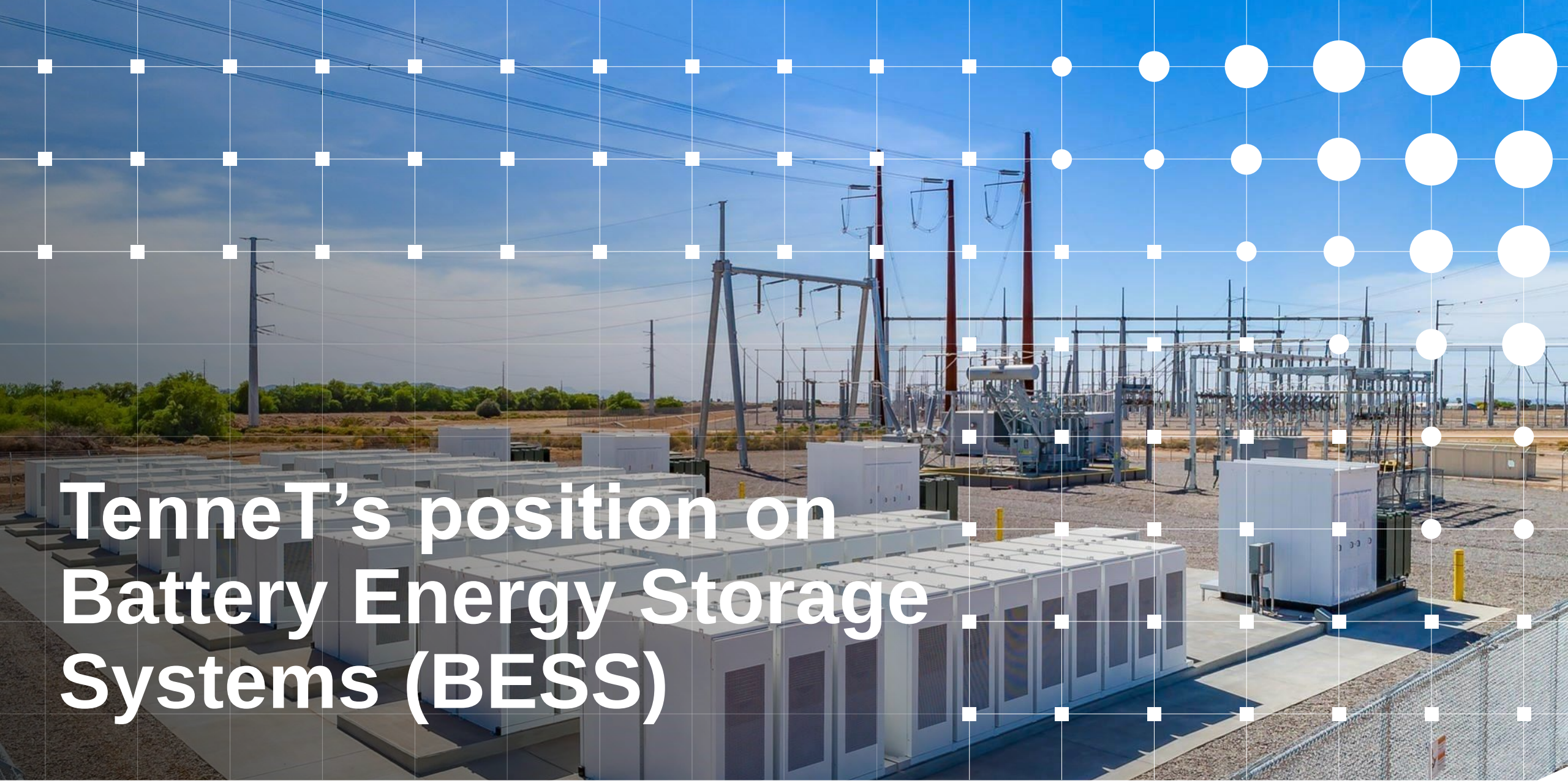


TenneT’s position on Battery Energy Storage Systems (BESS)

Index

1

Executive Summary

Executive Summary

TenneT's position regarding Battery Energy Storage Systems (BESS)

In order to be able to execute our TSO balancing task in the future, TenneT has a strategy to prepare for expected developments (2025-2030) in the Dutch electricity market. BESS connections can be of important added value to provide system stability. This document intends to provide an overview of TenneT's position on the application of large batteries (>70MW) by market parties to the grid, to be used as guidance to the market including the respective authorities

We face several near term challenges that require us to rethink our view on large energy storage solutions:

- Near term grid volatility (in terms of frequency, inertia and voltage), rises due to wind and solar dependence, which will progressively require more effort to stabilize the system and therefore have an acceptable Loss of Load Expectation ('LOLE')
- Multiple large market parties reached out to TenneT to understand our position with regard to BESS in the size of 70MW – 500MW, as recent market developments result in a potential viable business case for BESS
- **Within TenneT, BESS are very much wanted from a Transport perspective in the form of upward and downward dispatch. Also TenneT sees an increasing need of balancing (FRR), inertia and reactive power products, for which BESS can be deployed.**
- **However, batteries should not cause additional network congestion. Therefore a working group is setup between EnergyStorageNL, grid operators, ACM and market parties in the National Action Programme – Network Congestion initiated by the Dutch government**

