Ten-Year Network Development Plan 2020

TYNDP 2020

Main Report

August 2021 · Final version after ACER opinion

entsoe

ENTSO-E Mission Statement

Who we are

ENTSO-E, the European Network of Transmission System Operators for Electricity, is the **association for the cooperation of the European transmission system operators (TSOs)**. The 42 member TSOs, representing 35 countries, are responsible for the **secure and coordinated operation** of Europe's electricity system, the largest interconnected electrical grid in the world. In addition to its core, historical role in technical cooperation, ENTSO-E is also the common voice of TSOs.

ENTSO-E **brings together the unique expertise of TSOs for the benefit of European citizens** by keeping the lights on, enabling the energy transition, and promoting the completion and optimal functioning of the internal electricity market, including via the fulfilment of the mandates given to ENTSO-E based on EU legislation.

Our mission

ENTSO-E and its members, as the European TSO community, fulfil a common mission: Ensuring the **security of the interconnected power system in all time frames at pan-European level** and the **optimal functioning and development of the European interconnected electricity markets**, while enabling the integration of electricity generated from renewable energy sources and of emerging technologies.

Our vision

ENTSO-E plays a central role in enabling Europe to become the first **climate-neutral continent by 2050** by creating a system that is secure, sustainable and affordable, and that integrates the expected amount of renewable energy, thereby offering an essential contribution to the European Green Deal. This endeavour requires **sector integration** and close cooperation among all actors.

Europe is moving towards a sustainable, digitalised, integrated and electrified energy system with a combination of centralised and distributed resources.

ENTSO-E acts to ensure that this energy system **keeps consumers at its centre** and is operated and developed with **climate objectives** and **social welfare** in mind.

ENTSO-E is committed to use its unique expertise and system-wide view – supported by a responsibility to maintain the system's security – to deliver a comprehensive roadmap of how a climate-neutral Europe looks.

Our values

ENTSO-E acts in **solidarity** as a community of TSOs united by a shared **responsibility.**

As the professional association of independent and neutral regulated entities acting under a clear legal mandate, ENTSO-E serves the interests of society by **optimising social welfare** in its dimensions of safety, economy, environment, and performance.

ENTSO-E is committed to working with the highest technical rigour as well as developing sustainable and **innovative responses to prepare for the future** and overcoming the challenges of keeping the power system secure in a climate-neutral Europe. In all its activities, ENTSO-E acts with **transparency** and in a trustworthy dialogue with legislative and regulatory decision makers and stakeholders.

Our contributions

ENTSO-E supports the cooperation among its members at European and regional levels. Over the past decades, TSOs have undertaken initiatives to increase their cooperation in network planning, operation and market integration, thereby successfully contributing to meeting EU climate and energy targets.

To carry out its **legally mandated tasks**, ENTSO-E's key responsibilities include the following:

- Development and implementation of standards, network codes, platforms and tools to ensure secure system and market operation as well as integration of renewable energy;
- Assessment of the adequacy of the system in different timeframes;
- Coordination of the planning and development of infrastructures at the European level (Ten-Year Network Development Plans, TYNDPs);
- Coordination of research, development and innovation activities of TSOs;
- Development of platforms to enable the transparent sharing of data with market participants.

ENTSO-E supports its members in the **implementation and monitoring** of the agreed common rules.

ENTSO-E is the common voice of European TSOs and provides expert contributions and a constructive view to energy debates to support policymakers in making informed decisions.

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Home button
This will take you to the contents page. You can click on the titles to navigate to a chapter.

Arrows
Click on the arrows to move backwards or forwards a page.

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You will find a link to the glossary on each page.

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ENTSO-E Technopedia
www.entsoe.eu/Technopedia/

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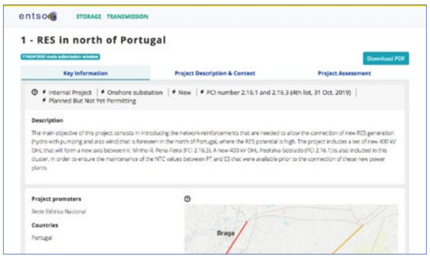
Main Report & Highlights

Project sheets



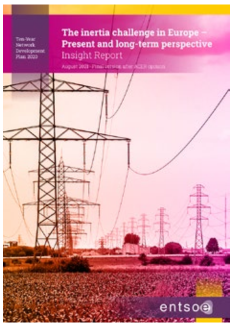
180 Project sheets, presenting the results of the cost-benefit analysis, key information and context behind each project assessed in the TYNDP 2020.

Available online at tyndp2020-project-platform.azurewebsites.net/projectsheets and downloadable as PDF.

Power system needs

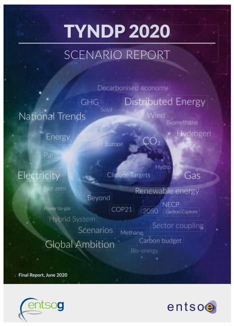
The pan-European *Power system needs report* and six regional investment plans present system needs in the 2030 and 2040 horizon. Four *system needs briefs* per PCI corridor and 31 *Country Factsheets* complete the needs analysis for the 2030 horizon. A side-report *System dynamic and operational challenges* investigates needs in terms of flexibility, frequency and inertia.

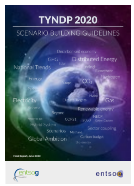
Deep dive



Insight reports deep dive into details of sector integration and the inertia challenge.

Scenarios





TYNDP 2020 scenarios for 2030 and 2040, co-developed with stakeholders.

