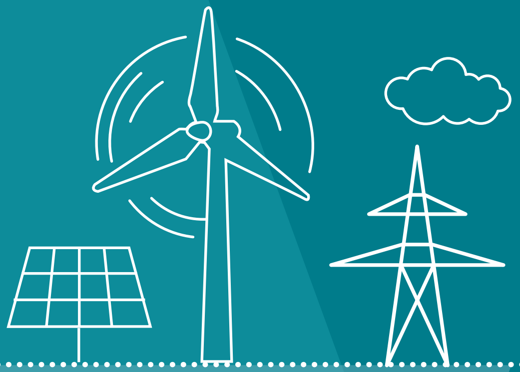
Future-proofing the EU energy system towards 2030

Levers to realise the next phase of the energy transition in a timely and efficient way with maximum welfare for society



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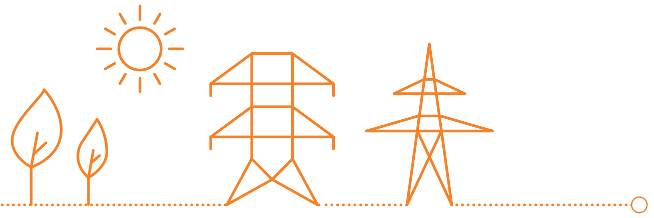
Let’s close the gap



Dear Reader,

The transition of the European electricity system is undeniably one of the major challenges of this century. The switch towards a decarbonised society brings fundamental challenges for the electricity system. On the way to 2030, renewables will further increase, some conventional generation will disappear and there will be more cross-border exchanges as Europe has set ambitious targets to implement an internal energy market.

As transmission system operators, we should make sure that we are ready to cope with the changing energy landscape and to realise the next phase of the energy transition in a timely and efficient way with maximum welfare and benefits for society.

Just letting things run their course is not an option as we see increasing challenges on both the hardware (grid infrastructure) and the software (market design) of the European, interconnected electricity system. Hence this study. We want to raise awareness on the need for improvements to pave the way for the increasing integration of variable, renewable energy on the path to 2030 and beyond.

What challenges are we talking about?

We observe a discrepancy between the development and construction times of renewable generation compared to the longer lead-times for building grid infrastructure. This creates congestions on the electricity grid. In Germany in particular, getting the large-scale wind energy production efficiently from the north to the consumption centres in the south, is a considerable challenge.

To keep physical electricity flows within operational boundaries, system operators regularly have to perform redispatching measures to adjust the pattern of generation and demand in the grid to avoid or resolve grid congestions. In some cases they even have to curtail RES*. These measures are expensive for consumers. The Bundesnetzagentur (German regulatory office for electricity) reported an amount of € 1.4 billion for Germany in 2018.

The congestions also create secondary effects, such as loop flows that pass unsolicited through the electricity grid of neighbouring countries, reducing cross-border exchange and sometimes threatening security of supply. Loop flows through Belgium for instance reach up to 2000 MW, which is about 50% of the interconnection capacity between Belgium and the Netherlands.

On the software side (i.e. the market design), we see an increasing divergence between the electricity flows optimised by the market mechanism (flow-based market coupling) and the physical flows in real-time.

To deal with the growing complexity of a decarbonised electricity system, timely infrastructure development has to be combined with an improved market design. As such the market can act as an efficient traffic agent that efficiently directs the electricity flows in the grid and makes optimal use of the available capacity.

What needs to be done?

In this report, Elia Group proposes two levers that we believe are needed to cope with the challenges of the increasing integration of renewables into the energy system.

The first and most important lever is the timely completion of the planned new grid infrastructure. Grid expansion is required to meet the European renewables targets in an efficient way. Our simulations show that not having the German north to south HVDC** lines in place would entail a yearly welfare loss of around € 1 billion to € 1.5 billion by 2030.

Elia Group is therefore committed to do the utmost to accelerate delivery of planned new infrastructure and to mitigate any risk of delays, in close collaboration with the competent authorities. Each project is a participatory process that integrates the input of local and regional stakeholders, allowing a better outcome.

In addition, Elia Group is investing strongly in the optimisation of existing assets by integrating new technologies and more advanced system operation concepts. We are focusing on replacing overhead lines by introducing a new type of conductor that can support higher flows, increasing grid capacity in cold and windy weather (Dynamic Line Rating) where appropriate, and finding better ways to control electricity flows via devices such as Phase-Shifting Transformers and HVDC lines. These optimisations can increase the available transmission capacities in the short term and partially close the gap in addition to grid expansion coming up to speed.

As a second lever, we propose an improved market design: the Flexibility-In-Market-Coupling design or Flex-In-Market design in short. The Flex-In-Market design gives the market access to a toolbox of controllable devices to better manage the flows in line with physical constraints. This enables a more efficient use of the grid and reduces the gap between markets and physics.

In the Flex-In-Market design, we introduce a new concept of Dispatch Hubs. These are strategically located blocks of flexible resources (e.g. conventional generation units) or redispatch potential, which the market can optimise independently from the bidding zone in which they are located. The first simulation results are promising. We believe that the proposed concepts merit further discussion and elaboration at European level.

What are the next steps?

This study is an invitation for further elaboration and discussion of the proposed concepts. The first contacts with our peers and with the European authorities are encouraging. To initiate a more intense pan-European dialogue, Elia Group suggests to set up a broader coalition and to start discussions with representatives of system operators, market parties, regulators and European authorities.

We believe that our proposals could be stepping-stones that bring currently opposing views closer together. Consensus among policymakers on how to close the gap could bring us an important step closer to realising a sustainable and reliable energy system that brings maximum welfare for society and for all Europeans.

I hope you enjoy reading our report.

Chris Peeters – CEO Elia Group

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*RES = Renewable Energy Sources - **HVDC = High Voltage Direct Current

1

Executive summary

An invitation for dialogue

This Elia Group study is an invitation for dialogue. From the perspective of two system operators (Elia in Belgium and 50Hertz in Germany) each facing different challenges, we want to raise awareness and come up with proposals that could tackle the increasing challenges on both the hardware (grid infrastructure) and the software (market design) of the European, interconnected electricity system.

We believe that our study provides interesting insights that might bring currently opposing views on how to improve the market design closer together. This report could serve as a stepping-stone to set up a broad coalition and start discussions with representatives of system operators, market parties, regulators and European authorities.

Key messages

In this report, Elia Group identifies two levers that we believe are valuable for the horizontal (European) energy system to realise the next phase of the energy transition towards 2030 on time and with maximum benefits and welfare for society.

LEVER 1

The timely completion of the planned grid infrastructure in the run-up to 2030 is the first and most important lever for realising the energy transition with maximum welfare and benefits for society.

Today in some European countries, grid infrastructure is lagging behind the rapid expansion of renewables generation. An important cause is the increasing discrepancy between the development and construction times of renewables compared to the longer lead-times for realising grid infrastructure.

Because of a lack of infrastructure, system operators regularly have to perform redispatching measures to keep physical electricity flows within operational boundaries. To resolve overloads in the grid, they change the generation and load pattern of the grid and sometimes even have to curtail renewables.

In **Germany**, further grid expansion is planned to get the renewables in the north to the consumption centres in the south (e.g. SuedOstLink project). In **Belgium**, new onshore corridors are under development (e.g. Ventilus and Boucle-du-Hainaut projects) to bring additional offshore wind generation (MOG-II project) to the consumption centres.

Our simulations show that not having the German north to south HVDC lines in place entails a yearly welfare loss of around € 1 billion to € 1.5 billion by 2030. In addition, this missing infrastructure also causes higher volumes of RES curtailment (approximately +40%). These numbers will further increase beyond 2030, as more renewables are due to be integrated into the grid on the road to full decarbonisation.

LEVER 2

In our role as market facilitator, we see potential options for an improved market design. The proposed Flexibility-In-Market-Coupling (Flex-In-Market) design allows the market to have a better control of the flows in line with physical constraints. This enables a more efficient use of the grid and closes the gap between markets and physics.

Discussions on market design improvements have led to fierce debates over the last couple of years, as they touch complex and delicate topics such as loop flows, redispatching costs, bidding zone delineation, etc. This study proposes relevant ideas for improving the market design that could bring currently opposing views closer together. As an example, our proposal does not plead for the bidding zone configuration to change, a well-known element in controversial debates today.

Concretely, we propose to co-optimise in the market coupling some of the actions, like defining the set points of controllable devices and performing redispatch, that system operators currently perform before and after market coupling (MC), to optimise the capacity made available to the market (before MC) and secure the grid (after MC) respectively.

With the new Flex-In-Market model, set points of controllable devices (relevant PSTs* and internal HVDCs) and so-called Dispatch Hubs are optimised during the market coupling, to manage congestions in a welfare optimal way. TSOs resolve residual congestions after the market with controllable devices and coordinated redispatch.

In the Flex-In-Market design, we introduce a new concept of **Dispatch Hubs**. These are strategically located blocks of flexible resources (e.g. conventional generation units) or redispatch potential, which the market can optimise independently from the bidding zone in which they are located. The only condition is that the generated welfare exceeds the related costs. The first simulation results are promising.

* PST = Phase-Shifting Transformer

Our simulations show welfare gains of € 300 to € 400 million per year in 2030 for the Flex-In-Market design compared to the current market design and a decrease of curtailed volumes of RES by 10% to 15%. The proposed market design improvements could also significantly reduce the redispatch costs in parallel to the grid expansion coming up to speed over the next couple of years. Simulations show a potential reduction of German redispatch costs of more than 50% in anticipation of the HVDC lines, along with a 20% to 30% reduction of curtailed volumes of RES.

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1. See full Report for exact assumptions on welfare losses, redispatching schemes, HVDC sensitivity,...

Our commitment

CONCRETE ACTIONS ON THE TIMELY COMPLETION OF PLANNED GRID INFRASTRUCTURE

We believe it is crucial to have a regular dialogue between system operators, competent authorities and governments (local and federal) to actively de-risk permitting processes. We have a joint responsibility to get clarity and a common understanding on constraints, risks and to work on solutions.

By improving mutual trust and creating more clarity at each step of the permitting process, we are convinced that the planning lead-times of crucial projects can be considerably reduced. As an example, the delivery of the SuedOstLink project in Germany could be accelerated by 1 to 1.5 years. This contributes immensely to social welfare.

One of the most important success factors for streamlining the permitting process and better controlling the lead-time and risks, is early stakeholder engagement. An intense participation approach gives the opportunity to build trust and understanding and to incorporate proposals from stakeholders in the early stages of planning. Elia and 50Hertz are committed to listening to the concerns of citizens, NGOs, associations and governments to improve the project and increase public acceptance.