In reference to the "Monitor Leveringszekerheid 2022", TenneT needs around 10GW of flexible storage in 2030 for an acceptable LOLE under the current government policy in which power plants are no longer allowed to burn coal by 2030. Since Demand Side Response is needed but not going quickly enough (entire industry is modelled on base load) and hydrogen will also take some time to develop. TenneT expects to need around 9GW of BESS connected to the TenneT grid for system stability

In the following chapters, we give an overview of the current market developments, the current products for which BESS can be used and where you can find additional info on BESS

Executive Summary

BESS potential support to TenneT

Provision of fast frequency response services (FCR, FRR)
With ultra-fast response times, BESS have a clear ability in providing FCR services. A BESS can also be used for the other balancing (FRR) products

Congestion management services (CBCs, Redispatch)
BESS can provide flexibility using bilateral contracts with network operators or via market-based congestion management, next to grid reinforcement, however it is important that batteries do not worsen congestion

Voltage support and stabilization, potentially grid forming
BESS can be deployed to deliver or absorb Reactive Power, provide Synthetic Inertia and can potentially provide Black-start services

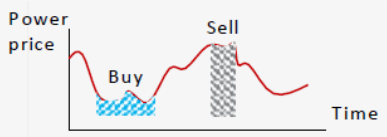
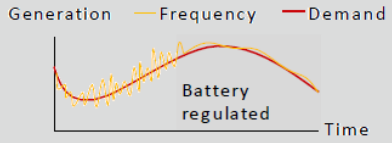
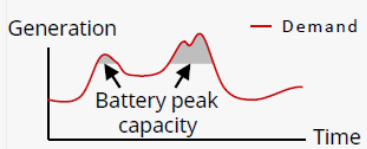
2

Details around BESS

Revenue streams for BESS

Revenue enablers for BESS

The recent trends offer growing opportunities for BESS in multiple application areas, as summarized in the table below. In addition, it is expected that the demand for flexibility will increase faster than the supply, creating rising potential revenues for BESS owners*. For this reason, multiple large market parties have reached out to TenneT on what our standpoint is with regard to large BESS

	Application		BESS & System Benefits	Revenue enablers
Of interest to TenneT	Energy Arbitrage		*Energy capacity of battery allows purchase of low-cost energy and reselling at a higher price on wholesale markets* Shifting of energy usage will reduce price volatility on wholesale markets	Access to wholesale energy markets
	Ancillary Services		*Balance energy / voltage / frequency fluctuations in grid* Sub-second response allows provision of fast frequency response services and safe management of a lower inertia system and reduced system curtailments Flexible capacity allows short-term management of supply and demand mismatch Reactive power / voltage support also possible through the inverter system	Access to balancing mechanism and ancillary service markets Fast response value recognized in advanced services framework
	Peaking capacity		*Provide on demand power capacity* To support peak power demand or provide longer duration reserve services To support in alleviating local constraints / congestion on the network	Capacity markets Tolling arrangements Local peaking services to network

**Based on the application areas above, market parties should be responsible for realizing their business cases. Contracts for specific application areas that have been agreed upon can be set up in conjunction with TenneT, once a solid business case has been presented by BESS owners*

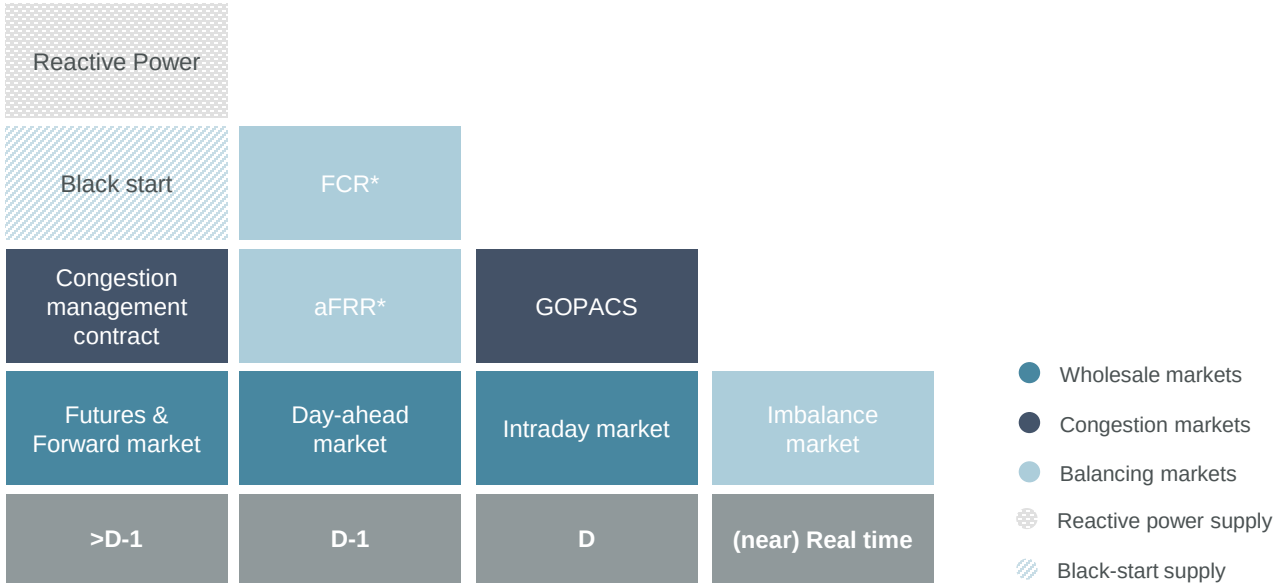
Source: CS corporate presentation: storage overview EMEA region (2022)

