.
- Since 2016 batteries active on the FCR market.
- Since 2018 aggregation of capacity is possible through a BSP.

3.1.2 Frequency Restoration Reserve (FRR)

The TSOs activate FRR consecutively to FCR to gradually replace and thus freeing up the original FCR capacity again. It is used for maintaining real-time power and frequency balancing after an event of power imbalance whereby the TSO makes use of regulating and reserve power offered by market participants (BSPs). There are three distinct FRR mechanisms with different characteristics: the automatically activated FRR (aFFR), which represents the secondary control reserves; the manually activated (mFRR), representing the tertiary control reserves, which is divided into direct activated (mFRRda) and scheduled activated (mFFRsa) reserves.

3.1.2.1 AUTOMATICALLY ACTIVATED FRR (aFRR)

As a BSP, there are two possibilities to enter the aFRR market:

1. Contracting capacity: contract with TSO to make capacity available for a certain period.
2. Bidding: bidding in with a certain amount of capacity for a certain period. Voluntary bids are allowed.

All activated FRR bids (aFRR/mFRRsa/mFRRda) share the same imbalance price (deployment price) that is defined as the highest/lowest bid price (upwards/downwards) of all activated bids within an imbalance settlement period (ISP), also referred to as marginal price setting according to the merit order. In case of a positive imbalance price in upward regulation, the BSP receives money. And if negative, the BSP has to pay monetary compensation. The opposite occurs for downward regulation[18]. There is no significant correlation between activated regulating volume and bid price.

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[16] Ancillary Services, TenneT, 2020. Also see: https://www.tennet.eu/electricity-market/ancillary-services/
[17] FCR Manual for BSPs, TenneT, 2020.
[18] Imbalance Pricing System, TenneT, 2020.

In case a BSP has a contracted aFRR capacity, it has to bid at least the minimum of 1 MW and specify for either upward or downward regulation. Voluntary bids require a minimum as well of 1 MW capacity. Further, the BSP with a contract is required to bid a volume minimally equal to the contracted value. Otherwise, the TSO is entitled to submit bids on behalf of the BSP for the remaining capacity and among all ISPs of the day[19]. The offered capacity (bid) requires an up- or down ramp rate that is equal to at least 7% of the bid volume per minute. The contracted power has no priority over the regulating power based on voluntary bids. The selection is only based on the bid ladder that is determined by the bid price only[20].

The TSO organizes daily tenders where BSPs can enter capacity contracts for aFRR. Gate closure is the day before delivery and bids can be revised up to 30 minutes before the ISP. As of 1 January 2021, it is no longer possible to offer symmetrical contracted capacity. aFRR bids must now be done separately for upward and downward regulation. Contracted aFRR receives a capacity remuneration for the volume auctioned in addition to the imbalance price if activated. Voluntary bids receive the imbalance price if activated (see 3.1.3).

3.1.2.2 MANUALLY ACTIVATED FRR (mFRR)

Occasionally, in situations with significant system imbalance during long-lasting periods, the TSO activates mFRR. These reserves are activated manually and on an infrequent basis. The aim of mFRR is to free-up the previously activated aFRR which then can become available for future imbalance disturbances. mFRR is divided into the scheduled activated mFRRsa that serves as the reserve power, and into the direct activated mFRRda, representing the contracted emergency power.

mFRRda participation is conducted through contracted capacity by daily auctions. An individual supplier can only have an mFRRda contract on one direction (not symmetrical)[21]. The contracted quantity offered requires a minimum of 20 MW and must be available for the entire agreed contract period (at least 60 minutes). Revenues from mFRRda are the contracted capacity remuneration and the imbalance price if activated.

mFRRsa participation occurs through voluntary bids and must prolong for at least one ISP. The TSO organizes daily tenders with gate closure on the day before delivery and bids can be revised up to 30 minutes before ISP. Minimum bid size is 1 MW. If activated the mFRRsa provider receives the imbalance price.

Both mFRRda and mFRRsa are activated a reduced number of times, less than 1% of the annual ISPs. The reduced activation frequency and the required long availability in the case of mFRRda, makes these services not a feasible market for batteries.