Data available for download

- TYNDP 2020 project portfolio (projects data and CBA results)
- TYNDP 2020 reference network (forthcoming)
- Scenarios datasets
- Results of system needs study (via PowerBi)

Key numbers

The TYNDP 2020 assessed **154** transmission projects, of which 97 cross-border projects representing close to **90 GW** of additional cross-border transmission capacity. Overall, the TYNDP 2020 portfolio represents **46,000 km** of lines or cables.

26 storage projects, representing **485 GWh** of storage capacity. That's 6 more storage projects than in the TYNDP 2018, with for the first time a TYNDP pilot cross-sector (transport) project.

Collectively, TYNDP 2020 projects generate an increase in socio-economic welfare by **7.3 to 13.2 billion euro per year**, depending on the scenario considered.

17 % of TYNDP transmission investments suffered delays in the past two years, a share similar to that of previous TYNDPs. Of the 44 projects in permitting phase, 39 were already in permitting phase in the TYNDP 2018.

Investing in the TYNDP project portfolio will contribute to the post-pandemic European economic recovery. During the construction and commissioning of the projects, **1.7 Million jobs** could be ensured in European Union countries. In addition, infrastructure projects have a positive impact on production, GDP and public administration revenues in the European Union.

The TYNDP in 10 key questions

1 What is the Ten-Year Network Development Plan?

ENTSO-E's 10-year network development plan (TYNDP) is the European electricity infrastructure development plan. It links, enables and complements national grid development plans. It looks at the future power system in its entirety and how power links and storage can be used to make the energy transition happen in a cost-effective and secure way.

2 Why does Europe need a plan for electricity infrastructure?

Europe has engaged on an ambitious path towards decarbonisation. The major change is the rapid replacement of fossil-fuel generation by renewable energy sources and the electrification of other sectors. Europe will only reach its decarbonisation objective and the successful deployment of variable renewables if:

- the costs of transforming the system are kept as low as possible, by an appropriate set of investments enabling better market integration and leading to competitive power prices, and
- the continuous secure access to electricity is guaranteed to all Europeans.

Achieving this requires a coordinated, pan-European approach to electricity system planning.

The TYNDP is essential to the timely and effective development of transmission infrastructure to deliver long-term European policy and aspirations while keeping the system secure. It describes a series of possible energy futures jointly built with the European Network of Transmission System Operators for Gas (ENTSOG), and co-constructed with environment and consumer associations, the industry and any interested parties. The TYNDP uses an approved range of European indicators to compare how electricity infrastructure projects help to deliver EU climate targets, market integration and security of supply.

3 Are transmission or storage projects presented in the TYNDP the only solution?

To be successful, the energy transition will require a multitude of solutions coming from all energy professionals and users. The TYNDP 2020 scenarios already assume some of these will be in place. As an example, the National Trends scenario assume increases of battery capacity in Europe by 60 GW, of Demand Side Response by 10 GW and of Power-to-Gas by 3.5 GW from 2025 to 2040.

A regulatory and market framework enabling the smart handling of peak demand, new roles and behaviours for consumers and demand-side participation, better inter-linkage of the gas, electricity and transport sectors, and better integration of renewable energy sources are all considered as starting points for the scenarios.

The TYNDP, and especially the **study on power system needs in 2030 and 2040**, looks at how power lines and storage projects can contribute. However, all the findings can be extrapolated to identify other technological solutions solving interconnection barriers on either side of a border (including demand response, generation, storage, power to gas, etc.). In addition, solutions to address internal bottlenecks in some countries will also be needed.

4 How can decision-makers decide today which electricity infrastructure will be fit-for-purpose in 10 years?

Predicting the future with certainty is not possible. Climate goals, renewable integration, technology breakthroughs, e. g. in mobility, batteries, heating and cooling or Power to gas as well as digitalisation are real game changers in the energy sector. That is why the TYNDP studies several scenarios of the future and updates them every 2 years according to the current regulation. Each scenario follows a distinct storyline but all are realistic paths towards European targets, co-designed by the whole electricity sector, consumers and NGOs thanks to an extensive engagement and consultation process, jointly with the gas sector.

Using a series of plausible scenarios helps investors and policy-makers to limit the risks linked to the building of new interconnections (no regret options). Developing a plan with a portfolio of projects that will be robust for a range of scenarios is an absolute necessity – a transmission network is relatively cost efficient for society to build, but very expensive for it to do without.

5 How are infrastructure projects assessed?

The added value of projects in the TYNDP is illustrated through the CBA indicators. The CBA indicators capture the bulk of a project's benefits and costs. Two main factors impact the results of the CBA:

- The scenarios investigated: new scenarios are developed for each TYNDP cycle. CBA results are therefore a function of the trends that prevail at the time when the scenarios are constructed, in terms of policy initiatives, market dynamics, technology advancements, etc.
- The CBA methodology applied: the 3rd CBA methodology has been applied for the first time in the TYNDP 2020.

Additionally, the CBA depends on hypotheses concerning the future development of the transmission network. Projects are assessed in a given network configuration, a "picture" of the grid as it is expected to be at the time of the project's commissioning. A full-blown analysis of all plausible network configurations for analysing a given project is impossible at the scale of the TYNDP. An approximation is therefore made, taking the form of the "reference grid" representing the most objective view of ENTSO-E on the state of the network in 2025. The unavoidable impact of this approximation on the absolute values of the cost/benefits is compensated by the fact that all projects are transparently assessed on a level playing field that allows for further analyses when needed. Project promoters are always allowed to challenge their results if they believe their project has been assessed inadequately and have the right, under ENTSO-E's guidelines, to request a review of their project's assessment.