Current products and systems

Revenue streams for BESS further detailed

Current market developments create attractive opportunities for BESS owners. Hence, it is important to investigate how does BESS potential match with our main focus areas, as TenneT

Overview of decision moments and products where BESS create revenue



*Activation of reserved power is determined (near) real time

- The potential of BESS can be harvested for each of the products depicted on the left, by deploying flexible capacity at various market segments and at different timeframes
- Many single markets are not profitable in themselves for BESS owners, but can contribute to a “stacked” business case*
- There is a wide variety of revenue streams to be realized by generating explicit value with storage. At the same time, BESS provide opportunities for TenneT by responding to TenneT’s needs in key focus areas

** Battery owners or portfolio owners with battery assets can optimize their revenues by utilizing different market segments: the wording “stacked” refers to value creation from different markets and services. Note that, however, entering into (e.g.) a FCR or FRR contract implies that it is not possible to utilize BESS to deliver other products during the period of contract*

Source: National Smart Storage Trend Report, DNE Reseach (2022)

BESS connection requests and TenneT's policy

Volume of connection requests is growing rapidly, currently 62GW

Overview of current connection requests to TenneT grid (110, 150, 220, 380kV), numbers dated from June 7th, 2023.

► Phase 1; information pack requested	#131	in total 37.5GW
► Phase 2; basic design quote requested	#61	in total 18GW
► Phase 3; basic design quote signed	#15	in total 6.5GW
► Phase 4; realisation quote requested	#0	n/a
► Phase 5; connection in realisation	#0	n/a
► Phase 6; connection in-service	#0	n/a

From phase 3 onwards, TenneT considers the market party to have a 'place in the queue'

TenneT currently develops a policy where and where not she want to have batteries, below already some high over guidelines

Substation policy

- Not under lines or over cables, due to operational safety and workability
- Not in the direction where TenneT in het future wants to (potentially) expand the substation
- As close as possible due to shorter cables, accounting for hazard safety

Grid topology policy

- Close to wind, solar farms and/or industry (high pockets of either production and/or load)

BESS can respond to needs in key focus areas

Opportunities for grid operators by integrating large BESS

BESS can be deployed in a multitude of ways to support our system and transmission services, with potential yet to be explored in several areas, as displayed below

System services

Balancing reserves

FCR / aFRR

- BESS penetration is already advancing
- Not high demand for FCR yet, but FRR demand size is expected to grow and its providers to change
- As less conventional power plants will be available to offer FCR/aFRR for balancing purposes, incorporating large-scale storage solutions is a promising way forward for TenneT

Black start facility

- BESS can offer reliable black start functionality in the event of grid collapse (experience with BESS application to be gained)
- Current specifications in the Netcode are drawn up focussing on fossil-based generation plants, while DERs (e.g. wind, solar and BESS) are currently not accounted for
- To harvest BESS potential to deliver black start functionality, the Netcode should be adjusted to accommodate for the technical possibilities offered by storage and RES

Transmission services

Congestion management

Redispatch

- There is a high demand for upward, but also downward dispatch
- At the moment, congestion is growing faster than the possibilities of timely grid reinforcements, while the storage costs are decreasing
- Batteries are a (even when temporary) solution, to deliver congestion management, especially in the form of upward, downward and cross-border dispatch

Contracts

- In the future, BESS might provide flexibility by means of bilateral contracts with network operators through Capacity Restriction Contracts
- In the LAN parties are working on the integration of batteries in such a way to ensure that they do not result in additional congestion

Reactive Power

- There is a high potential for BESS to absorb and generate reactive power to alleviate voltage level challenges, as renewable energy generation continues to grow it causes more and more voltage level challenges in our grid

Synthetic Inertia

- BESS are able to provide Synthetic Inertia, since they can react very quickly to frequency changes. Synthetic Inertia is needed, due to the diminishing inertia provided by generators from fossil fuel power plants

Source: Battery energy storage systems in the Netherlands: market opportunities & financing challenges, DNV and InvestNL (2021)

3

What is needed for system stability

BESS from a system perspective

Developments in the market for flexibility and role for BESS

The rise of power generation from renewables, coupled with a major shift in demand towards electrification, leads to new challenges in balancing out demand and supply