We also see a great deal of potential in shortening and better controlling the lead-time of the permitting processes by further improving the coordination between different competent authorities, governments and system operators via a systematic and joint project approach. We believe in a joint time planning, methodological harmonisation upfront and transparency on risks and limiting factors.

Such a collaborative approach has already been formalised in Germany. Since the introduction in May 2019, only one project of 50Hertz (out of 15 line sections currently) experienced a noticeable delay. In Belgium, new concepts of collaboration and early stakeholder management are currently implemented for the development of two new onshore corridors (projects Ventilus and Boucle-du-Hainaut).

On top of the realisation of the planned grid infrastructure, we are also committed to upgrading and optimising existing assets. To increase the available transmission capacity, we are integrating more advanced system operation concepts and new technologies.

To give some examples, we are focused on increasing grid capacity in cold and windy weather by dynamic line rating (when relevant) and by replacing overhead lines by new types of conductors (HTLS technology) with higher transmission capacities. As their implementation lead-time is shorter than building new corridors, these measures are essential to partially bridge the existing gap and are in addition to grid expansion coming up to speed over the next couple of years.

FURTHER ELABORATION OF THE PROPOSED FLEX-IN-MARKET DESIGN

Our proposed market design improvements (Flex-In-Market design) could bring closer together opposing views since they reconcile the main interests of involved parties: reduction of redispatch costs and RES curtailment and closing the gap between markets and physics. They also enable a more efficient handling of loop flows and an overall better utilisation of the grid, leading to improved welfare for society.

In the interest of European society, Elia Group calls for dialogue and a further elaboration of the proposed market design concepts at a European level. We will invite other system operators, market parties, regulators and European authorities in a broader coalition and initiate the dialogue to reach a consensus on an improved market design.

2

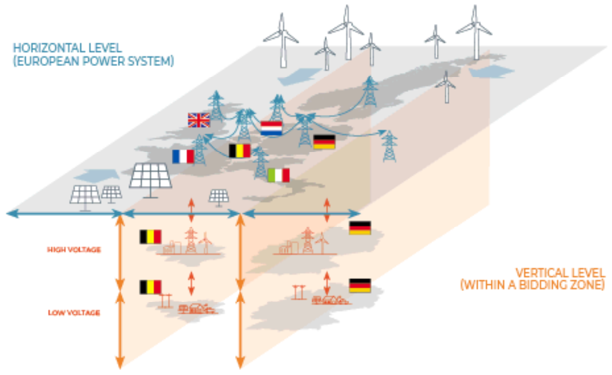
Technical summary

2.1. Context of the study

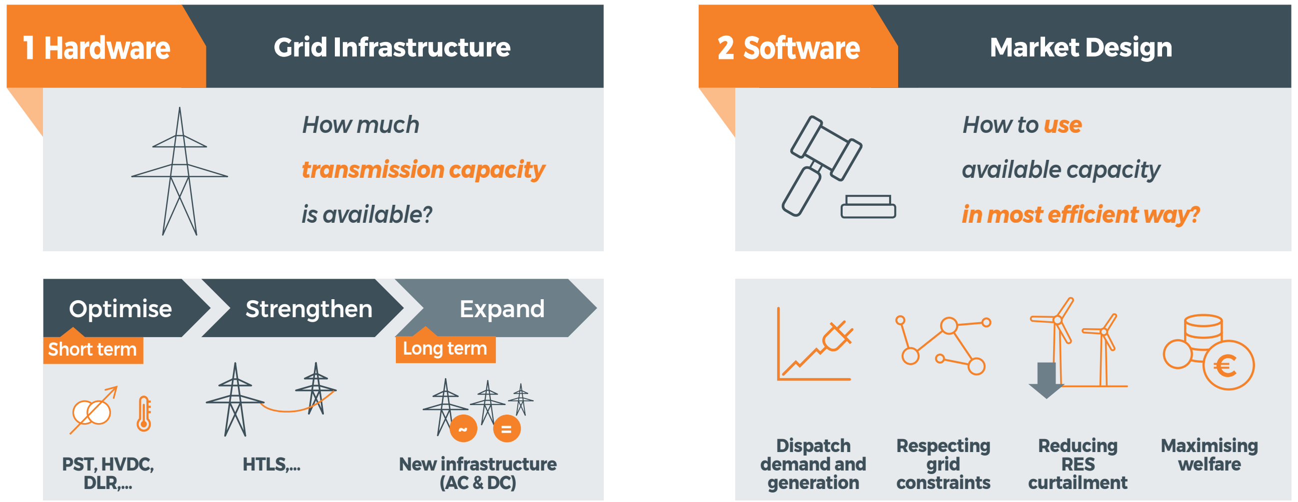
Discussions on climate change are accelerating. The share of renewable power production in the electricity system will further increase to adhere to the European 2030 climate targets [EUC-3]. Germany has recently increased its targets from 55% of renewable electricity generation in 2035 to 65% in 2030 [DEG-2]. The Belgian draft of the National Energy Climate Plan (NECP) estimates a need for around 40% of renewable electrical power generation in Belgium by 2030 if it is to meet its climate targets [BEG-2]. At European level, discussions are ongoing to increase the target for greenhouse gas emissions reduction by 2030, which may lead to an upwards revision of RES targets.

After having focused on the consumer side last year (vertical energy system), Elia Group now takes a deeper look into the horizontal or European energy system (see Figure 1). The horizontal system refers to the electricity highways (e.g. 380 kV grids) that are responsible for transporting bulk energy volumes within and across national borders. It consists of a "hardware" (grid infrastructure) and a "software" (market) component, as illustrated in Figure 2. A smooth interaction between both is key for the efficient functioning of the European electricity system.

HORIZONTAL AND VERTICAL ENERGY SYSTEM [FIGURE 1]



MAIN COMPONENTS OF THE HORIZONTAL ELECTRICITY SYSTEM EXPLAINED [FIGURE 2]



Over the last decade, the horizontal system went through some fundamental changes. The European transmission grid faces higher and more volatile flows. Bulk volumes of electrical power need to be transported over larger distances. This is mainly driven by the rapidly increasing share of intermittent renewable energy, which is often produced far away from consumption centres on remote locations with favourable meteorological conditions.

Keeping up with rising RES infeed is a challenge for grid development as grid infrastructure takes longer to realise than renewables (>5 years difference). In some countries the grid (hardware) is lagging behind the rising transmission needs. To deal with the increased complexity of higher and more volatile electricity flows, we also see a need for an improved market design (software) to better control the flows in line with the physical constraints of the grid.

EFFECTS OBSERVED IN THE HORIZONTAL SYSTEM DRIVEN BY THE RAPID INCREASE IN RENEWABLES COMBINED WITH A GRID THAT IS LAGGING BEHIND [FIGURE 3]

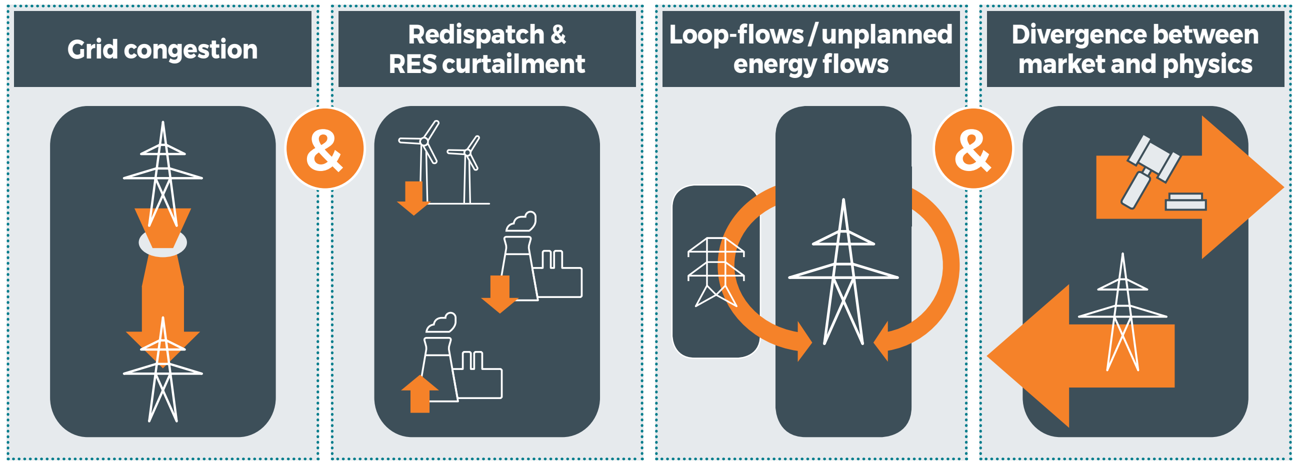


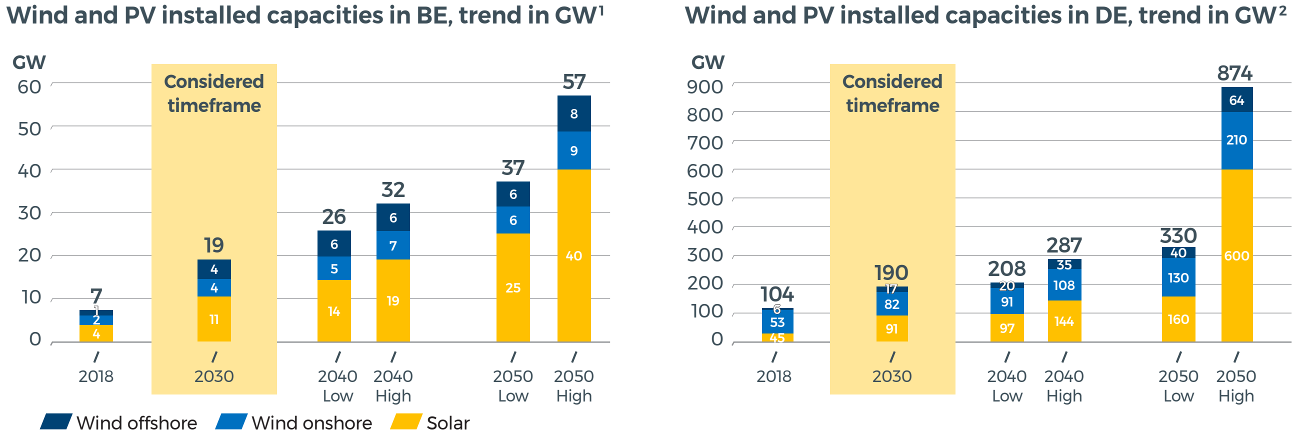
Figure 3 shows the increasing challenges on both the hardware and the software of the European, interconnected electricity system.