[19] Product information automatic Frequency Restoration Reserve, TenneT, 2020.
[20] Product information automatic Frequency Restoration Reserve, TenneT, 2020.
[21] Product information mFRRda (incident reserves), TenneT, 2019.

3.1.3 Passive or voluntary balancing[22]

The Dutch market design enables market parties to voluntarily contribute to maintaining the system balance based on actual imbalance prices, in parallel with TenneT activating contracted regulating power (FRR; see 3.1.2) and/or imbalance netting (through IGCC; International Grid Control Cooperation).

For this purpose, TenneT publishes near real-time balancing information (i.e. a snapshot of the highest active bid and activated capacity) and settles imbalances for each balance responsible party (BRP) on 15 minute basis, based on the highest bid that has been activated during this Imbalance Settlement Period (ISP). The publication of this information provides an economic incentive for each BRP to assist in contributing to maintaining the system balance, even when the result is that they deviate from their own E-programme. If the price signals and consequent market behaviour works as it should, it results in BRPs adjusting their portfolio in such a way that this helps to alleviate system imbalances. The amount that they contribute is settled against the imbalance price[23] for that ISP and they are left with a surplus equal to the price delta for each MWh[24]. Vice versa, each BRP may take financial hits if its portfolio position is not contributing to the system balance.

By using an imbalance price predictor based on the near real time information from TenneT, flexibility from a BESS can be exploited to economically optimize the actual amount of power consumption (MWh) based on the imbalance price (do less or more when the price is right).

Imbalance prices have decreased over time since 2015. While the imbalance prices tend to decrease, a trend can be seen until 2017: the imbalance price delta is higher if the system is in 'short' state and lower if it is in 'long' state. The 'Short' state implies a need for upwards balancing energy to stabilise the system. This behaviour could be due to a higher number of participants able to provide downward balancing energy than the ones that could provide upwards services[25]. In 2018, the difference in price delta between short and long system states, lowered. Both in 2018 and 2019, an almost equal price delta is observed for short and long system states[26].

From 2017 onwards, regarding imbalance price delta spreads, the price delta of large imbalance volumes has been higher (including negative values) compared to the price spread of low imbalance volumes. This effect corresponds to higher incentives to stay balanced, or to avoid further system imbalances when larger imbalance volumes are experienced.

The voluntary balancing mechanism provides BESS with opportunities to economically optimise power trades by accessing close to real time data on prices and volumes, and benefit from this additional revenue potential by offering additional (voluntary) balancing response power to the market. If the BESS owner is not a BRP, it is important for him to align with his BRP on how revenues and costs will be shared and transferred to the asset owner.

[22] Description adopted from a (unpublished) paper by TenneT TSO: "Flexibility Monitor - Quantitative Analysis of Flexible Capacity in the Dutch Electricity System - A First Round Inventory", by A. Tijdink and F. Wiersma, August 2019.

[23] The IGCC merit order determines the imbalance price at any moment. TenneT TSO is allowed to deviate from this price if the situation requires this, e.g. based on urgency.

[24] Although there is a price for every ISP, it is not the imbalance price itself that is the incentive for a market party to act upon. Generally, the imbalance price is always compared to the DA price to reflect the market incentive or value from the electricity extracted or fed in into the grid. For example, if a portfolio is 1 MWh short, the DA price for this ISP was 50 €/MWh while the imbalance price 40 €/MWh, market parties can gain 10 €/MWh. After all, if it had to buy this 1 MWh shortage on the DA market it would have paid 50 €/MWh, whereas leaving this as an imbalance only costs 40 €/MWh. Therefore, it is the difference between the imbalance price and the market price (imbalance price delta) that provides the incentive for market participants to act and to provide beneficial contributions to the system balance or to guard against adverse contributions.

[25] Market Review, TenneT, 2017.