In addition, the expected inflow of RES as compared to consumption levels might challenge current network capacity, eventually exacerbating congestion issues

The use of available flexibility allows to retain reliable and cost-efficient operation of the power system

Technical considerations

Flexibility can come from different sources, like demand response (industrial and residential flexibility), system integration (converting electricity to other energy carriers, such as heat and gasses) and more interconnection capacity for cross-border exchanges of electricity

Market considerations

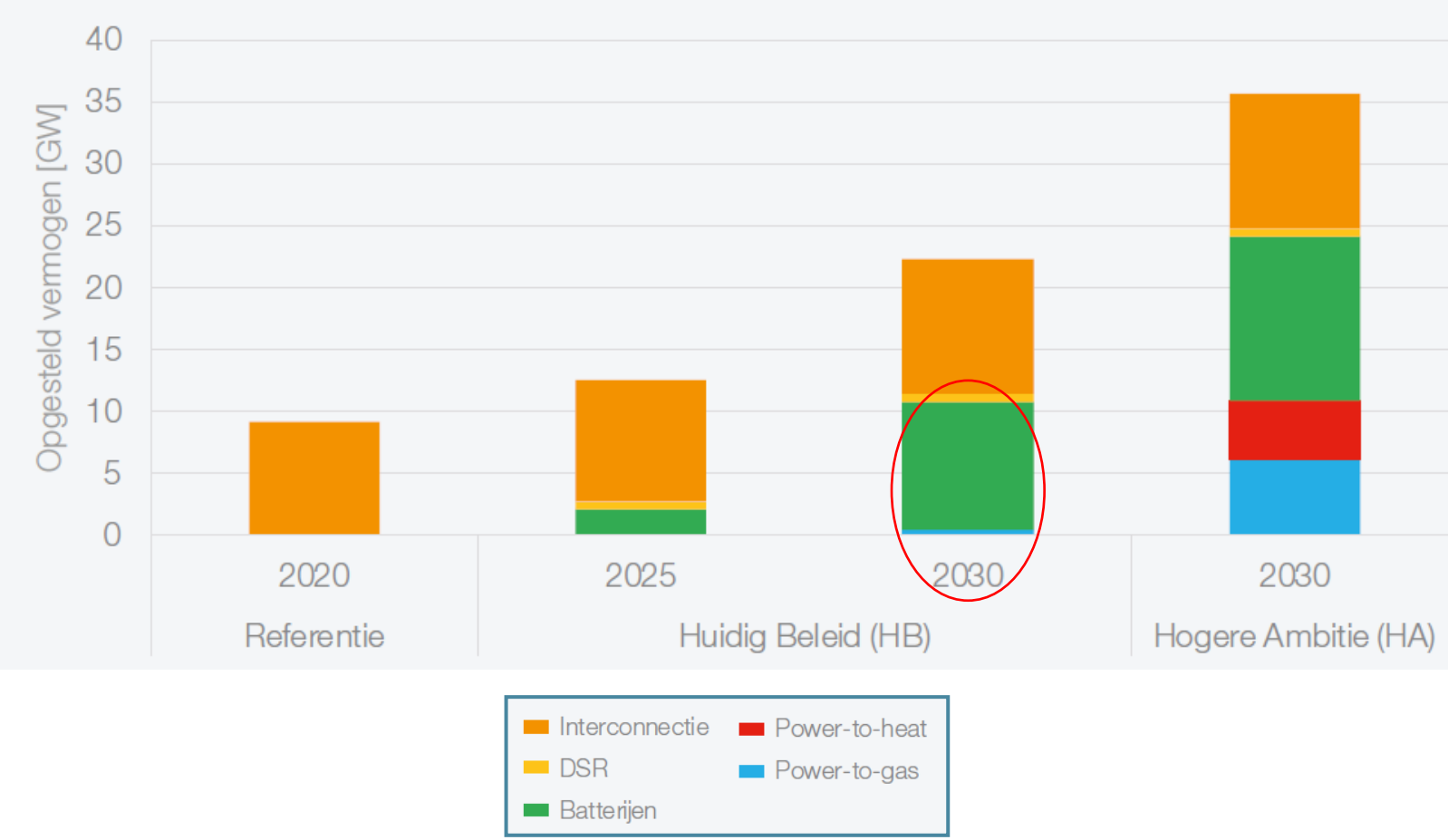
BESS is an interesting flexibility source as it can facilitate near-real time system balancing, provide congestion management and alleviation services, and deliver voltage support and stabilization. At present, the number and type of parties providing these services is changing

BESS connected to TenneT's grid

- TenneT believes it is important that BESS are net neutral so it does not contribute to congestion. In the 'Landelijke Actieprogramma Netcongestie' parties are working on the integration of batteries in such a way to ensure that they do not result in additional congestion
- Voluntary Non-Firm ATOs can be offered, in accordance with the upcoming NFA addition in the 'Netcode'