In the next 10 years, the electricity flows in the horizontal system will further increase and become even more volatile. The share of conventional generation, often located near consumption centres, is expected to continue to decline across Europe. For example, nuclear generation will be phased-out in Belgium and Germany and there is the planned coal phase-out in Germany. The share of renewables in the electricity grid will further increase in order to reach the climate targets of 2030 and beyond. Figure 4 gives an overview of the projected installed capacities of wind and solar generation in Belgium and Germany for 2030, along with the lower and upper boundaries for RES potential for 2040 and 2050 respectively.

Besides the higher and more volatile flows in the horizontal system as a result of the change in generation pattern, the Clean Energy Package puts ambitious targets in place for making 70% of the transmission capacity of grid elements available for cross-border exchanges [EUC-3]. This will also lead to an increase in commercial (and hence physical) electricity flows in the grid.

The projections of the ambitious political goals make one thing very clear: if we do not anticipate in time, the electricity system will not – not on the grid infrastructure nor on the market side - be able to integrate the next wave of renewables in an efficient way. Consequently, the system will be increasingly confronted with grid congestions, redispatch measures (including RES curtailment) and loop flows, even more than it is today.

FORECAST OF INSTALLED CAPACITIES OF WIND AND PHOTOVOLTAIC GENERATION IN BELGIUM AND GERMANY FOR 2018, 2030, 2040 AND 2050 [FIGURE 4]


Wind and PV installed capacities in BE, trend in GW[1]

Wind and PV installed capacities in DE, trend in GW[2]

1. Sources for Belgian numbers:
2018: Elia [ELI-3];
2030: TYNDP 2020 Scenario Report 'National Trends' [ENT-2];
2040: TYNDP 2020 Scenario Report 'National Trends' & 'Distributed Energy' [ENT-2];
2050 LOW: own source, meta analysis;
2050 HIGH: Elia Study [Eli-4].

2. Sources for German numbers:
2018: BMWi AG Energiebilanzen [AGE-1];
2030: TYNDP 2020 Scenario Report 'National Trends' [ENT-2];
2040: TYNDP 2020 Scenario Report 'National Trends' & 'Distributed Energy' [ENT-2];
2050 LOW: own source, meta analysis;
2050 HIGH: Enervis Study [ENV-1].

Having the current and the future challenges of the energy transition in mind, Elia Group embarked on a study to investigate what is required to implement the next stage of the energy transition in the run-up to 2030 in a timely and efficient way with maximal welfare for society. We therefore looked both at the hardware and software components of the horizontal system.

The status quo is not an option for the coming decade if we want to deliver the next phase of the energy transition in a timely and efficient way and with maximum welfare for society.

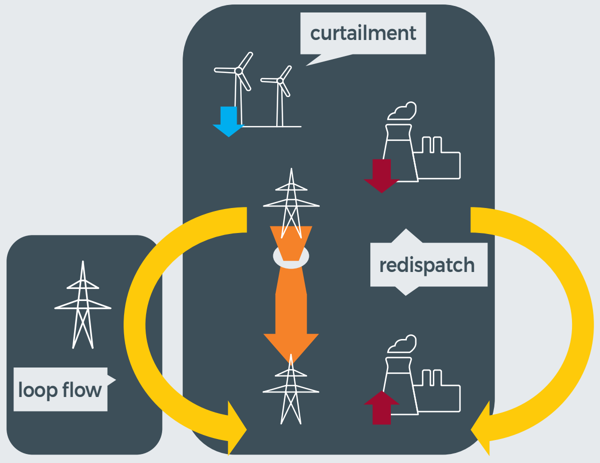
BOX 1: KEY CONCEPTS OF THE HORIZONTAL SYSTEM EXPLAINED

Loop flows are cross-border power flows that originate from an exchange of energy between generation and consumption within a bidding zone. Loop flows are inherent to a zonal market design. Their size should however be kept under control, as they can limit the cross-zonal capacities available to the market for neighbouring bidding zones (potentially negatively affecting market welfare and security of supply).

Redispatch refers to a costly measure by which the TSO alters the power generation and/or load pattern in order to change the physical power flows in the grid to relieve a physical congestion. Redispatch usually consists of two or more actions (upward or downward change of power generation or load) at the opposite sides of a congestion. In the simulations performed in this study, redispatch is applied after the market to secure the grid.

RES curtailment is the reduction of renewable generation, when the grid is at risk of overload. It is usually a last resort option for the TSO, when other redispatch measures are not sufficient. The market itself can also curtail renewables, e.g. when market participants face negative prices and therefore choose not to produce.

KEY CONCEPTS OF THE HORIZONTAL SYSTEM EXPLAINED [FIGURE 5]

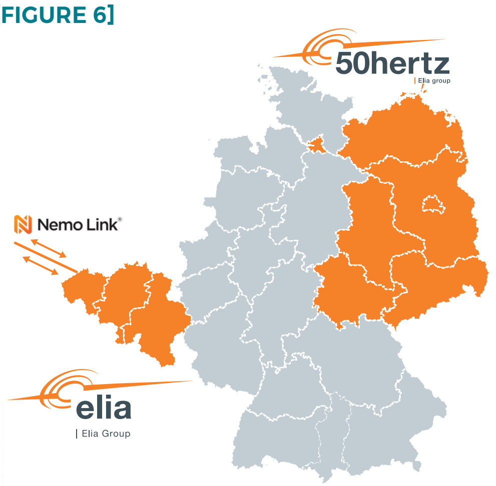


2.2. Why this study?

Transmission system operators have a central role in the European energy system. They build and maintain the grid, operate the system, make the infrastructure available to market parties and have a role as market facilitator. To handle the societal demand for a carbon free world, it is our mission to integrate the constant increase of renewables in the most effective and efficient way.

Elia Group is operational in two countries with different challenges and approaches on how to realise the energy transition. The Belgian grid is strongly interconnected and faces security of supply concerns in the future.

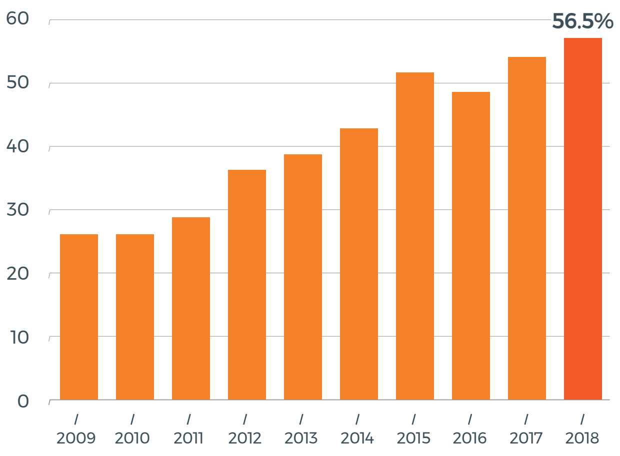
ELIA GROUP IS ACTIVE IN BELGIUM AND GERMANY [FIGURE 6]



In this study, Elia Group provides, from the perspective of two grid operators which are each confronted with different challenges, practical proposals to ensure a more effective and efficient European transmission system in the run-up to 2030. Our focus is to maximise welfare for society.

Germany already integrated a large amount of renewables in its electricity grid. Figure 7 shows the share of renewable power production in the 50Hertz grid, reaching more than 56% in 2018. The German grid however has to deal with congestions as the renewable production units (in the north) are far away from the consumption centres (in the south) and grid expansion has been lagging behind.

SHARE OF RENEWABLE ELECTRICITY PRODUCTION IN 50HERTZ CONTROL AREA [%] [FIGURE 7]



2.3. Approach of the study

In this study, Elia Group investigates what is required to implement the next stage of the energy transition in the run-up to 2030 in a timely and efficient way with maximal welfare for society. We therefore looked both at the hardware and software components of the horizontal system.

Concretely, we have performed the following market simulations for 2030:

- Simulation to investigate the effect of timely implementation of grid expansion on the realisation of the energy transition in the run-up to 2030, with a particular focus on the German north-south HVDC reinforcements. For this, the study compares a scenario with all the planned grid expansion for 2030 in place with a scenario in which part of the grid expansion would not be in place. This is outlined in Section 2.4.
- Simulation to compare the performance of the reference market design for 2030 (i.e. the market design as planned to be implemented in 2030) with a proposed new Flexibility-In-Market-Coupling design (hereafter referred to as Flex-In-Market design), in which the market gets access to more flexible measures (e.g. controllable devices) to manage congestions. Under the proposed new market design, the market can optimise set points of Phase-Shifting Transformers (PSTs) and (internal) HVDC lines. The market design also introduces the concept of Dispatch Hubs as an efficient way for the market to manage congestions. This is outlined in Section 2.5.

The performed market simulations are based on a single climate year (2012). As this study focuses on orders of magnitudes and relative comparisons between different options, the insights obtained on that basis can be considered relevant and robust. Unless otherwise specified, all results on welfare, redispatch costs, etc. are on European level (i.e. for the entire simulated perimeter as shown in Figure 20). Box 2 elaborates on the definition of the term 'welfare' that is used in this study. Finally, Section 2.6 provides an overview of the assumptions, input data and underlying scenarios for the 2030 market simulations that were performed.

BOX 2: DEFINITION OF WELFARE IN THIS STUDY

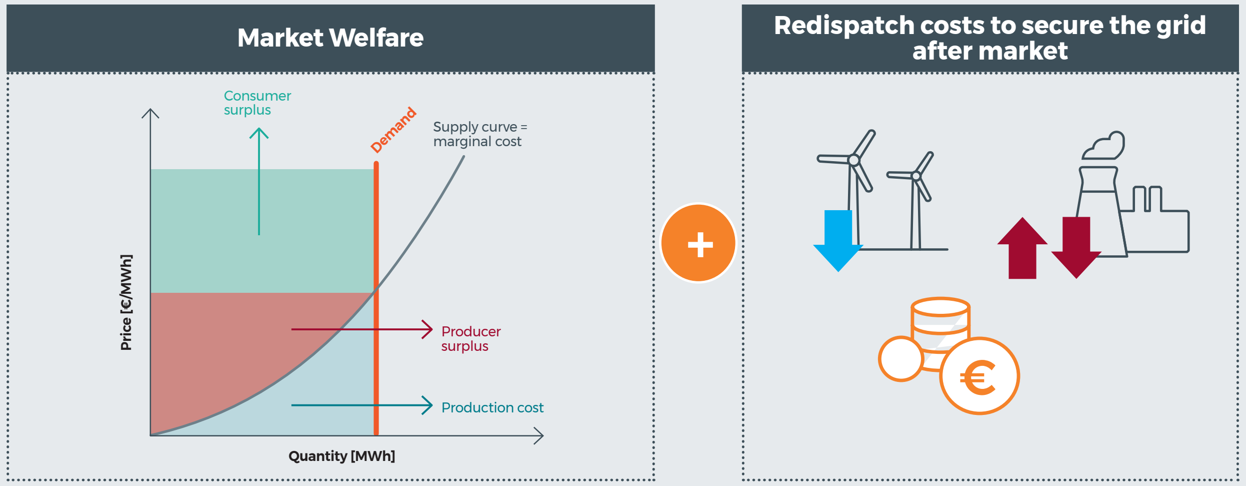
The market welfare, as calculated in this study, is an indicator to determine the additional economic gain or loss induced by changes in the electricity system (such as investments, a different capacity mix or change in market design) for the consumers, producers and congestion rents.