6 Are the proposed grid investments fit for purpose to address future power system needs?

To interpret the TYNDP, one must consider the full framework of the planning analysis, in particular by juxtaposing the system needs study for the 2030 and 2040 horizons with the cost-benefit analysis of specific projects. Only by considering the full framework can robust conclusions be drawn on the contribution of each individual project to a successful EU energy transition. Identified system needs, because they considered only benefits in terms of socio-economic welfare, provide a partial view of the needs on the borders analysed. The cost-benefit analysis completes that view by investigating how specific projects would benefit all Europeans by increasing socio-economic welfare, reducing CO_2 and other GHG emissions, increasing security of supply …

Comparing the identified needs based on socio-economic welfare and the proposed projects shows different situations depending on the border. While on some border the capacity increases of the proposed projects matches the SEW-based needs, on others there are needs that are not yet addressed by concrete projects, or projects that are either competing to address the same need or that address other needs than SEW-based.

7 Should all projects progress?

The value of a long-term plan is that it is not a commitment to build all projects, but rather to ensure that those that need to be developed at this stage do progress. Overall, the portfolio of projects is relatively stable between TYNDPs, indicating that the collection of European development projects is progressing towards maturity. The costs of assessing potential future projects are small when compared to their construction costs, justifying, to some extent, the assessment of diverse solutions for uncertain needs. Hence why several TYNDP projects that remain years away from starting construction may still be explored by project promoters, even though the benefits, as assessed in the TYNDP, are yet to materialise. Both future system needs and projects benefits must be monitored over years.

On the contrary, it is unlikely that a construction decision would be taken by promoters or allowed by regulators if the project cannot prove its benefits in the near future. The future needs identified by the TYNDP and the CBA results may also lead some promoters to reconsider the scope or timing of their projects. The TYNDP provides a solid basis to compare European projects through a series of indicators. However, it cannot claim to provide a full and exact value of future investments which will eventually depend, for instance, on the actual energy mix, local acceptability or on changed to the current market design.

8 How is the TYNDP developed?

Step 1: At the heart of the TYNDP lays a collection of **scenarios** indicating how the European power system might look in the future. ENTSO-E and its gas counterpart ENTSOG have developed the scenarios together with a wide scope of stakeholders. Each scenario's impacts on energy markets and networks are analysed with the help of tailored modelling tools.

Thanks to the models, ENTSO-E can explore various energy market needs and the corresponding power grid configurations. In this way, we can understand where the network infrastructure is working well, and where it needs to be reinforced. The main role of the TYNDP is therefore to identify where investment in the electricity system would help deliver the EU climate and energy goals. This has been done in two stages:

- Investigating where increasing cross-border electricity exchange capacity would be the most cost-efficient (**Step 2: system needs study**). The identified system needs are presented in the System needs study, released in August 2020.

- a call for transmission and storage projects under different stages of development across Europe and an analysis of their performance under the different scenarios (**Step 3 and 4: project collection and cost-benefit analysis of projects**). TYNDP 2020 assessed 154 transmission projects and 26 storage projects. ENTSO-E has worked with project promoters to develop individual project sheets presenting the results of the cost-benefit assessment and key information on each project.

In response to new challenges, TYNDP started exploring real-time system operation needs (voltage and frequency control). These needs are expected to grow in the future as a result of the changing energy generation mix and increasingly responsive energy demand.

9 What is the role of the TYNDP in the EU energy and climate policy?

Regulation (EC) 714/2009 and Regulation (EU) 347/2013 specify that the TYNDP should help identify those infrastructure projects that are key to the EU achieving its climate and energy objectives. Such projects, known as European projects of common interest (PCI), are selected among the TYNDP overall list of transmission and storage projects. Every two years, the European Commission utilises the information in the latest TYNDP as part of its selection and adoption of a new biannual list of PCIs. From the moment a TYNDP project becomes a PCI it may benefit from favourable treatment such as accelerated planning and permit granting. Therefore, the PCIs have a special status among the TYNDP projects.

The TYNDP, through its unique access to data, stakeholder involvement, and analytical capabilities, provides a transparent picture of the European electricity transmission network. In this way, it supports informed decision-making leading to strategic investment at regional and European level. It also offers unique datasets and analysis.

10 How are stakeholders involved in the TYNDP?

Stakeholders contributed to building the TYNDP2020 scenarios via 2 public consultations and 4 workshops or webinars during 2018 and 2019. The entire TYNDP package, including this report and insight reports, the project sheets, the pan-European System needs report and the six regional investment plans were submitted to a public consultation from 6 November 2020 to 4 January 2021.

Stakeholders comments allowed to improve the reports. Comments regarding the methodology itself will be taken into account to improve future editions of the TYNDP. Stakeholders wishing to engage further with ENTSO-E are welcome to contact us at **tyndp@entsoe.eu**. In February 2021, the entire TYNDP 2020 package will be submitted to ACER for a formal Opinion. ACER's comments will be implemented as far as possible in this edition of the TYNDP, or alternatively considered for implementation in the 2022 exercise.

In addition, stakeholders have been heavily involved in the development of the Cost-Benefit Analysis methodology (CBA 3.0), which has been written in large parts by stakeholders themselves.