InvestmentPlan 2024

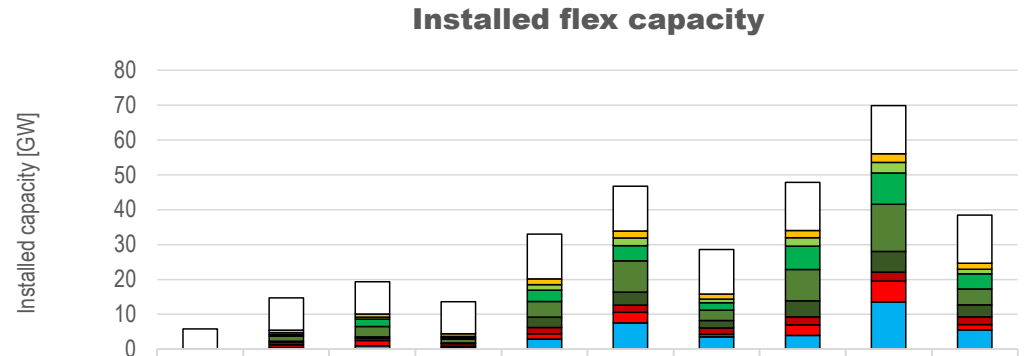
Amount of BESS needed connected to TenneT for acceptable LOLE



Zie ook: https://www.tennet.eu/nl/nieuws/monitoring-leveringszekerheid-2022

InvestmentPlan 2024

Flexibility scenarios – can we keep the grid stable with batteries



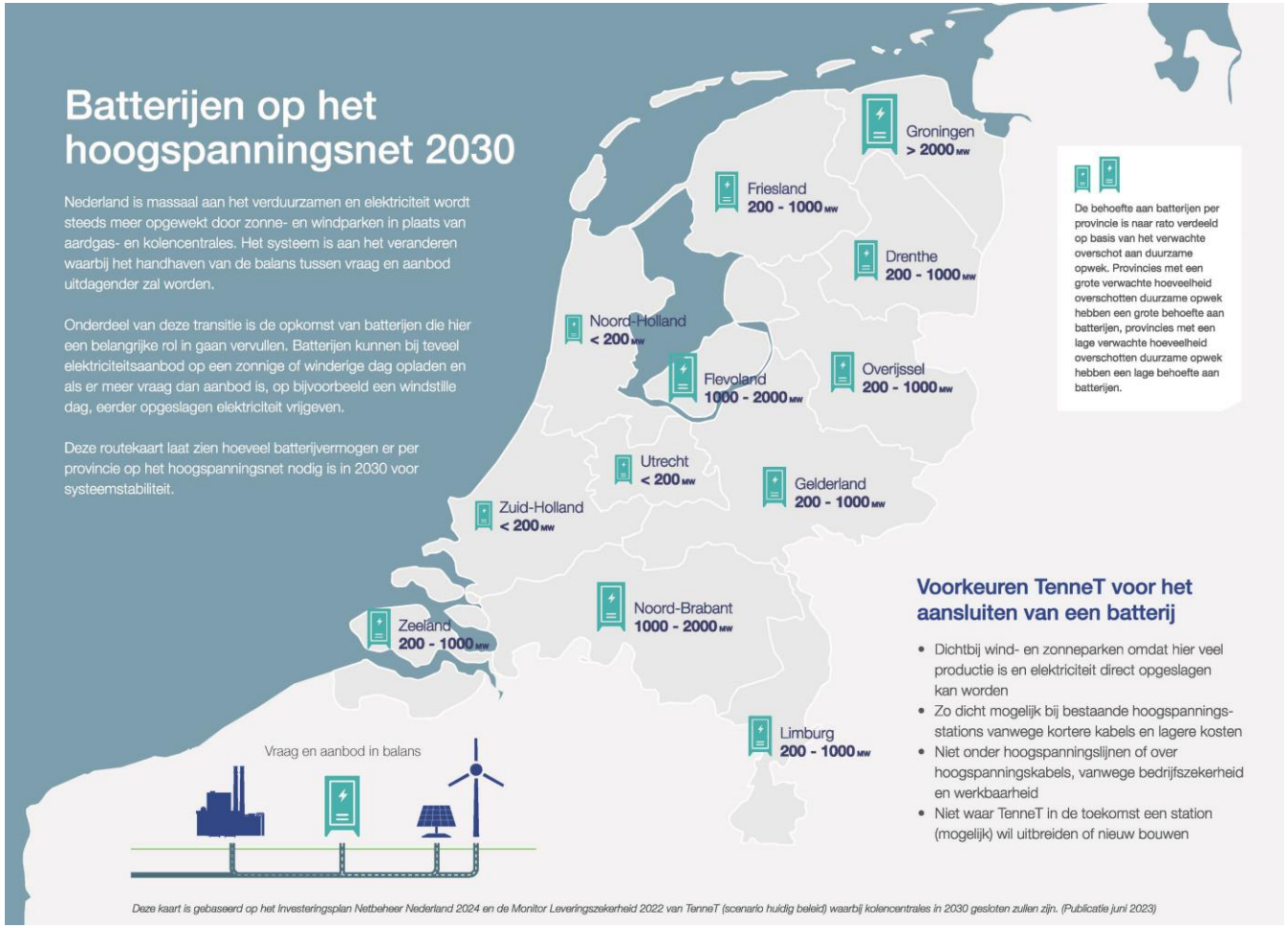
	REF 2019	KA 2025	ND 2025	IA 2025	KA 2030	ND 2030	IA 2030	KA 2035	ND 2035	IA 2035
Electricity exchange	5,9	9,2	9,2	9,2	12,8	12,8	12,8	13,8	13,8	13,8
DSR (industry)	0,0	0,8	0,9	0,7	1,7	2,0	1,5	2,0	2,5	1,7
Batteries (EV)	0,0	0,5	0,6	0,4	1,6	2,2	1,0	2,5	3,0	1,3
Batteries (households)	0,0	0,4	2,1	0,4	3,2	4,4	2,1	6,7	9,0	4,4
Batteries (large-scale)	0,0	1,5	3,0	1,0	4,5	9,0	3,0	9,0	13,5	4,5
Batteries (solar PV)	0,0	0,3	0,4	0,3	3,0	3,7	2,2	4,6	6,0	3,5
Power-to-heat (industry)	0,0	0,7	0,6	0,7	1,8	2,1	1,8	2,3	2,5	2,2
Power-to-heat (district heating)	0,0	0,8	1,5	0,4	1,5	3,0	0,8	3,0	6,0	1,5
Power-to-gas	0,0	0,5	1,0	0,5	3,0	7,6	3,6	4,0	13,6	5,6