In this study, the term welfare always refers to the sum of market welfare and redispatching costs, hence the sum of the following components:

- The **market consumer surplus** is defined as the difference between the maximum price which the consumer is willing to pay (here: price cap of the model) and the actual price they pay.
- The **market producer surplus** is defined as the market price, multiplied by the quantity produced, minus total variable cost of production.
- The **market congestion rent** is equal to the sum over all area's of the multiplication of the area's balance with the price of the area, where imports/exports reflect a positive/negative balance.
- The **redispatching cost** reflects the costs made by the TSO to secure the grid after the market by changing generation and load patterns to relieve physical congestions[2].

[2] Evaluated at marginal cost in this study; RES curtailment is considered at zero marginal cost.

DEFINITION OF WELFARE FOLLOWED THROUGHOUT THE STUDY [FIGURE 8]



The market welfare is always assessed against a chosen reference case. The study therefore only shows relative differences on the above-mentioned indicators to compare different simulated scenarios.

2.4. The role of grid infrastructure (hardware) in the next stage of the energy transition

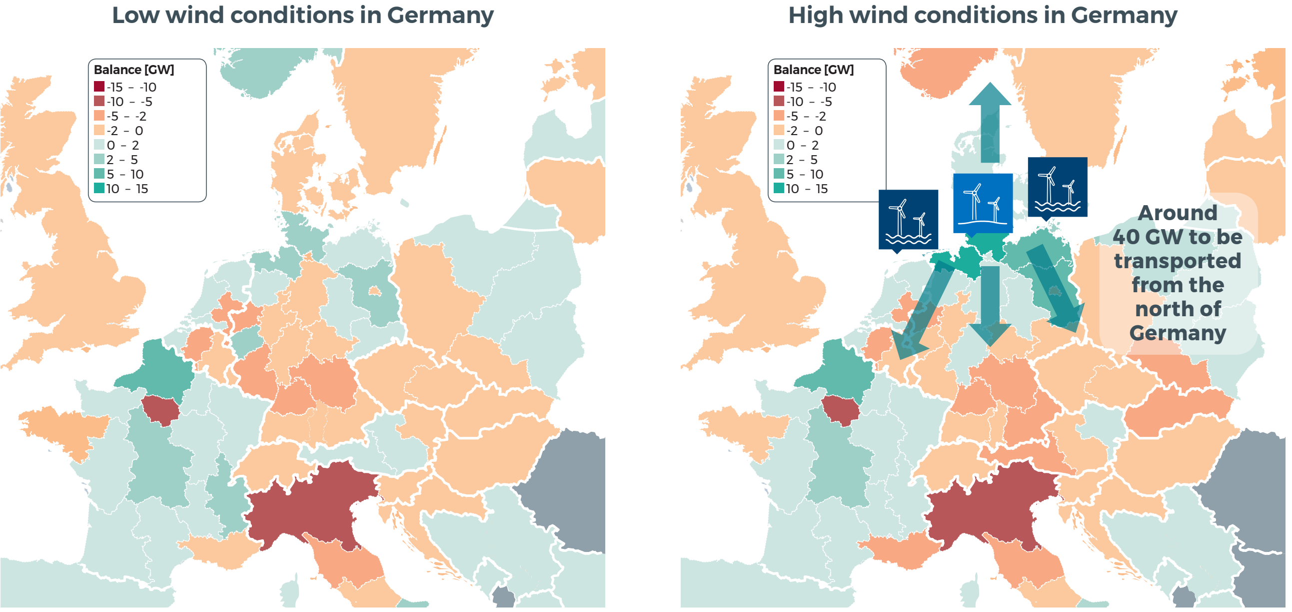
The first and most important lever for an efficient realisation of the next stage of the energy transition in the run-up to 2030 is the timely completion of the planned grid expansion.

2.4.1. Increasing share of renewables as a driver for grid expansion in the run-up towards 2030 and beyond

The energy transition results in higher and more volatile flows in the electricity grid. Figure 9 shows the simulated average energy balances (as defined by the market clearing[3]) for different geographical areas in the existing bidding zone configuration for high and low wind energy conditions in Germany by 2030[4].

The performed simulations show that the German bidding zone on average shifts between import (approx. 2 GW) and strong export (more than 20 GW) in low wind and high wind conditions respectively. This causes significant volatility for the electricity flows in the entire European horizontal system. The green areas in the north of Germany for high wind conditions indicate a significant volume of wind energy (around 40 GW on average) to be evacuated, to the consumption centres in the south of Germany amongst others. Figure 10 shows the approved north to south High Voltage Direct Current (HVDC) corridors in Germany for transporting those renewables to the consumption centres (C2030v19 scenario of the German Federal Grid development plan ("Netzentwicklungsplan" [NEP-1]).

NET BALANCES [GW] OF DIFFERENT AREAS FOR HIGH (LEFT) AND LOW (RIGHT) WIND CONDITIONS IN GERMANY [FIGURE 9]



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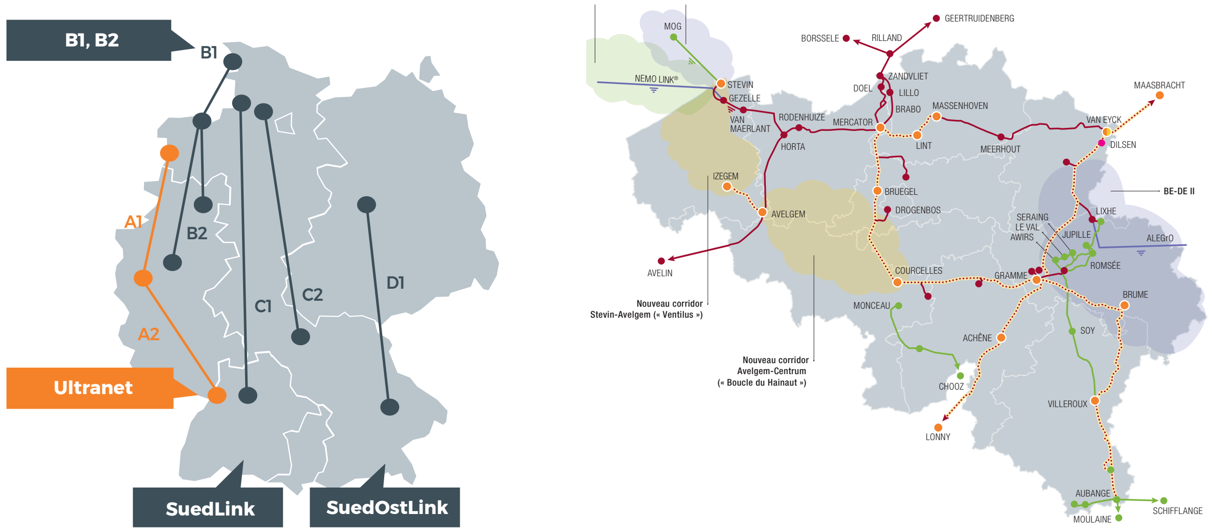
[3] I.e. after potential RES curtailment by the market.

[4] Values for high (low) wind conditions represent the average value for all hours where more (less) than 67% (33%) of the yearly maximum observed wind infeed is realised in Germany.

In Belgium, new onshore corridors are required to transport the additionally planned 2 GW of offshore wind production to the consumption centres. The approved Federal Grid Development plan [ELI-2] foresees two new corridors for this (c.f. yellow areas of Figure 10).

GRID REINFORCEMENTS DRIVEN BY THE INCREASE OF RENEWABLES ENERGIES [FIGURE 10]



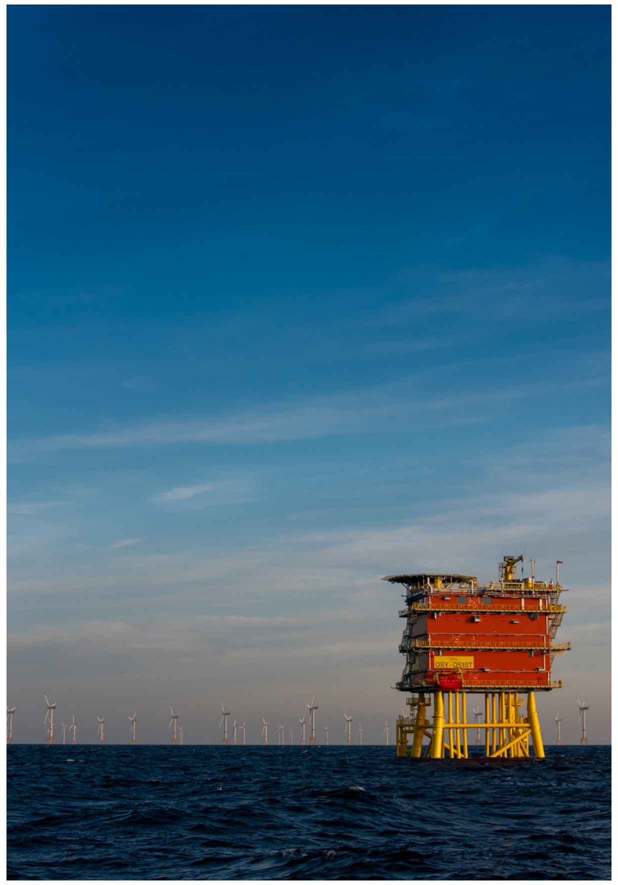
Approved German north – south HVDCs (NEP 19)

Ventilus and Boucle-Du-Hainaut (yellow areas)

2.4.2. Delayed grid expansion is a cost for society

In some countries, the current grid is lagging behind the rapid increase of renewables. The main reason is the significant difference of more than five years in lead-time between realising grid expansion and developing renewables. In Germany, this led to a situation in which the TSOs need to activate significant amounts of redispatch[5] to relieve congestions. A timely execution of the planned grid expansion would therefore bring benefits for Germany in the form of reduced redispatch costs and lower RES curtailment. Moreover, neighbouring countries would also benefit as the grid expansion would reduce the loop flows through their grids as well. This ultimately leads to an increase of welfare in Europe.