3.2 Outlook

Balancing reserves are experiencing a reduction in contract durations to increase market participation and liquidity. FRR has reduced its contract period from monthly to daily. From mid-2020, FCR is auctioned based on 4-hour blocks for delivery the next day (instead of daily auctions). Since then, the peak price per bid has significantly increased. This could be the result of relatively limited competition between Dutch suppliers of FCR in these timeframes. Nevertheless, DNV foresees that overall, the FCR prices in the Netherlands will gradually converge to the (lower) levels that can be observed in surrounding countries, based on increasing availability of possible FCR suppliers on the Dutch market, increasing liquidity over time.

This change towards shorter bid periods could imply a decrease in the imbalance volumes as more accurate FCR activation is procured (based on better weather forecasting and availability of cross border capacity). Additionally, price spreads could be lower, as historically, lower volumes show lower spreads of imbalance prices.

Traditionally, FCR is delivered by conventional generation units. They reserve a part of their capacity to be able to ramp up or down depending on the grid frequency. This incurs opportunity costs, typically lost income on the DA and ID markets (assuming they deliver FCR energy neutral). DNV estimates that the ceiling price for both FCR and FRR will therefore be largely set by the clean spark spread of existing conventional gas fired units, over the years to come. Towards 2030, DNV foresees this will still be the case but for fewer full load hours. When renewables have an even more substantive role, opportunity costs to bid into the DA market will further lower. Beyond 2030, the moments in which gas fired capacity is price-setting decrease further, as RES become more dominant. This results in the fact that there will be fewer opportunities for conventional power plants to earn back annual costs. This will increase the (economic) pressure on these plants and may further drive up peak (and the ceiling) prices used for reference in the long run. This can also be seen in the maximum prices depicted for 2021 and 2030 in Figure 3. They indicate an increase in peak prices over the coming decade, that is caused by rising marginal costs of generation (due to rising fuel and CO_2-prices). A potential additional effect of changing trading behaviour on (peak) prices has not been analysed further.

3.2.1 Passive or voluntary balancing

In a system with growing renewables generation, the volumes traded in the ID market are expected to increase in the coming years, to balance out portfolios in response to updated weather projections and generation forecasts closer to real-time. As a result of increasing ID trading, imbalance volumes may decrease. However, in spite of more ID trade and improving generation forecasts, higher renewables generation and last-minute weather changes could still cause large short-term imbalances due to the sheer volumes of solar and wind power generation in the future system. This can have sudden impacts upon the need, available power, and the resulting price levels for passive balancing in the future. Despite improving projections and forecasts, certain last-minute disruptions may not be foreseen and catered for through ID trades. Such unforeseen disruptions on the very short-term may result in scarcer, but (very) high peak prices for passive balancing, from which a BESS could profit.

As an example, when the system has a high dependence on solar generation, it may very well be that a suddenly passing cloud unexpectedly decreases generation, because the affected solar panels immediately loose power output. With solar PV, this effect of sudden changes in the available weather resource (direct sunlight affected by passing clouds) is more direct than in the case of dropping wind resources; as far as sudden changes in available wind power are not forecasted, wind turbines will still have some momentum in turning and generating power if the wind suddenly disappears.

Regarding imbalance market price spreads, similar to what has been observed in the past years, the price spreads can be influenced by the change in fuel prices. Growing participation in IGCC (International Grid Control Cooperation) is another factor that influences imbalance prices: an increase of TSOs exchange of imbalance power can help to reduce imbalance volumes and prices, although a further increase of these exchanges will also require more cross-border cable capacity to be developed.

Note, passive balancing is not in line with EU Guidelines as it allows market parties to go into an imbalance position with their own portfolios. This makes it uncertain whether this passive balancing regime can last in the Netherlands. Should it be abolished, it is likely that the imbalance volumes on the Dutch market increase, likely also increasing price levels for other balancing products.

4 Battery trading opportunities

The Dutch balancing market is developing towards an increased bid frequency: from weekly to daily bids for FRR contracts and from daily to 4-hour blocks for FCR bids. Shorter auction times can be beneficial for distributed energy sources like battery energy storage systems (BESS).

The shorter times facilitate that BESS can ensure the availability of the contracted capacity for the entire period. This shift towards more frequent auction periods could introduce new market participants, thus increasing liquidity, competition and price efficiency[27]. Given the relatively small size of these markets (see table on next page) and the increasing amount of assets that can supply the required services (including electric vehicles and other forms of demand-side flexibility) there is a risk of these markets becoming saturated over the next decade.