- Rapid uptake of different battery types increasing from **8.3 – 19.3 GW** in 2030 to **13,7 – 31,5 GW** in 2035
- Flexible power-to-gas & power-to-heat (both for district heating and industry) evolve in all scenarios
- Contribution of industrial DSR remains limited until 2035
- Interconnection with other countries increases according to latest insights from European studies

Zie ook:
https://www.netbeheernederland.nl/_upload/RadFiles/New/Documents/Netbeheer_NL_Scenarios_IP2024_v1.01_final%20(1).pdf

How is the 9GW of system batteries distributed

Windy and sunny provinces where there is not enough load need more batteries for system stability



4

Market Information

Market Information

External Publications

In the (recent) past several documents have been published which include history, future, financial aspects and other relevant information on a BESS as well as grid opportunities. Please find below a list of suggested readings for the Dutch market specifically.
It must be said that parts of these reports are actually already outdated with the current situation. More international reporting can be found online.

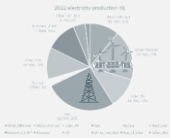
- Investment Plans grid operators 2024, published by Netbeheer Nederland (see: Netbeheer_NL_Scenarios_IP2024)
- TenneT publication on transport tariffs 2023, published by TenneT (see: Transporttarieven)
- Transporttarieven en elektriciteitsopslag 2023, published by ACM
- Kernrapport Beleid voor grootschalige batterijsystemen en afnamenetcongestie 2023, published by CE Delft
- Monitor Leveringszekerheid 2022, published by TenneT (see: Monitoring-leveringszekerheid-2022)
- Smart Storage Trendrapport 2022, published by DNE Research
- Omslagpunt grootschalige batterijopslag 2021, published by CE Delft
- Annual Market Update 2021, published by TenneT (see: Annual_Market_Update_2021)

Annex

Recent market developments and price volatility

Current electricity market NL

Natural gas and coal mitigates grid volatility* caused by wind and solar today



Natural gas generated 63% of electricity in 2022

Electricity producers are conventional, large-scale and concentrated

Wind and solar generated 25% of electricity in 2022

Today's grid is a balanced mix of volatile wind and solar combined with stable conventional electricity sources

RES output fluctuates due to weather dependency and high ramp rates

Stable conventional generators and flex provided by natural gas and coal manages RES volatility

It is expected that the increasing penetration of renewables in the long-run, will exacerbate the volatility in the grid even more. Also decommissioning of coal-fired powerplants does relate to higher volatility expectations

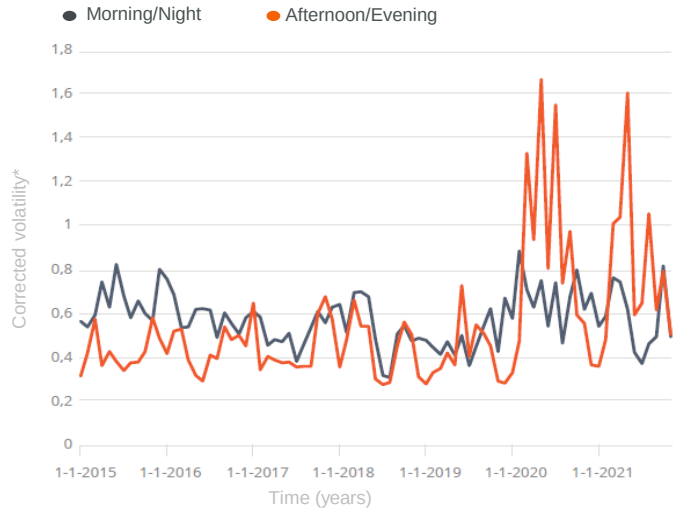
** Refers to the instability of the grid that can result from intermittent generation from renewable sources*