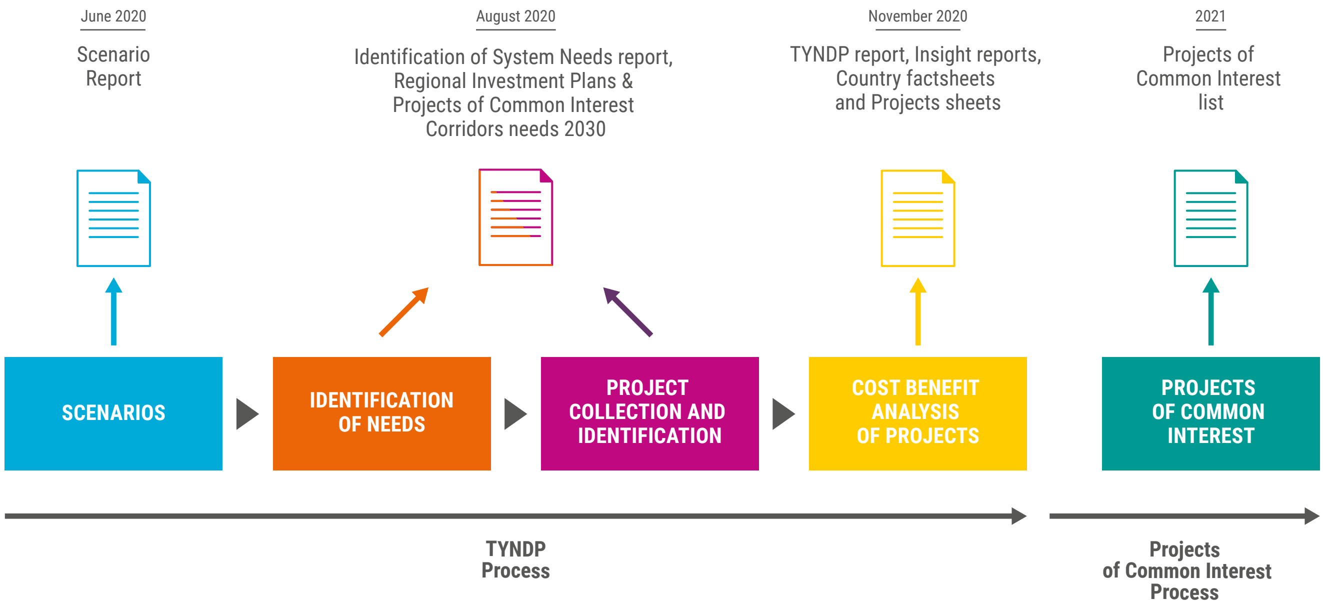


Figure 1 – Key steps of the TYNDP 2020 process

Life-cycle of a transmission project step by step

STEP 1 Identifying the needs

The first step, before developing a project, is to identify the needs for reinforcement of the transmission network. TSOs assess needs at national level on a regular basis. This assessment is completed by studies of needs at regional and pan-European level, carried out by ENTSO-E in the bi-yearly **System needs study** and Regional investment plans.

Assessing needs at national, regional and pan-European level allows to identify needs that may not have been identified with a national-only approach, or that would have been defined in a different way. It is especially important as RES development is triggering needs for an increasingly interconnected pan-European network, allowing electricity from RES to flow across borders.

Needs may be triggered by a wide list of factors, including changes in the generation portfolio and in the localisation of generation units, network stability and frequency issues, ageing infrastructure … The solutions to the needs are equally diverse and can come in the form of multiple technologies including other solutions than transmission lines, hence the importance of step 2.

CASE STORY TYNDP 2020 Future projects, responding to power system needs in 2030 and 2040

As part of the TYNDP, ENTSO-E investigated future power system needs in the 2030 and 2040 horizon. For the first time in the TYNDP 2020, project promoters were given the opportunity to propose new projects that address some of the identified needs. Nine projects were proposed, all in the very long term with a commissioning date after 2035.

These include two projects on the Bulgaria-Turkey and Greece-Turkey borders, where the System needs study identified needs for capacity increase of 1,500 MW in 2030 and 2040. Both projects have the potential to improve the stability of the connection of the Turkish power system to the Continental Europe synchronous area, allow integration of renewable energy and support the convergence of electricity market prices between Greece, Bulgaria and Turkey. Two other projects address needs on the Greece-North Macedonia border, with either the refurbishment of an existing interconnector or the building of a new one expanding also to Bulgaria. A last project in South-Eastern Europe plans for new interconnectors between Lybia, Northern Greece and Albania.

Further North, another identified need that was not already addressed by an existing project, is located on the Serbia-Hungary border. Promoters of the "Pannonian Corridor" project expect that it has potential to positively increase market integration in the region, while vastly enhancing security of supply and allowing for integration of renewable energy sources. In the Baltic, a project proposes to connect Sweden to Latvia via the Island of Gotland to integrate further renewable generation, reduce the current level of curtailed energy and increase market integration in the Baltic Sea region. Finally, a last transmission project proposes to connect 700 MW of offshore wind in Ireland.

The only storage project proposed in this window, the Online Grid Controller "PSKW-Rio" in Germany, answers the need to balance wide areas of the distribution grid and improve renewable energy grid feed-in, grid security and stability. The project could also support the management of fluctuating energy production from renewable energies and therefore significantly reduce carbon footprint as well as operation and maintenance costs.

STEP 2 Identifying solutions to address the need

Addressing tomorrow's challenges will require the parallel development of all possible solutions, including not only different transmission technologies or connections and routes, but also electricity storage, the role of prosumers and generation, in addition to reinforcing the transmission grid.