Performed simulations show that not having the grey north to south HVDC lines of Figure 10 in place in Germany would entail a yearly welfare loss of about € 1 billion to € 1.5 billion by 2030, and would also increase the curtailed RES volumes by approximately 40%. These numbers will further increase as more renewables are integrated beyond 2030 on the road to full decarbonisation.



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[5] BNetzA reported a total cost of € 1.437 million for 2018, of which € 635 million are related to compensation for curtailment [BNA-1].

2.4.3. Strengthening and optimising existing grid infrastructure

The energy transition comes with higher and more volatile flows in the horizontal system. Before considering grid expansion, TSOs optimise and strengthen the existing transmission grid in order to accommodate the increasing transportation needs. As such, they enable a higher utilisation of the grid infrastructure. The Elia Group is strongly focused on these measures to increase the available transmission capacity in the short term, in addition to the planned grid expansion that will come up to speed over the next couple of years. Figure 11 provides an overview of the most important measures applied by the Elia Group to accommodate a higher utilisation of the grid.

OVERVIEW OF SOME OF THE MEASURES APPLIED BY THE ELIA GROUP TO ENABLE HIGHER GRID UTILISATION [FIGURE 11]

Higher utilisation	**Control flow**	Optimise the power flow distribution to use available capacities more efficiently	· Phase-Shifting Transformers (PST) · High Voltage Direct Current Lines (HVDC)
	Increase capacities	Strengthen the grid at local bottlenecks to increase capacity for the overall utilisation	· High Temperature Low Sag Conductors (HTLS) · Dynamic Line Rating (DLR)
	Ensure safety	Ensure a secure operation of a system with higher flows and more power electronics (dynamic stability)	· Static Compensators (SC) · ....

Over the next decade, the share of devices that can actively control or steer the power flows (PSTs, HVDCs,...) will increase in the European grid. These devices allow for a higher grid utilisation, as they can steer flows away from highly loaded grid elements towards elements with lower loadings, enabling a more even distribution of the flows. An efficient coordination of the operation of these devices across Europe is of utmost importance to enable the higher utilisation of the grid. Over the next decade, the Elia Group will further deploy those technologies in its grid (cf. [ELI-2] and [NEP-1]). We are also working on the optimisation and coordination of those controllable devices in the European system. As a result of this study, we propose to optimise the set points of PSTs and (internal) HVDCs directly in the pan-European market coupling, enabling optimal welfare and an efficient utilisation of the grid (see Sections 2.5.2 and 2.5.3).

Elia Group increases the transmission capacity of the grid elements by replacing conductors with new technologies allowing higher electricity flows (HTLS) (see [ELI-2] and [NEP-1] for planned projects). These conductors can be operated at higher temperatures and have less sag, meaning that they can comply with the minimum safety distances from the ground at higher loading levels. Changing conductors to HTLS technology can, depending on the initial situation, significantly increase the transmission capacity on existing corridors. Additionally, the Elia Group invests in Dynamic Line Rating (DLR) when appropriate, which allows us to increase the capacity of transmission lines in cold and windy conditions by having an advanced monitoring of their temperature. Elia -as one of the front-runners in Europe - has equipped all of its important 380 kV lines that could limit the market with DLR (see [CRG-1] for more information on the mechanism).

At the same time, the Elia Group is preparing the grid to deal with higher flows and declining shares of conventional generation, as this introduces challenges for the secure operation of the system (e.g. in terms of voltage and frequency stability). The Elia Group will deploy the right technologies –at the right time- to maintain a secure operation of the system. As an example, 50Hertz plans to integrate Static Compensators (SCs) in its grid over the coming years to enable a secure system operation (in particular dynamic stability) in a system with higher power flows, more renewables and more power electronics. More information on the higher utilisation of the grid can be found in [50H-1] and the Addendum to this study [ELI-1].

Our simulations show significant yearly welfare losses of about €1 billion to €1.5 billion in 2030 and approximately 40% more RES curtailment if the German north to south HVDCs would not be in place. Those values will further increase as more renewables are integrated into the system beyond 2030.

2.5. Improved market design (software) for an even more efficient use of grid infrastructure

More grid infrastructure alone is not enough. We need to make the most out of it. As a second lever, the Elia Group proposes an improved market design (Flex-In-Market design) which provides the market with access to more flexible measures to manage congestions. The study introduces the concept of Dispatch Hubs as a promising measure for doing so. The first simulation results are positive and show a more efficient use of the grid infrastructure and increased welfare.

2.5.1. Key results

The timely completion of the planned grid expansion (hardware) is the first and most important lever for realising the energy transition in an efficient way in the run-up to 2030 and beyond. However, infrastructure alone is not enough. The Elia Group, in its role as market facilitator, identified and assessed interesting concepts for improving the market design[6]. The newly proposed Flex-In-Market design prepares the market (software) to deal efficiently with higher and more volatile flows, resulting from the energy transition and the requirement from the Clean Energy Package to make 70% of the available transmission capacity of grid elements available for cross-zonal exchanges. The focus of this study is on the pan-European day-ahead electricity market.

The Flex-In-Market design (explained in Section 2.5.3) provides the market with an extensive toolbox of flexible measures to achieve a more efficient utilisation of the grid. This toolbox consists of controllable devices (PSTs and HVDCs) and Dispatch Hubs. These Dispatch Hubs, being a new concept introduced in this study, are a promising tool within the Flex-In-Market design for the market to cope more efficiently with congestions (see Section 2.5.4). The first simulations for the Flex-In-Market design show positive results. They are summarized in Table 1 which compares the performance of the proposed Flex-In-Market design with the reference market design for 2030.

Performed simulations for the Flex-In-Market design, optimising controllable devices and Dispatch Hubs, project welfare gains of € 300 to € 400 million per year in 2030 compared to the reference market design and a 10% to 15% decrease of curtailed volumes of RES.

The Flex-In-Market design could also significantly reduce redispatch costs, internalising the cost for solving congestion into the market. This is an efficient way to manage congestions in anticipation of planned grid expansion (needed to accomodate the increased transportation needs caused by RES integration) coming up to speed over the next couple of years. Simulations show a potential reduction of German redispatch costs by more than 50% in anticipation of the construction of the grey HVDC lines of Figure 10, along with a 20% to 30% reduction in the curtailed volumes of RES.

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[6] Also within ENTSO-E improvements to the market design for 2030 are being investigated [ENT-5]. This study builds further on the work performed within ENTSO-E.

2.5.2. Flex-In-Market design leading to more efficient grid utilisation

The left-hand side of Figure 12 gives an overview of the main characteristics of the reference market design (i.e. the planned market design for 2030) and the Flex-In-Market design (on the right). The main difference between both market designs is the way in which the final dispatch of the system is determined.

Under the reference market design, virtual margins (i.e. margins exceeding the available transmission capacity of the grid elements) are offered to the market. These virtual margins could result in high overloads in the grid after the market, which the TSOs then resolve in a second step, by changing grid topology and set points of PSTs and HVDCs and performing redispatch. Redispatch costs in the reference market design can therefore be high, triggering difficult discussions on mechanisms for sharing them.

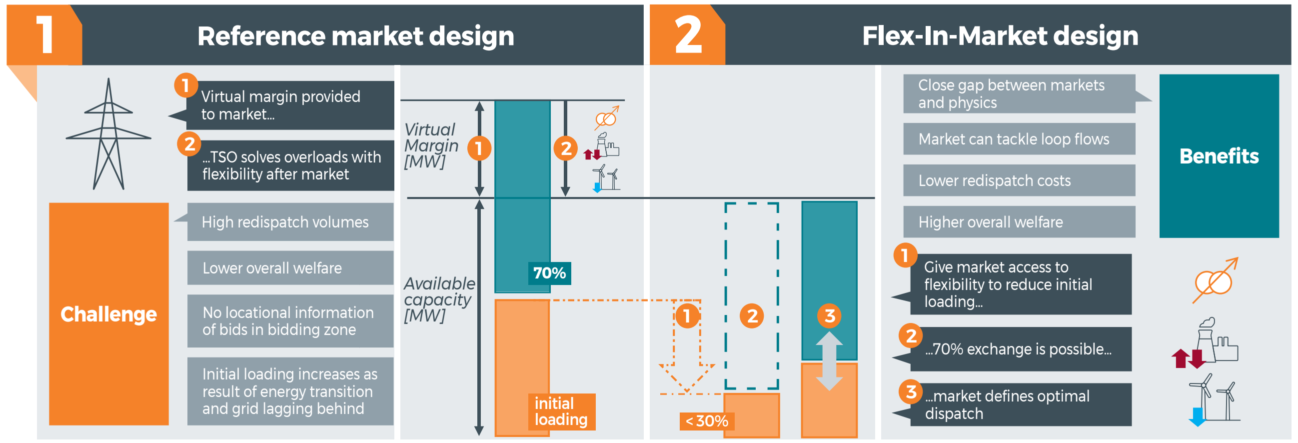
As well as this, the reference market design could lead to lower overall welfare, as costs for securing the grid after the market are not compared with the welfare generated within the market.

Finally, there can be a significant difference between the market results and the final physical dispatch in the reference market design in case of significant redispatch volumes. This impacts system security (e.g. activation of significant redispatch volumes late in the process) and the quality of the price signals (e.g. market prices which are not reflective for the final physical dispatch after redispatch).

The Flex-In-Market design aims to integrate the second step directly into the market coupling by enabling the market to optimise set points of controllable devices (PSTs and (internal) HVDCs) and Dispatch Hubs (see Section 2.5.4). This means that the market mechanism itself will define the optimal dispatch and application of flexible measures, thereby respecting grid constraints. The majority of the costs for activating flexibility would be absorbed directly in the market. This solves some of the main challenges observed under the reference market design, such as high redispatch costs and increasing divergence between markets and physics and leads to higher welfare for society.

The difference between both market designs becomes more obvious in cases where the initial loading of the lines (i.e. the loading of the lines without cross-zonal exchanges) increases, leading to higher virtual margins. This could be the case when the grid is lagging behind the increased transportation needs in the horizontal system as a result of the energy transition.

Box 3 provides more information on the flow-based domains, i.e. the transmission capacity offered to the market, for the Flex-In-Market design and the reference market design. It shows that the underlying idea of the Flex-In-Market design is to offer at least the amount of capacity to the market that would be offered under the reference market design.