Volatility developments: day-ahead market prices

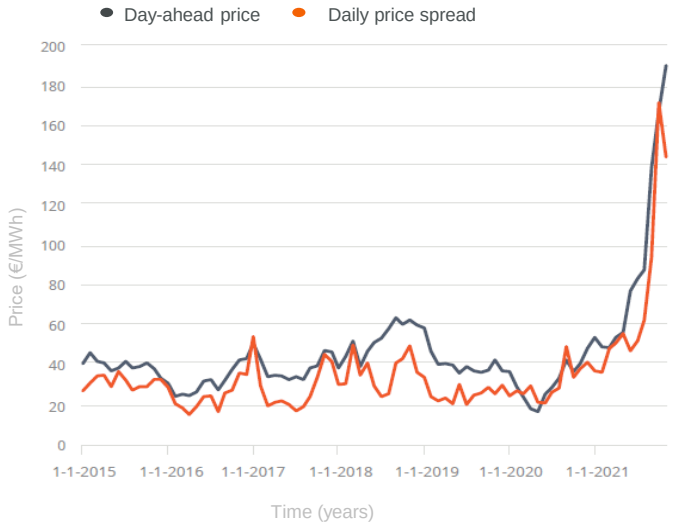
Volatility remains as high as ever

The day-ahead data displayed in the figure on the right-hand side is useful to show structural price trends in electricity markets. What is striking is not only the upward trend of recent months, but also the huge increase in volatility compared to the period before - as reflected in the growing daily price spread (i.e. the spread between daily peak and off-peak electricity prices)

- The increasing penetration of intermittent renewables and the consequent weather dependency boosts grid volatility and rapid price changes



* 0.8 means that the price fluctuation in that half of the day was 80% of the average daily price.



By correcting the absolute price fluctuations for the average price on that day, it is visible that price fluctuations have been steadily increasing

- While in 2019 the adjusted volatility in the afternoon was lower than that in the morning almost every month, since 2019 midday volatility has become increasingly prominent
- The reason for this is the rapid growth of renewables, which has led to relatively lower prices in the afternoon compared to the evening
- This trend offers growing opportunities to deploy BESS for peak shaving, as combined with arbitrage on wholesale markets

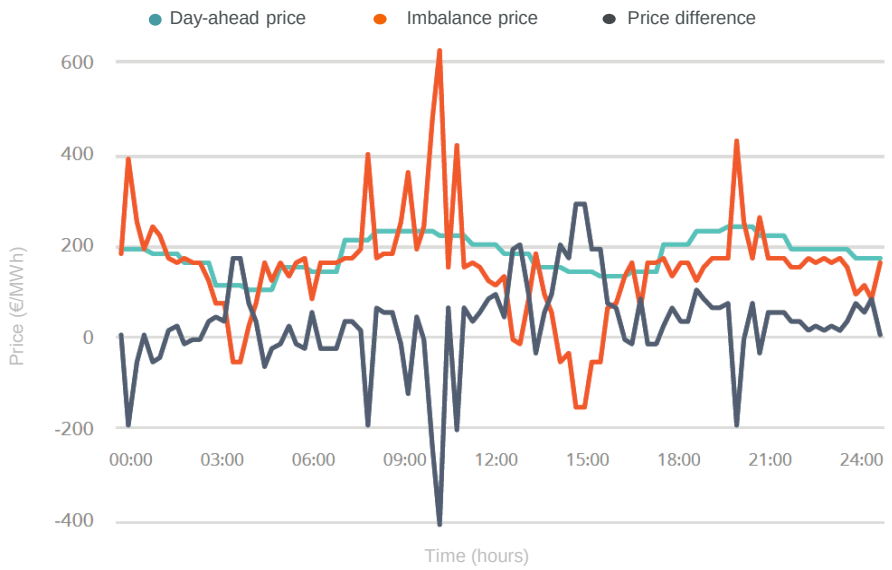
Source: National Smart Storage Trend Report, DNE Reseach (2022)

Volatility developments: balancing market prices

Volatility remains as high as ever

Just like the day ahead market, balancing markets are also undergoing significant and rapid changes

- Near term grid volatility rises due to wind and solar dependence, which progressively requires more effort to balance the national energy grid
- An important solution for any mismatch is the use of flexibility, of which BESS is a direct source, to retain reliable and cost-efficient operation of the power system
- The nature of BESS makes it interesting as flexibility source, as BESS can store and supply to the power grid almost instantaneously, facilitating near-real time system balancing