Opportunities on the DA and ID wholesale markets are in using price arbitrage between low prices for buying, and high prices for selling stored power. A strong commitment (high volumes) dedicated to trade on the DA-market may not be the best option to choose, as the price formation on all the other markets (ID and balancing) still need to occur for delivery in the same time frames. Therefore, the ID-market will likely be more attractive for a BESS, despite historically higher price levels on the DA-market (also see 2.2.1).

Although, besides balancing services, other ancillary services for system operators are not within the scope of analysis for this whitepaper, securing an income from this kind of services is generally crucial for a BESS on the Dutch market. One development to highlight in this respect is the development of GOPACS and the connection to the ID marketplace on ETPA. This better enables a market-based approach to managing congestions in the grid. At the same time, owners/operators of a BESS can profit from a much greater transparency about where and how big congestion challenges throughout the country are.

The table on the following page lists the relevant characteristics for BESS participation on each market. FCR is presented as a currently attractive model (bid for 4-hour block on next day should be defined on D-1 at 15h), and additionally, further earning opportunities can be pursued through voluntary balancing. Options to also bid into other markets/ services also depend on the pre-qualification that should be discussed with the TSO; There could be trading opportunities in the ID or DA market while the FCR block time arrives. Under certain conditions, it may also be allowed to offer load management services (e.g. congestion management or peak-shaving), while providing FCR. It should be noted that the battery must be in the correct state of charge (50%) to fullfil FCR requirements by the time FCR is activated.

Further views and direction on different ways of using BESS in the Dutch energy system, are provided in the report on 'Smart Grid Ready Energy Storage', by TKI Urban Energy[28].

[27] 'Distributed energy resources and the organized balancing market: A symbiosis yet? Case of three European balancing markets', Poplavskaya, & Vries, d. (2019).
[28] 'Smart Grid Ready Energy Storage', TKI Urban Energy, February 2020.

	AUCTION PERIOD	AVAILABLE TIME	REVENUE STREAMS	VOLUME AND PRICE INSIGHTS (2020 UNTIL 27 SEPTEMBER)	REMARKS	SUITABLE MARKET FOR BATTERIES?
FCR	4-hour blocks (closing date is day before, D-1)	Full activation time is 30 sec. Full availability of min. 15 mins. (ISP)	Contract	Contracted volume: 113 MW	Batteries (especially Li-ion batteries) are more feasible for FCR than FRR because of their limited energy content. EV Smart charging can be a competitor. V2G can be competitor after 2030.	++
Passive balance	No auctions, daily imbalance invoice	15 mins. (ISP)	Imbalance price delta	Volume: n.a. Avg. imbalance price delta: 16.4 EUR/MWh (2019)	Close to real time information on imbalance volumes and prices is published. Opportunity to economically optimise BRP portfolios by contributing to system balance.	++
aFRR	Daily auctions (closing date for offers is day before (D-1) and can be revised up to 30 min. before ISP)	Per 15 mins. (ISP) Ramp-rate is 7% per minute of bid volume	Contract & bids (voluntary bids allowed)	Contracted volume: 310 MW Activated volume: *Upwards* 788 GW *Downwards* 741 GW Avg. contract price: ~6.5 EUR/MW/h (2019) Avg. bid price: *Upwards* per activated ISP is 46 EUR/MWh (max. 713 EUR/MWh) *Downwards* per activated ISP is 10 EUR/MWh (max. -461 EUR/MWh) Max. earning potential: 150,443 EUR/MW*	Relatively high income, dependent on activations. High volatility and uncertainty; if system stays 'short' for too long (various consecutive ISPs with upward need) a BESS may struggle in this market since they are energy-llimited in nature.	+
mFRRsa	Daily auctions (closing date for offers is day before (D-1) and can be revised up to 30 min. before ISP)	Per 15 mins. (ISP)	Bids	Activated volume: *Upwards* 4.36 GW *Downwards* 0.245 GW Avg. bid price: *Upwards* per activated ISP is 304 EUR/MWh (max. 713 EUR/MWh) *Downwards* per activated ISP is -146 EUR/MWh (max. -461 EUR/MWh) Max. earning potential: 12,022 EUR/MW**	Activated less than 1% of ISPs.	-
mFRRda	Daily auctions	Available for 60 mins. Full activation time is 10-15 mins.	Contract (min. volume of 20 MW) & activation renumeration	Contracted volume: 994 *upwards*/ 705 *downwards* Avg. contract price: *Upwards* ~4.1 EUR/MW/h (2019) *Downwards* ~2.5 EUR/MW/h (2019) Max. earning potential: *Upwards* 33,510 EUR/MW*** *Downwards* 17,149 EUR/MW***	Activated less than 1% of ISPs and needed for several hours.	--
Intraday	Up to 5 mins. before delivery	1 hour/15 mins.	Bids		Buy low, sell high in regular market party transactions. Opportunity to optimise/balance out portfolios closer to real-time.	+
Day-ahead	Day before delivery	1 hour	Bids		Buy low, sell high in regular market party transactions, when not bound to balancing requirements in e.g. FCR blocks.	-