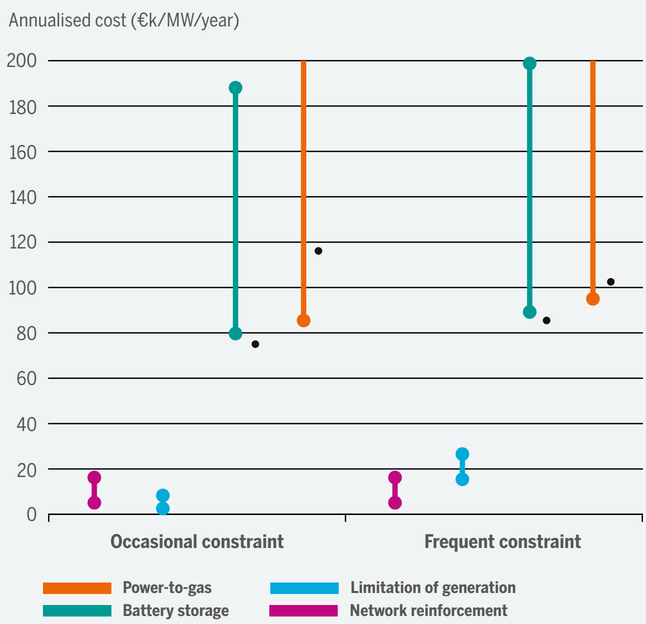
Once a need has been identified, it is necessary to identify the possible options to address the need, considering these options' respective costs and overall benefits for the power system.

In future, infrastructure planning will require to go even further, with a truly multi-sectorial approach, considering electricity assets but also gas, transport and heat. Smart sector integration will enhance flexibility across various energy sectors and allow a development towards a more energy- and cost-efficient energy system. ENTSO-E's roadmap for the development of multi-sectorial planning towards 2030 (MSPS) is meant to serve as a starting point.

CASE STORY Assessing alternative solutions

The French TSO RTE investigated in its **2019 national development plan** the cost-effectiveness of various solutions to tackle occasional and structural constraints, including power-to-gas, battery storage, limitation of wind generation via active network management controllers, compared to reinforcements of the transmission network. While limitation of production paired with dynamic line rating proved to be the most cost-efficient solution in case of occasional grid constraints, for structural constraints economic analyses show that reinforcing the network remains, for the moment, the most economical solution in general case (see figure). In the mid- to long-term, battery storage and power-to-gas could be additional solutions provided that specific conditions are met in terms of where they are located (near renewable energy production sites) and how they are used. The possible decrease of the cost of the batteries and the evolution of their benefits from other services could also increase their competitiveness and interest for congestion management.

In 2021, RTE will carry out experimental calls for tenders that put in competition market assets offering flexibility services – such as battery storage – with network reinforcement projects. This experimentation will focus on regional network congestions and on some cases where batteries are most likely to be competitive as early as today: thus, batteries mainly used for frequency containment reserves could get additional revenues by providing a congestion management service, and associated grid reinforcements could be postponed or even avoided.



Economic comparison of the various solutions for managing constraints an the transmission system (2018 cost assumption)

STEP 3 Preliminary design of a project & Cost-benefit analysis

Performing the cost-benefit analysis of a project consists in assessing its benefits for society as a whole, considering its impacts in terms of reduction of generation costs and CO_2 emissions, improved security of supply, etc. These benefits are then compared to the projects' expected costs. The cost-benefit analysis is monitored through the lifecycle of the project development.

To evaluate the costs of the project, a preliminary design is required, involving engineering and environmental studies, analysis of alternatives both for the project and the technologies to be applied. It also requires in some cases a request for information to manufactures to try to incorporate the latest technology improvements. Each TSO has its own methodology to perform the CBA of its projects at the national level, developed with and approved by the national regulator, although the TYNDP CBA methodology provides an overall umbrella and it is usually applied for cross-border projects.

Because the transmission grid acts as the backbone of the pan-European power system, many projects entail benefits in more than one European country (both cross-border and internal projects). That is why the EU has foreseen a cost-benefit analysis at pan-European level, the TYNDP, where projects are assessed based on the Guideline for cost-benefit analysis of grid development projects (latest version of the 3rd Guideline from February 2020 available **here**).

CASE STORY Biscay Gulf: Increased RES integration, reduced electricity prices and CO_2 emissions[1]

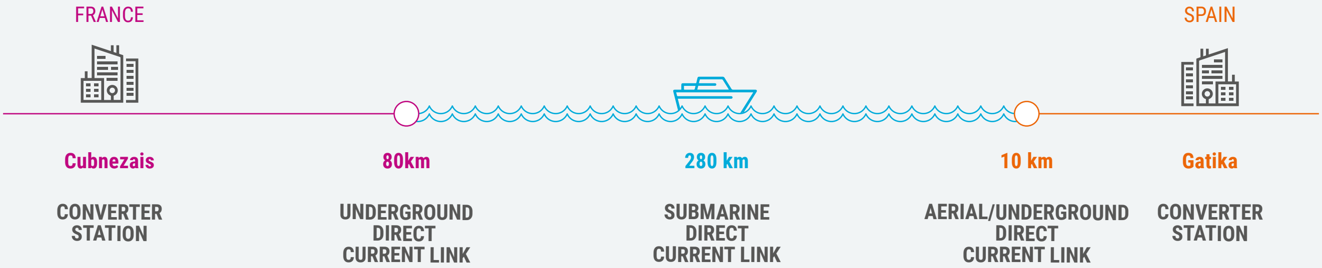
The electricity interconnection between Gatika (Spain) and Cubnezais (France) through the Biscay Gulf will be the first fundamentally submarine interconnection between Spain and France. This submarine and underground direct current dual connection will be 370 km in length. This project will increase the exchange capacity from 2,800 to 5,000 MW, increasing the safety, stability and quality of electricity supply between the two countries and also with the rest of Europe.

Despite the high cost of the project, the high benefits provided by increasing the capacity between France and Spain compensate this cost, as shown in each successive release of the TYNDP. CBA results show that the project allows mainly to take advantage of the cheapest and most sustainable energy in Southeastern Europe at any moment, reducing variable generation cost and energy prices in the region. As a result, it reduces energy curtailment and improves integration of renewable energy sources. This results in a high decrease in generation cost of electricity (up to 438 M€/year in the TYNDP 2018 for the Sustainable Transition 2030 scenario). Besides, the better integration of cheap low-carbon generation (RES and nuclear) reduces CO_2 emissions and supports the fight against climate change. Finally, the TYNDP also demonstrated that the project contributes to improving security of supply in concerned countries.