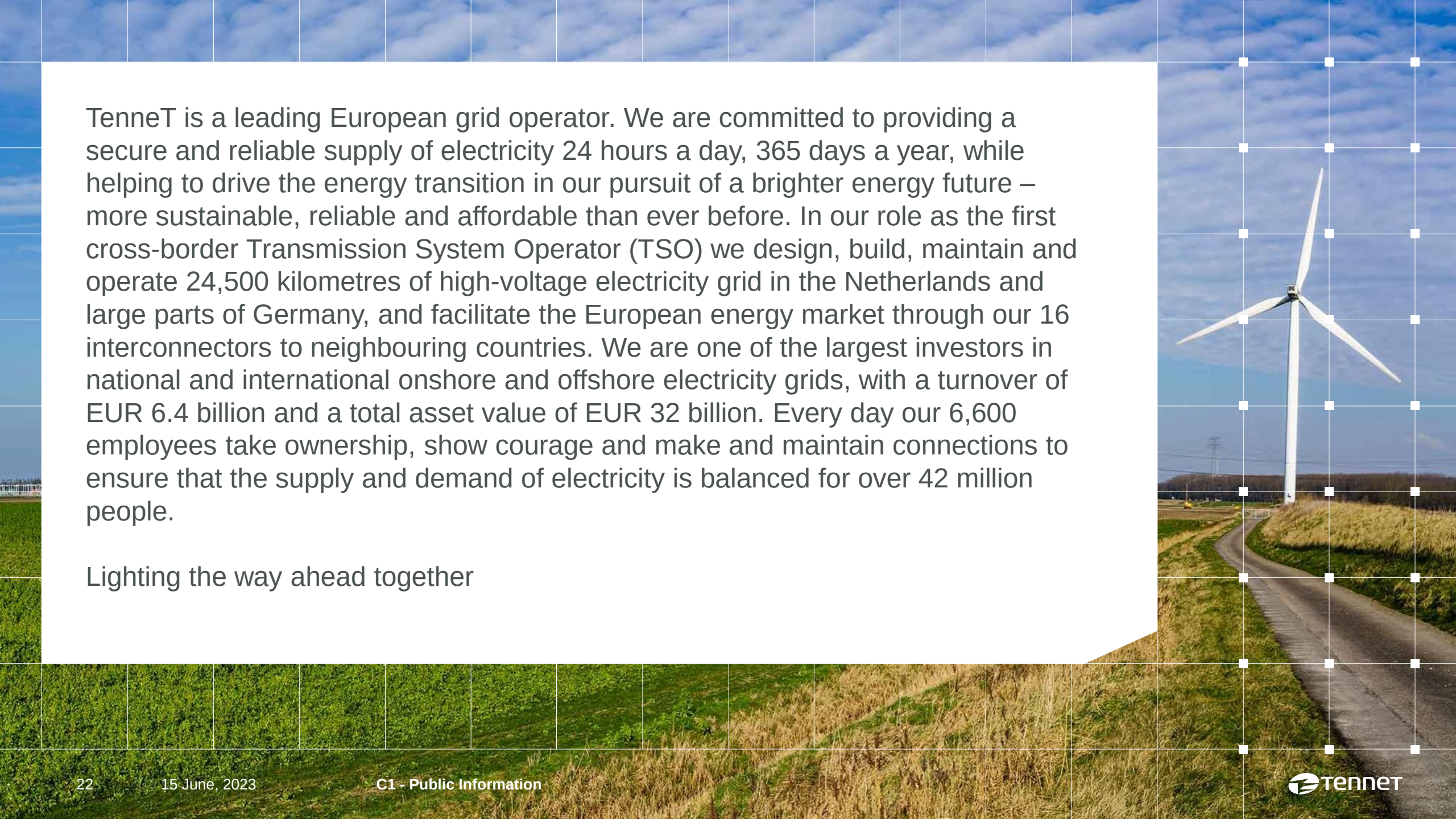
The day-ahead price, imbalance price, and the price difference between them, on an autumn day

Due to a growing share of renewable energy in the long term, and high fossil fuel prices in the short term, price volatility and thus demand for flexible power will further increase. It is expected that the demand for flexibility will grow faster than the supply, hence BESS will become an increasingly valuable asset

Source: National Smart Storage Trend Report, DNE Reseach (2022); Frank Nobel SOP (2021) - Appendix

TenneT is a leading European grid operator. We are committed to providing a secure and reliable supply of electricity 24 hours a day, 365 days a year, while helping to drive the energy transition in our pursuit of a brighter energy future – more sustainable, reliable and affordable than ever before. In our role as the first cross-border Transmission System Operator (TSO) we design, build, maintain and operate 24,500 kilometres of high-voltage electricity grid in the Netherlands and large parts of Germany, and facilitate the European energy market through our 16 interconnectors to neighbouring countries. We are one of the largest investors in national and international onshore and offshore electricity grids, with a turnover of EUR 6.4 billion and a total asset value of EUR 32 billion. Every day our 6,600 employees take ownership, show courage and make and maintain connections to ensure that the supply and demand of electricity is balanced for over 42 million people.

Lighting the way ahead together



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