* If available every hour and used for each activated ISP (upward & downward)
** If used for each activated ISP (upward & downward)
*** If available every hour + activation renumeration

5 Financing challenges for the development of BESS

This last chapter assesses some of the major challenges faced by developers of a BESS, in getting required financing from providers of funds (debt or equity) to a project. It provides some important highlights concerning improvements that can be made by developers in general, to reduce (possible) concerns of investors.

These insights are based on experiences from Invest-NL with actual funding requests from BESS project developers in the Netherlands. Please be aware that the highlights mentioned here are deemed very important to be able to convince investors, but the list is non-exhaustive.

HELP TO UNDERSTAND THE REVENUE OPTIONS

Probably the first and foremost challenge for investors is to break down the complexity of the different markets a BESS project-developer could be active in, as well as assessing the relative contribution of these markets to total projected revenues. Currently, this makes the financing of BESS projects in the Netherlands challenging. This paper aims to contribute to a better understanding of potential revenue streams for a BESS on the Dutch market. This should help developers to build better (substantiated) business case propositions and build confidence in these cases among their investors. The business case for BESS project-developers is dependent on the following:

- On the costs side; BESS CAPEX and OPEX, the energy tax and ODE paid and the electricity transport costs/ connection costs incurred. Currently, the energy tax is incurred twice in the Netherlands (when charging and when discharging a BESS), but this policy is expected to be abolished[29].
- On the revenue side, BESS business cases in the Netherlands are built on:
  - Revenues from ancillary services to the system operator (e.g. congestion management) or portfolio optimization (e.g. peak shaving and imbalance risk management) for balance responsible parties. As these revenue streams are dependent upon conditions in the grid and the location of the BESS, these revenue potentials vary per location
  - Market-based revenue streams from the provision of balancing services (FCR, FRR, voluntary balancing), and from wholesale market trade on the DA or ID market can generate revenues. The history and earning potentials from these revenue options are largely independent from a chosen location and have been the focus in the previous chapters.

DEVELOP A PROBABILISTIC APPROACH TO BUSINESS CASES TO BETTER UNDERSTAND UNCERTAINTIES

On top of understanding the different possible revenue streams, the options to stack revenues from multiple sources can be another complex puzzle. Many investors thus perceive a black box when it comes to trading and forecasting overall revenues. Concerns about the complexity and forecasting challenges can be reduced by providing investors with profound insights into the foreseen revenue contribution of the various markets and (grid) services served by the BESS, to its business case. A better (probabilistic) insight into the business case helps investors in much better understanding their risks and in evaluating required returns on both equity and debt.

UNDERSTAND AND HEDGE THE RISK OF DEFAULT

Returns on debt are typically based on the exposure in case of default, as well as on the probability of default. The exposure upon default is unclear if there is no hedge against market prices (as is the case for renewable generation capacity with the SDE+). Consequently, it is important for lenders to have a clear understanding of the default scenario regarding revenues for the BESS.