1 The texts and pictures of all case stories in this Chapter were provided by project promoters.

The robust CBA analysis allowed the acceptance of the project during the decision of investment by the national regulators and the support of the High-Level Group. It was also complemented with a Cross-Border Costs Allocation following TEN-E recommendations. In 2018, the project obtained 578 M€ from the CEF programme. To date, this is the largest grant given by the EU for an energy Project of Common Interest, and it allowed the project to go on. Currently the project is in the permitting process, and it is expected to commission in 2027.

However the France-Spanish border is likely to still be congested and further investments might bring more benefits than costs. Madrid and Lisbon Declarations (2015 and 2018 respectively) reaffirmed the strategic role of future interconnections to achieve a fully operational, secure, competitive, clean and interconnected internal energy market, and pledge to increase energy sustainability in line with the European energy and climate commitments. Two additional projects included in the last PCI list beyond the Biscay Gulf are under assessment to improve the definition and consolidate their CBA analysis: Aragón-Atlantic Pyrenees and Navarra-Landes.



Biscay Gulf project (REE, Rte)

STEP 4 Inclusion of the project in the National Development Plan and in the TYNDP

Most European countries release on a regular basis a National Development Plan (NDP), describing the planned investments in the national transmission network, including building of new infrastructure and replacement of existing infrastructure.

Looking at the mid- to long-term, NDPs are developed by TSOs in close collaboration with their national regulatory authority and are sometimes submitted to a public consultation process before their final publication. They are legally binding, meaning that the TSO commits to implement the network developments planned in the NDP, and must report and explain any deviation to the national regulator. NDPs usually contain an assessment of network needs in the mid- to long-term and consider different scenarios of the future.

Unlike NDPs, the TYNDP is not a binding development plan, though its publication is a legal requirement according to Regulation (EU) 2019/943. Its primary purpose is to ensure transparency of the EU electricity transmission network. Consistency between NDPs and the TYNDP is essential: EU Regulation 2019/943 states that the TYNDP must build on NDPs, while many national regulators require NDPs to be compatible with the most recent edition of the TYNDP. Cooperation of European TSOs through the TYNDP allows for harmonised methodologies to develop.

CASE STORY Nemo Link: An example of successful TSO cooperation

The Nemo Link interconnector electrically connects Belgium and the United Kingdom offering both countries access to a broader energy mix and providing opportunities to expand into other electricity markets. This new connection will also provide significant social benefits. By connecting the UK and Belgian electricity markets customers have access to different sources of generation and lower priced electricity. Nemo Link is expected to see 1,000 MW in electricity exchanges (equivalent to the capacity of a small nuclear reactor), a significant plus in terms of ensuring security of supply.

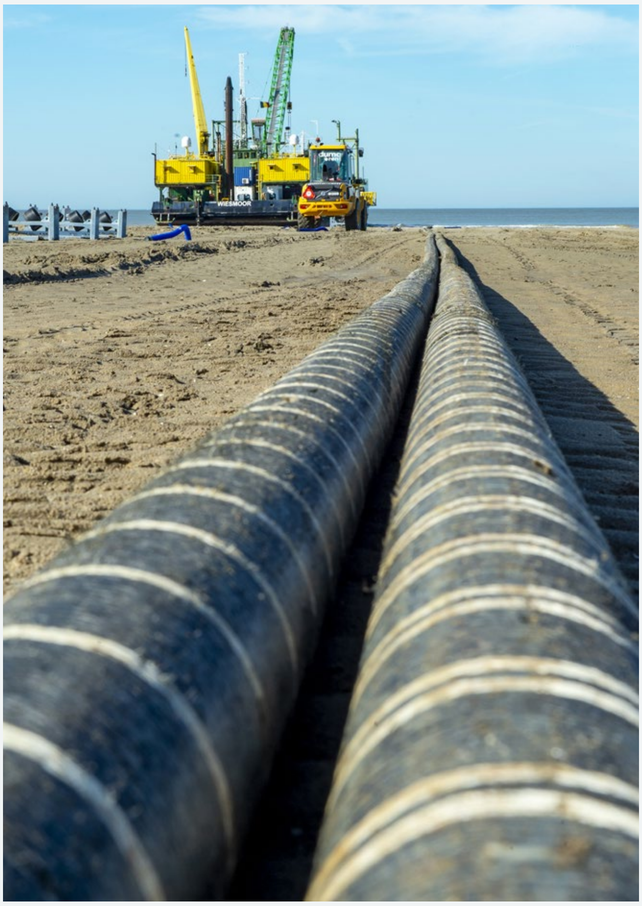
Nemo Link was included in Elia's Federal Development Plan 2010–2020 and 2015–2025 editions, and the need for a UK–BE interconnection has been assessed in the UK's Electricity Ten Year Statement. In parallel, the project has been assessed in all TYNDPs since the very first one in 2010, until 2018.

Transmission operators Elia and National Grid created a joint venture with a mixed Belgian-British team. The team did not only had to overcome technical challenges during the installation of the subsea HVDC-cable between Belgium and UK, but also had to align the access rules and principles on which charges for the use of Nemo Link are based with two National Regulatory Authorities.

Through Nemo Link, customers have the opportunity to buy up to 1,000 MW capacity in either direction via explicit and/or implicit auctions. Transparent access rules and principles were established, but ongoing negotiations on Brexit between GB and the European Commission and uncertainties on energy policy issues made the alignment of the access rules and principles more complicated.