COMPARISON OF MAIN CHARACTERISTICS OF REFERENCE MARKET DESIGN (LEFT) AND FLEX-IN-MARKET DESIGN (RIGHT) [FIGURE 12]

2.5.3. Zoom in on Flex-In-Market design

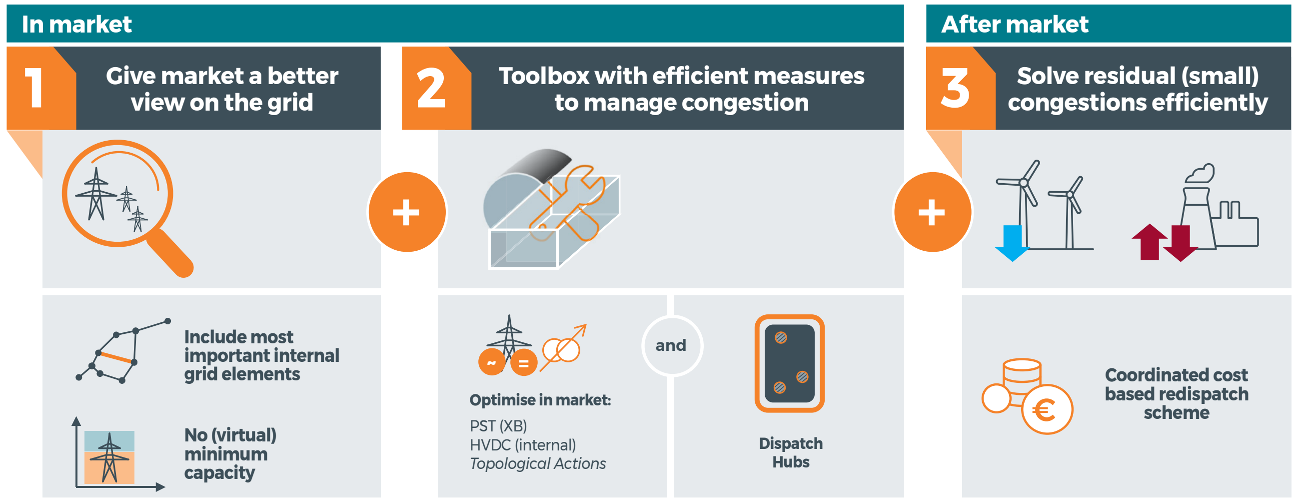
Figure 13 explains how the Flex-In-Market design closes the gap between markets and physics. To achieve this goal, it is important that the **market first gets a better view on the physics**, i.e. the grid and its constraints. Under the reference market design, the market only considers cross-border grid elements as constraints in accordance with the decision of ACER on the Capacity Calculation Methodology for the Core region [ACR-1] and, hence, has no view on what is happening inside the bidding zones. To remedy this, the Flex-In-Market design considers important internal lines, i.e. those who are significantly impacted by cross-border exchanges, as grid constraints in the market. For the same reason, the new market design refrains from the use of virtual margins.

As a second step, the Flex-In-Market design provides the market access to a toolbox with efficient measures for managing congestions on the considered grid constraints. The optimisation of topological actions in the market (instead of prior to market coupling) is considered as a matter for further study.

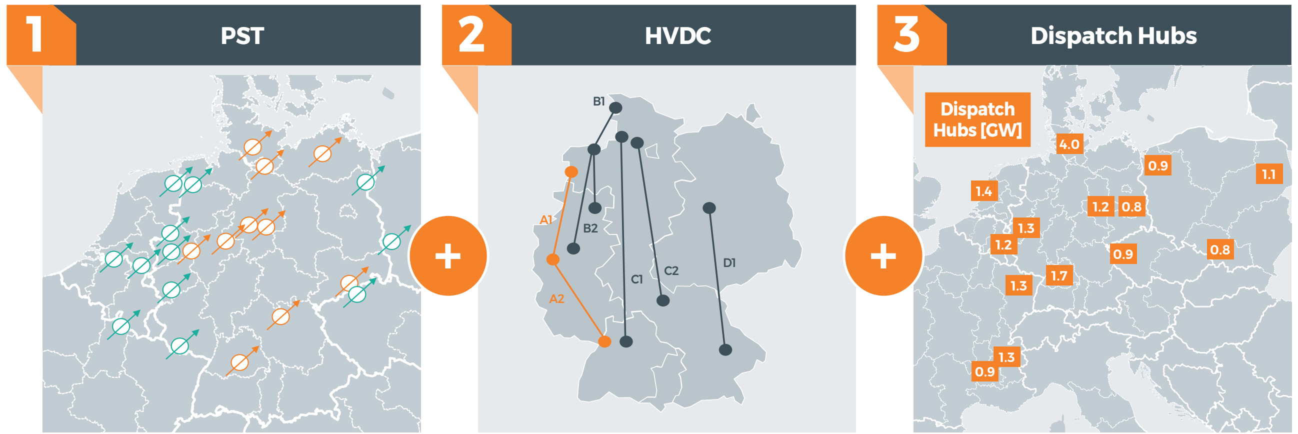
The flexibility measures considered in this study (see Figure 14) provide the market with extra degrees of freedom to manage congestions.

In a third step, the Flex-In-Market design is complemented with a coordinated redispatch scheme to resolve the remaining, small post-market overloads in the most efficient way. Indeed, a certain level of post-market congestions is inherent to a zonal market model, e.g. due to model inaccuracies. The post-market overloads are nevertheless much smaller under the Flex-In-Market design than under the reference market design.

KEY PRINCIPLES OF FLEX-IN-MARKET DESIGN [FIGURE 13]



FLEXIBILITY OPTIMISED WITHIN THE SIMULATIONS FOR THE FLEX-IN-MARKET DESIGN FOR 2030 [FIGURE 14]



Selection for BE, CZ, DE, NL, PL; Not shown: FR, IT, SL

Figure 14 gives a detailed overview of the flexibility that is optimised in the simulations performed in this study for 2030, i.e. PSTs relevant for cross-border flows (blue ones), (internal) HVDCs and Dispatch Hubs (see Section 2.5.4). Controllable devices such as PSTs and HVDCs bring significant welfare benefits to the horizontal system, both under the reference market design and the Flex-In-Market design. Under the reference market design, they are optimised by the TSOs, prior to the market, to maximise the amount of transmission capacity available in the forecasted market direction.

Under the Flex-In-Market design, the market coupling algorithm itself can optimise their set points and as such relieve congestions on the considered grid elements. The optimisation of those devices directly within the market coupling could have a further positive impact on the welfare generated in the market. Under both market designs, the full extent of those devices is used by the TSOs to secure the grid post-market in the most cost-efficient way.

BOX 3: FLOW-BASED DOMAINS FOR THE DIFFERENT MARKET DESIGNS

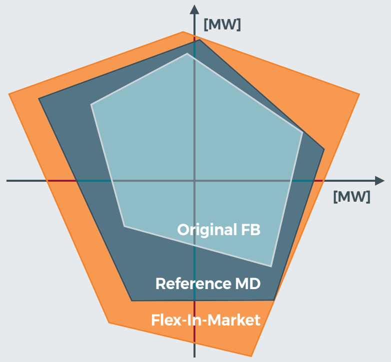
Figure 15 (on the right) summarises, for the different investigated market designs, which grid elements are considered as constraints in the market (cross-border and/or important internal lines), whether the market design applies virtual margins and optimises the identified flexibility measures in the market. For ease of understanding, the original flow-based market design (without virtual margins and flexibility in market coupling) is also included. An illustration of the flow-based domains for each of the market designs is provided on the left of the figure.

In the Flex-In-Market design sufficient flexibility measures must be provided to the market to manage congestions on the considered grid elements, making sure that at least the same amount of capacity is provided to the market as under the reference market design. Every flexibility measure provided to the market (like PST, internal HVDC, Dispatch Hubs) gives the market more possibilities to manage congestions, and hence increases the flow-based domain accordingly (i.e. extending the original flow-based domain to the orange one).

Solutions can be envisaged to mitigate situations where insufficient flexibility would be offered to the market to provide a domain that at least matches the reference market flow-based domain. Those measures were not considered in this study.

COMPARISON OF FLOW-BASED DOMAIN FOR THE DIFFERENT CONSIDERED MARKET DESIGNS [FIGURE 15]

Domain given to the market

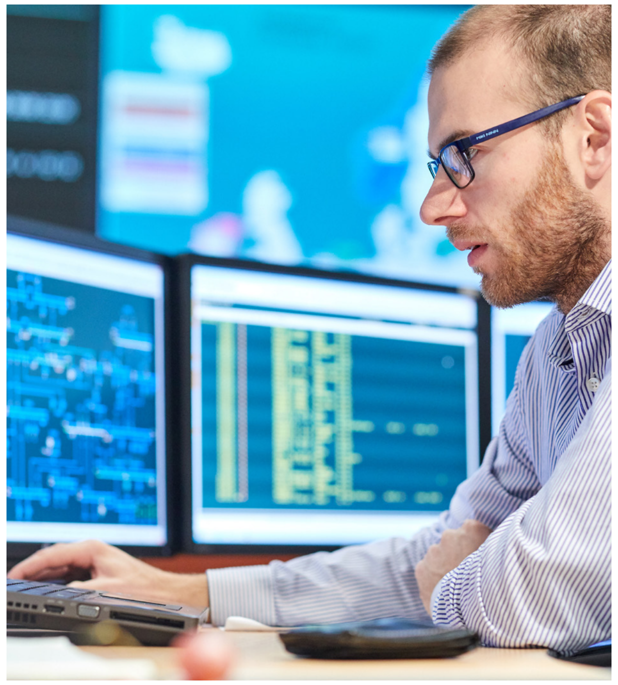


Key aspects of different market designs

	Cross-border lines?	Important internal lines?	Virtual margins?	Flexibility optimised in market?
Original flow-based	✓	✓	✖	✖
Reference market design (MD)	✓	✖	✓	✖
Flex-In-Market design	✓	✓	✖	✓

2.5.4. Dispatch Hubs as a promising tool within the Flex-In-Market design

This study introduces the concept of Dispatch Hubs as a promising tool for the market to manage congestions in a more efficient way. They are part of the flexibility measures in the Flex-In-Market design. The Dispatch Hub concept is explained in more detail in the following paragraphs.