A BESS owner can for example, use a “hedge” in form of a contract. A BESS asset owner could set up contracts with energy-trading firms or utilities to lease their battery capacity. Such counter parties pay e.g. a capacity fee over a longer period of time. In such a set-up, the merchant risk is replaced with a credit risk. Diversified traders with track-record can arguably pose a reduced risk compared to traders that are fully exposed to pure merchant risk. Applying a bankable agreement (where lender has recourse on the contract) the financing conditions for BESS can be improved[30].

[29] See: Kamerbrief “Voortgang strategische aanpak batterijen”, Ministerie van Infrastructuur en Waterstaat, 17 december 2020, p. 7.
[30] ‘Financierbaarheid van energieopslag in gesloten distributiesystemen’, Invest-NL, 2021.

LOCATION CAN HELP TO ENSURE SPECIFIC REVENUES OR COST SAVINGS
Certain locations on the map or within the grid may – besides additional revenue potentials, such as in the case of congestion management and peak-shaving – also offer CAPEX savings potential. For example, on (former) power plant locations where required (grid connection) infrastructure is already available.

EXPERTISE FOR DEVELOPMENT AND OPERATION
In general, all the revenue and cost-saving options, as well as the downside risks should be made clear to investors to be able to convince them of investment risks and earning potential. The success of any business case for BESS in an environment with growing competition, will strongly depend upon the capabilities of the people operating the asset and trading its capacity and energy across different markets and services. This will also be an important factor in building confidence and attracting required funds from investors.

UNCERTAINTY ABOUT APPROPRIATE DEBT/EQUITY RATIO
The internal rate of return of a BESS business case, is sensitive to both the costs as well as future revenues of the project. It is therefore highly dependent on the assumptions regarding future FCR and FRR market prices as well as the revenues from trading activities on DA or ID markets. Given the related insecurities, a higher equity stake is likely to be required when compared to more traditional business cases, e.g. for a conventional combined cycle gas turbines (CCGT). However, the risk profiles of more 'traditional' investment opportunities in the energy market are also changing in response to the energy transition and changing market conditions, which is why a clear benchmark for the debt/ equity ratio for a BESS is currently lacking.