Ofgem and CREG (British and Belgian National Regulatory Authorities) approved the Nemo Link Non-IEM access rules. These rules will come into force in case no agreement is found on the future UK-EU relationship, meaning that GB will have to leave the Internal Energy Market (IEM) and that the implicit day ahead market coupling will be replaced by explicit day ahead auctions, run by the Joint Allocation Office.

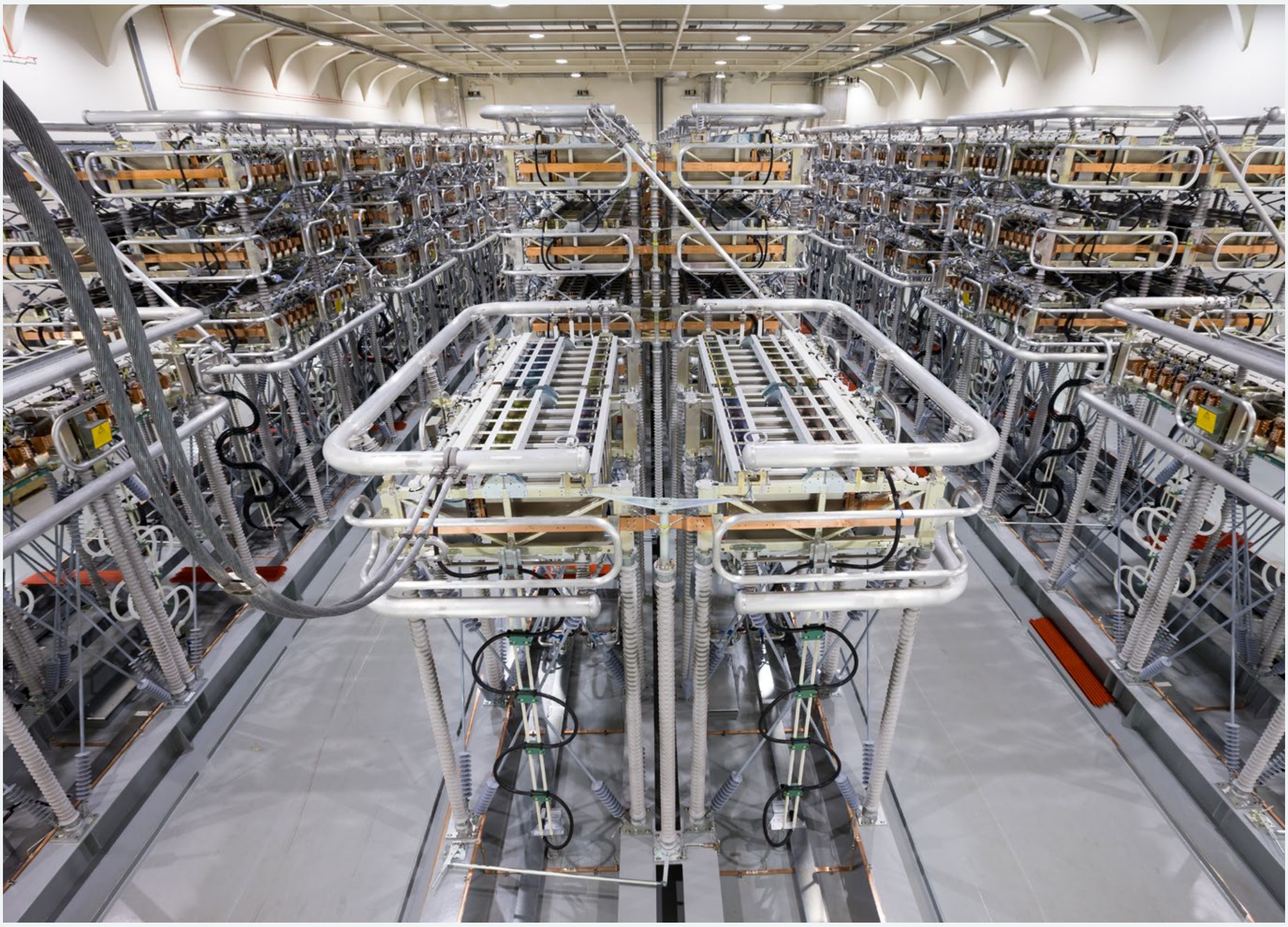
The go-live of the Nemo Link interconnector commercial operations on 31 January 2019 marked the culmination of an enormous project that took nearly 10 years to complete.



Nemo Link consists of subsea and underground cables connected to a converter station and an electricity substation in each country, which allows electricity to flow in either direction between the two countries.

The location of the converter station and electricity substation in the UK is an 8 hectare site. A similar converter station and substation is located in the industry zone Herdersbrug in Bruges, Belgium.

(Pictures: Nemo Link)



STEP 5 Applying for European "Project of Common Interest" status

European Projects of Common Interest (PCI) are key cross-border infrastructure projects that link the energy systems of EU countries. They are intended to help the EU achieve its energy policy and climate objectives. PCIs must have a significant impact on energy markets and market integration in at least two EU countries, boost competition on energy markets and help the EU's energy security by diversifying sources as well as contribute to the EU's climate and energy goals by integrating renewables.