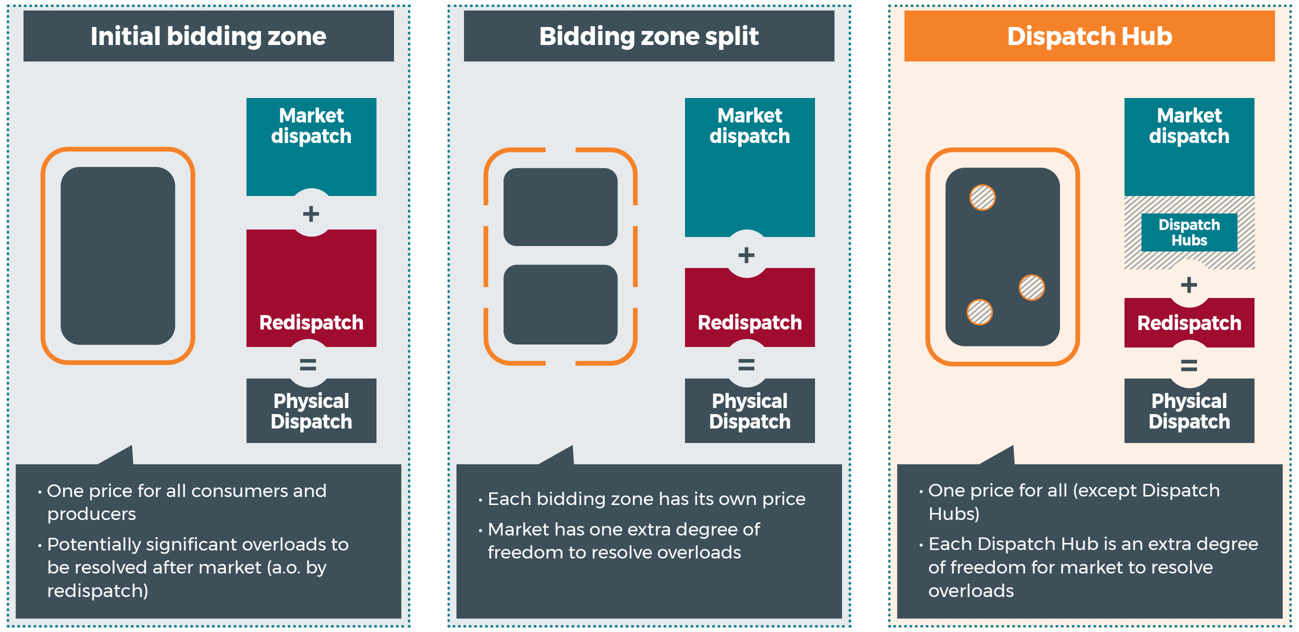


What does a Dispatch Hub do?

The concept of Dispatch Hubs is explained in Figure 16. Dispatch Hubs typically consist of large blocks of flexible generation (e.g. one or more conventional generation units)[7]. They can also be composed of blocks of RES (e.g. in the case where there are no other means to manage the congestion) or reflect redispatch potential available to the TSO. This is explained further on in *"What is in a Dispatch Hub?"*.

Dispatch Hubs provide the market with additional degrees of freedom to manage congestions, leading to a more efficient utilisation of the grid and higher welfare. For this, they are located on strategic places in the grid (see Box 5). They behave like (virtual) small bidding zones within the existing bidding zone, each getting their own price in the market. Box 4 provides a concrete example of the functioning of Dispatch Hubs.

CONCEPT OF DISPATCH HUB EXPLAINED [FIGURE 16]



Initial bidding zone

- One price for all consumers and producers
- Potentially significant overloads to be resolved after market (a.o. by redispatch)

Bidding zone split

- Each bidding zone has its own price
- Market has one extra degree of freedom to resolve overloads

Dispatch Hub

- One price for all (except Dispatch Hubs)
- Each Dispatch Hub is an extra degree of freedom for market to resolve overloads

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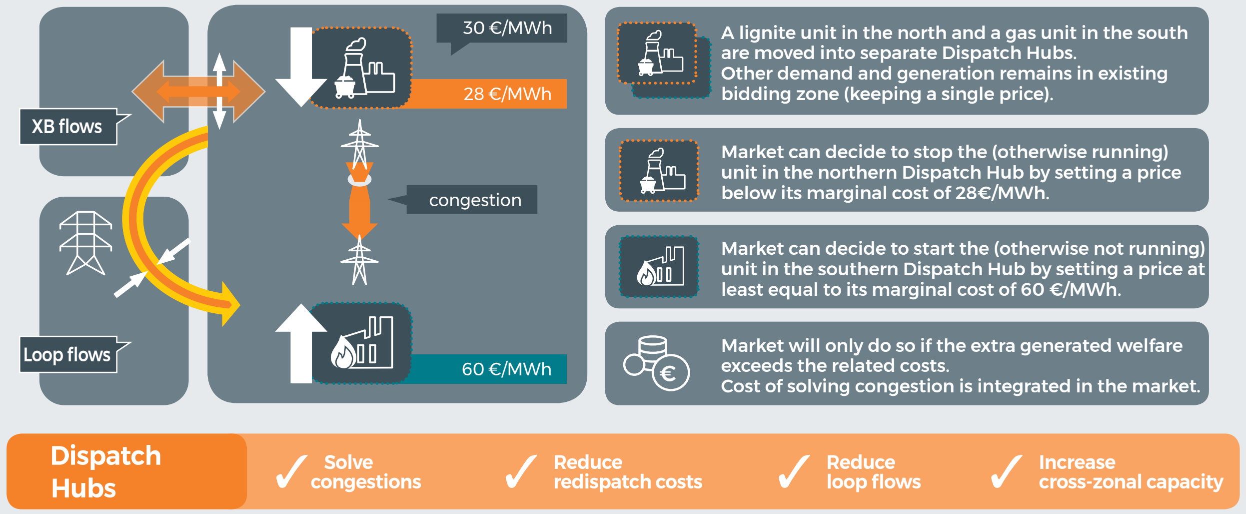
[7] Also some demand units, such as large industrial consumers,... could participate to those hubs. The simulations in this study assume that all demand is kept in the existing bidding zone, having one single price.

BOX 4: CONCRETE EXAMPLE OF THE FUNCTIONING OF DISPATCH HUBS

Figure 17 gives a didactical example of the functioning of Dispatch Hubs in the horizontal system. In this particular case, two Dispatch Hubs are integrated in an existing bidding zone, located at the opposite sides of an observed north-south congestion. As explained before, the Dispatch Hubs will behave like small virtual bidding zones. Units located within the Dispatch Hubs have to submit bids specifically for the Dispatch Hub.

ILLUSTRATIVE EXAMPLE ON THE FUNCTIONING OF DISPATCH HUBS [FIGURE 17]



A lignite unit in the north and a gas unit in the south are moved into separate Dispatch Hubs. Other demand and generation remains in existing bidding zone (keeping a single price).

Market can decide to stop the (otherwise running) unit in the northern Dispatch Hub by setting a price below its marginal cost of 28€/MWh.

Market can decide to start the (otherwise not running) unit in the southern Dispatch Hub by setting a price at least equal to its marginal cost of 60 €/MWh.

Market will only do so if the extra generated welfare exceeds the related costs. Cost of solving congestion is integrated in the market.

As shown in the figure, the concept of Dispatch Hubs gives the market the possibility to stop the lignite unit in the north and start the gas unit in the south. The market would only do so in a case when the additionally generated welfare would exceed the extra costs generated in the Dispatch Hubs. Those extra costs are absorbed directly in the market coupling, leading to reduced redispatch volumes and costs (see also explanations in Section 2.5.2).

The example demonstrates that Dispatch Hubs give the market the ability to deviate from the merit order list within a bidding zone for managing congestions in cases when this would increase overall welfare. This results in market prices that reflect better the physical (technically feasible) dispatch. This will –in most cases– result in a slight upward effect on the prices, as costs for congestions are now correctly internalised in the market. On the other hand, redispatch costs (borne by the end consumers) will reduce and the overall welfare increases.

The advantages of Dispatch Hubs in this example are multiple: congestion is solved in the market, redispatch costs and loop flows are reduced and the system can allow more cross-zonal exchanges.

Dispatch Hubs are fundamentally different from the other flexibility measures considered in the Flex-In-Market design. PSTs and (internal) HVDCs allow the market to redirect flows from highly loaded to less loaded lines, enabling a more even distribution of the flows and hence a more efficient utilisation of the grid. They have no (direct) impact on the dispatch of generation and demand and can therefore not change the amount of power flows in the system. Dispatch Hubs however have an effect on the dispatch of the system and hence can change the amount of flows. This makes them a particularly interesting tool to manage congestions in the market in an efficient and effective way. Dispatch Hubs internalise the cost of solving congestions directly in the market, leading to reduced redispatch costs.

Dispatch Hubs provide the market with extra flexibility to manage congestions, both within and across bidding zones. Hence, in terms of congestion management, Dispatch Hubs lead to effects similar to a split of bidding zones (see Figure 16). However, the impact of the introduction of Dispatch Hubs is very different from a split of bidding zones. Firstly, Dispatch Hubs allow the existing bidding zones to maintain a single price. This increases the acceptance of the Dispatch Hub solution, as discussions on a change in bidding zone delineation often result in difficult debates on welfare transfers and price differences within the bidding zone (mostly coinciding with national borders). Secondly, Dispatch Hubs can be defined in a more flexible way, depending on the needs and the congestions in the horizontal system, whereas a bidding zone split is a more static, structural decision. structural decision. Dispatch Hubs offer the market more degrees of freedom to solve congestions compared to a split of a bidding zone (providing one extra degree of freedom). Dispath Hubs could be seen as an interesting solution to manage congestions in the horizontal system in anticipation of planned grid expansion (which is needed to accomodate the increased transportation needs in the horizontal system as a result of the energy transition) coming online in the coming years.

What is in a Dispatch Hub?

Two possible implementation models for the Dispatch Hubs are defined in this study. In a first model, large blocks of dispatchable generation (e.g. conventional generation units) are placed within the Dispatch Hubs, requiring them to submit bids specifically for the Dispatch Hub. The market will set a price for each of the Dispatch Hubs (see Box 4), which will define the dispatch of the units. Regulatory oversight on the bidding within those Dispatch Hubs might be required, given their (potentially) limited liquidity.

In a second model, the Dispatch Hubs would reflect redispatch potential (volume, price) deemed available by the TSO at a specific location in the grid. All generation and demand would therefore be kept within the existing bidding zone. In this case, the Dispatch Hubs would define the redispatch that the TSO must perform post-market to make the market results technically feasible. The second method allows for a “wait and see” approach (e.g. only curtailing renewables in case when there is no other solution available at a later stage).

Both approaches have advantages and disadvantages and require further discussion with other TSOs, stakeholders and policymakers at European level. Mechanisms for selecting resources to be part of the Dispatch Hubs must be elaborated and transitory measures (e.g. compensation for units placed in Dispatch Hubs, depending on the implementation) should be explored where required. In any case, it is of key importance that the implemented solutions provide full transparency for market parties.