APPENDIX 1

Peak power variability of Dutch residual load at different timescales

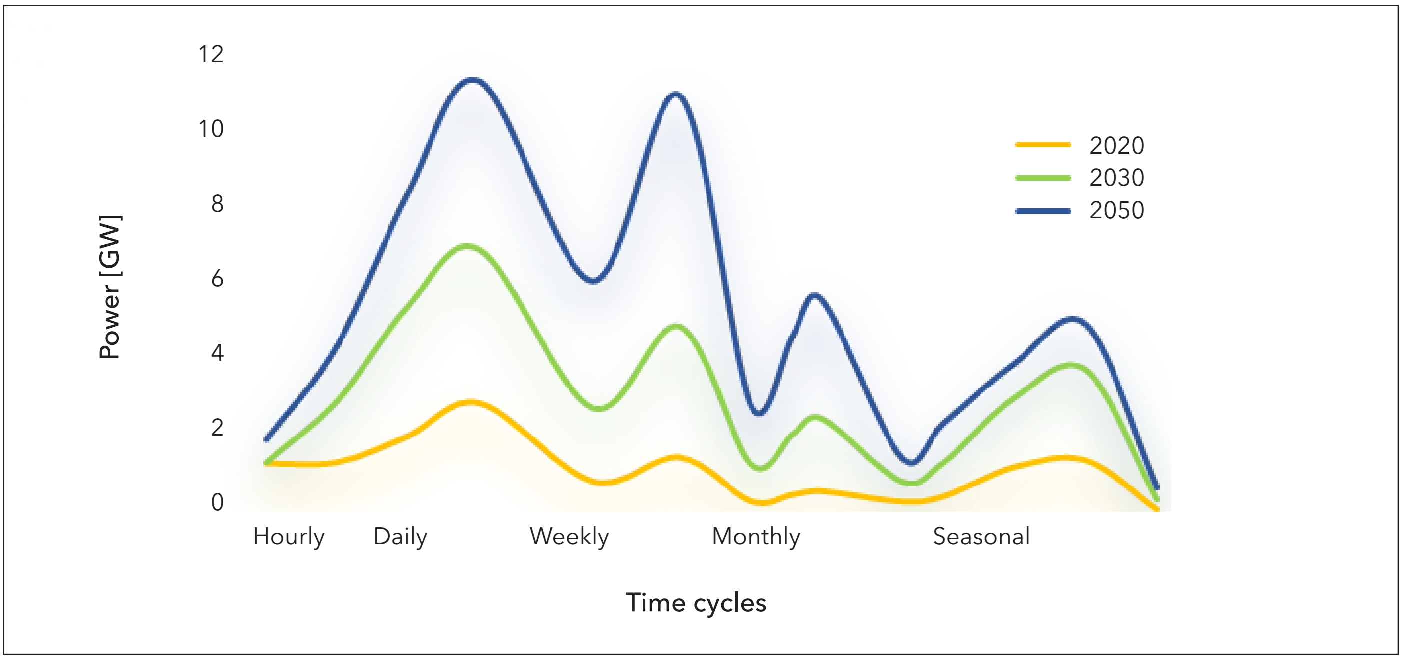

Figure 5: The peak power variability of the Dutch residual load among different time cycles

Figure 5 displays the increase in power variability in 2030 and 2050 for the Netherlands and, hence, also illustrates the flexibility needs to create a reliable and balanced future power system. This is based on inputs and simulations using DNVs European Power Market model in Plexos, which simulates power plant dispatch and price formation on European power markets. Inputs for this model are (widely accepted) national and European plans and scenario assessments from policy makers, network operators and sector organizations (e.g. ENTSO-E).

On the demand side, electrification among various sectors (e.g. electric heating, electric vehicles) is incorporated and projected to 2030 and 2050. The supply side considers solar and wind generation (VRES) based on projected (national action plans and/ or European targets) installed capacities. The resulting residual power load is then analysed for power variabilities at different time cycles (e.g. days, weeks, seasons) based on a power spectrum analysis. Results indicate the increase and value of flexibility measures required to balance the power system in 2020, 2030 and 2050.

The peak power variability among all time cycles increases in 2030 and 2050 which indicates that more flexibility measures will be required (see Figure 1). A large increase can be observed in daily variability which is partly caused by an expected installed capacity of 34.1 GW of solar PV in 2050. The impact of wind power (49.4 GW in 2050) influences multiple time cycles but predominately on the weekly and seasonal one.

APPENDIX 2

Historic and forecasted highlights of Dutch power markets

The Dutch power markets

In the Netherlands the wholesale market consists of the DA market and the ID market. Next to these markets, BESS could also be used to provide balancing services on the Dutch FCR or FRR market, or it could provide passive (sometimes also referred to as 'voluntary') balancing.

Based on a historical analysis of the Dutch power markets, the following is observed:

- Closer to real time bidding as per updated regulations in Dutch FCR and FRR markets. The introduction of four-hour bidding blocks introduced significant price spikes in the FCR market in the short run.
- Larger volumes were required on the Dutch FCR market between 2015-2020.
- Average FCR prices are still going down, so smart, well-informed bidding is required to be able to make the most of the high price peaks on this market.
- Increasing volumes are traded on the ID market, most likely because of forecast errors becoming more relevant with power supply being more weather dependent.
- In 2020, higher price spreads were observed on DA markets in comparison to 2019. However, there is not a clear trend yet.

DNVs forecasting analysis of the Dutch power markets, indicates:

- Relatively stable volumes on the FCR market with prices set largely by opportunity costs of conventional gas-fired units on the DA market.
- Risk of FCR and FRR market 'saturation' in long-term, due to relatively small market size and increasing supply.
- Increasing price volatility on the DA markets between 2021-2030.
- Convergence between DA and ID markets due to better load forecasts.
- New forms of participation in the ID market are expected, as dictated by the Directive (EU) 2019/944 all member states should enable their regulatory frameworks to allow independent aggregators to emerge in all markets including the emergence of

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