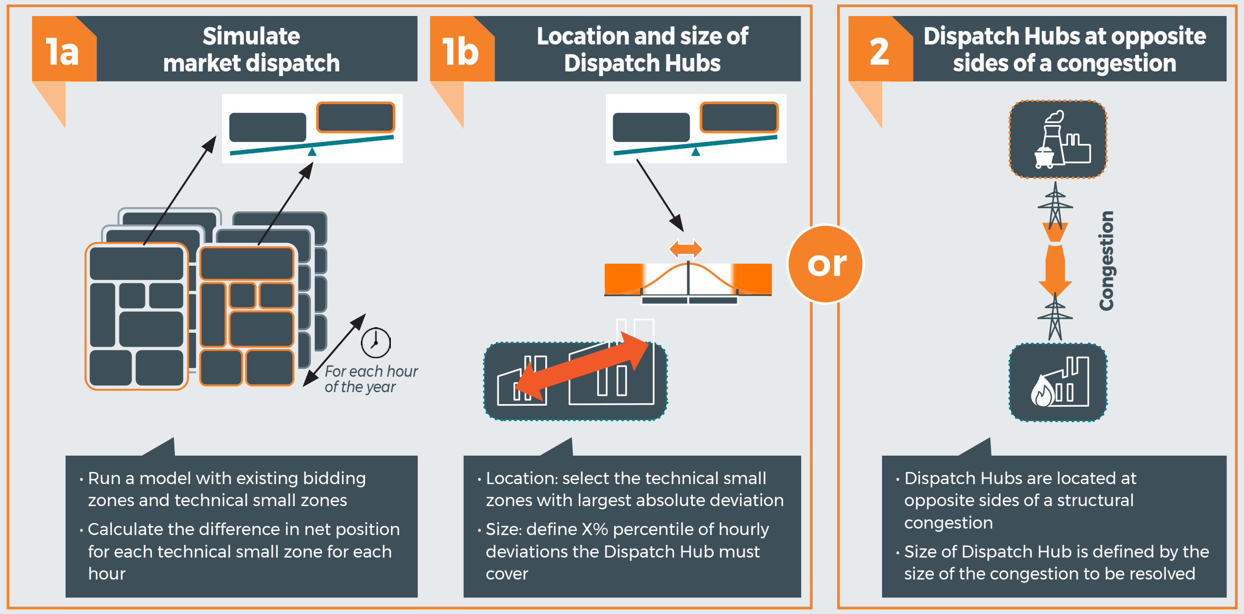
BOX 5: WHERE ARE DISPATCH HUBS LOCATED AND HOW ARE THEY DIMENSIONED?

There are multiple ways to define the location and dimension of the Dispatch Hubs (see Figure 18). The most straightforward approach would be to locate Dispatch Hubs at opposite sides of a congestion. In this case, the Dispatch Hubs should be sized in a way that enables them to manage the concerned congestion.

This study applies another approach to define the location and size of the Dispatch Hubs. The results of two different market simulations, one based on very small bidding zones (used in this study as a technical reference for redispatch simulations) and the other one based on existing bidding zones, were compared with each other. For each of the technical small zones the difference in net position between both simulations was calculated on hourly basis for the simulated year. The locations with the highest (absolute) deviations were selected as optimal locations for the Dispatch Hubs (as the market would value extra flexibility for changing the dispatch in those areas). The size of the Dispatch Hubs was then defined as the 90% percentile of the observed deviations. More information on this approach can be found in the Addendum to this study [ELI-1].

Both methods should be further discussed at European level with other TSOs, stakeholders and policymakers.

DIFFERENT WAYS TO DEFINE THE LOCATION AND SIZE OF DISPATCH HUBS [FIGURE 18]



- Run a model with existing bidding zones and technical small zones
- Calculate the difference in net position for each technical small zone for each hour

- Location: select the technical small zones with largest absolute deviation
- Size: define X% percentile of hourly deviations the Dispatch Hub must cover

- Dispatch Hubs are located at opposite sides of a structural congestion
- Size of Dispatch Hub is defined by the size of the congestion to be resolved

2.5.5. Conclusion

The simulations in this study confirm the potential of the Flex-In-Market design to enable a more efficient utilisation of the grid in the pan-European day-ahead market. Dispatch Hubs are introduced as a promising tool for the market to manage congestions in anticipation of planned grid expansion (needed to accommodate the increased transportation needs in the horizontal system as a result of the energy transition) coming online in the upcoming years.

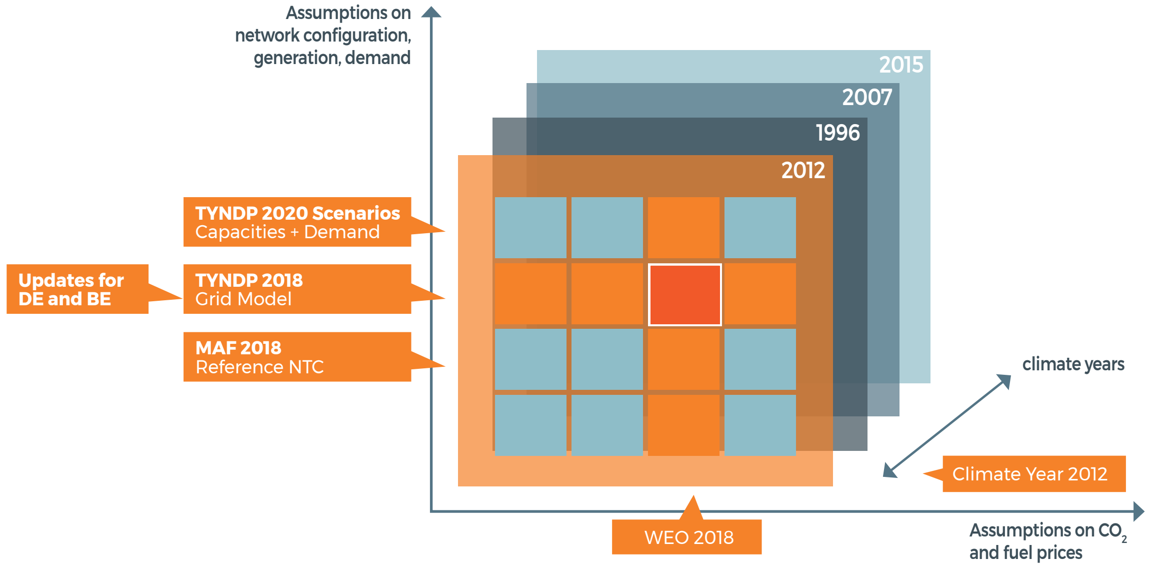
Our proposed market design improvements (Flex-In-Market design) could bring currently opposing views closer together as they reconcile the main interests of the involved parties: reduction of redispatch costs and RES curtailment and closing the gap between markets and physics. They also enable a more efficient handling of loop flows and an overall better utilisation of the grid, leading to improved welfare for society. The Flex-In-Market design, and in particular the concept of Dispatch Hubs, needs further discussion and elaboration (e.g. how to select units in a Dispatch Hub, link with other market timeframes, compensation schemes,...).

Elia Group believes it is relevant to discuss and further elaborate the proposed market design improvements at European level. We invite other TSOs, stakeholders and policymakers to join the discussions about our proposals.

2.6. Scenarios and assumptions of the study

Figure 19 highlights the main assumptions of this study. Simulations are based on the 2030 transmission grid as defined in the TYNDP2018 process [ENT-2], with some updates for Belgium and Germany on the basis of the latest stage of the national grid development plans [ELI-2], [NEP-1]. For the installed capacities of generation and the demand in 2030, the study uses the most recent input data from the TYNDP 2020 scenario report [ENT-2] (e.g. including the German target of 65% renewable electricity production by 2030). On the market side, the latest European regulations (Clean Energy Package [EUC-3]) and the ACER decision on the Capacity Calculation Methodology for the Core region [ACR-1] are taken into account in the reference market design. Fuel and CO2 prices are based on the “New Policies” scenario in the World Energy Outlook 2018 (WEO 2018) by the International Energy Agency [IEA-1].

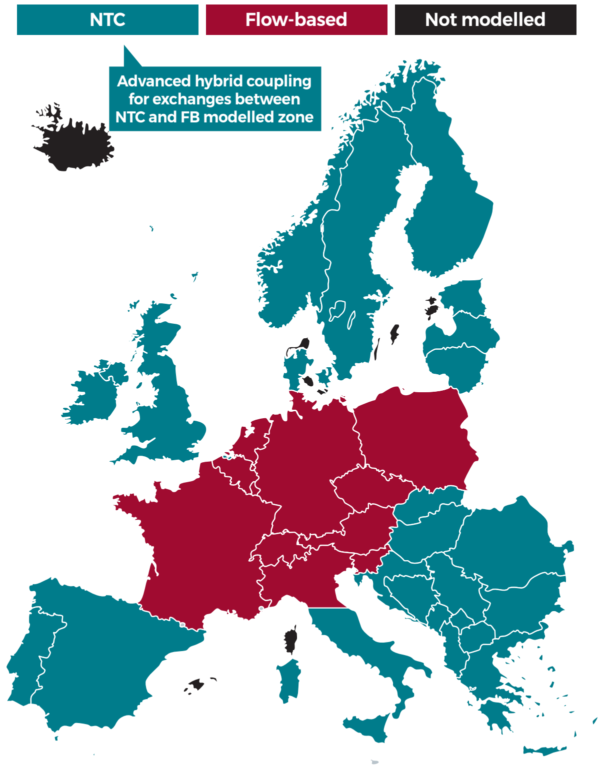
OVERVIEW OF THE ASSUMPTIONS TAKEN IN THE STUDY FOR 2030 GRID, LOAD AND GENERATION DATA [FIGURE 19]



Simulated perimeter

The simulations performed in this study cover the whole of Europe. Figure 20 shows which areas are modelled with a flow-based approach and which ones with an NTC approach.. A detailed description of the applied methodology, input data and assumptions can be found in the Addendum to this study [ELI-1].

SIMULATED PERIMETER IN STUDY [FIGURE 20]



Assumptions on redispatch mechanism

The redispatch costs and volumes in this study are calculated on the basis of a national cost-based redispatch model. The model allows all generation and demand bids within the bidding zone to be redispatched at cost (i.e. no add-ons to the marginal cost offered into the market). Renewables can be redispatched at zero marginal cost, meaning that no compensation for subsidy schemes is considered. The model applies a penalty for cross-border redispatch.

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