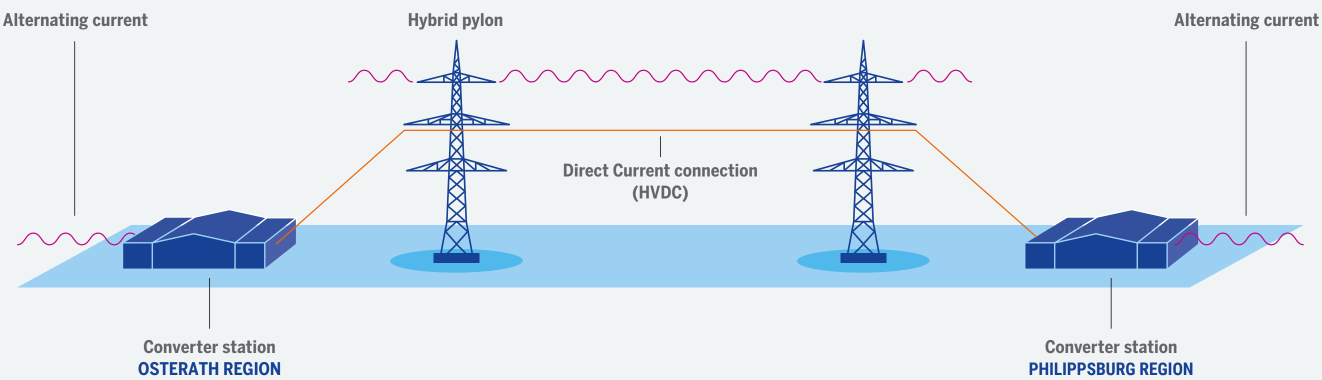
Being assessed in the TYNDP is a pre-condition for a project to be granted PCI Status. Every two years, the European Commission utilises the information in the latest TYNDP as part of its selection and adoption of a new biannual list of PCIs. The draft list is then submitted to the European Parliament and Council of the EU for approval.

From the moment a TYNDP project becomes a PCI, it may benefit from favourable treatment such as a single national authority for obtaining permits, improved regulatory conditions or increased visibility to investors. Projects with PCI status are also eligible to apply to funding from the Connecting Europe Facility.

CASE STORY ULTRANET – Hybrid overhead line with innovative converter technology

ULTRANET is one of the leading projects in Germany's energy transition process. It stands for a nearly 340 km long high voltage direct current (HVDC) connection between two federal states: North Rhine-Westphalia (Osterath) and Baden-Württemberg (Philippsburg). The innovative pilot scheme is a result of a collaboration between the two German transmission system operators (TSOs) Amprion GmbH and TransnetBW GmbH.

ULTRANET project is an important part of the German energy policy and resulting national grid development plans. It forms the southern section of the so-called "Corridor A" concept foreseeing connection of the northern and southern regions of Germany via direct current (HVDC) power lines. As such, ULTRANET does reinforce the grid after nuclear phase-out. It also complies to the European North-South Interconnection idea aiming at connecting the significant offshore renewable generation capacities in the North Sea with the load centres in the southern parts of Europe.



How ULTRANET works: The new direct current connection is connected to the existing alternating current grid via two converters located in Rhineland and North Baden.

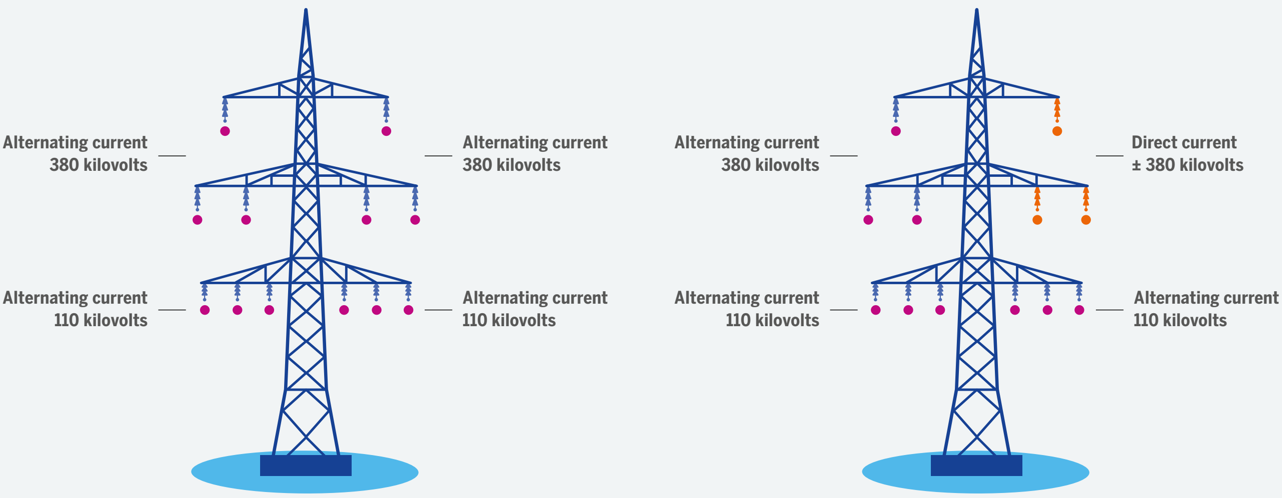
ULTRANET concept bases on an innovative approach that considers using existing transmission infrastructure (towers and pylons) in order to adapt it for deployment of additional HVDC lines. Such solution – usage of the existing transmission routes – improves significantly the overall grid performance by increasing transmission capacity in an efficient and resource-saving manner. Respectively, the ULTRANET HVDC overhead lines will be operated using same rated voltage level as the transmission lines they would be added on to (here: 380 kV).

ULTRANET will be operated using a complete new, most modern and unique multi-terminal system located at either end of the planned HVDC link enabling transfer capacity of 2,000 MW. The innovative converter technology is capable of supporting the grid re-configuration process in the unlikely event of a power outage. Furthermore, the converter stations will also be able to regulate and stabilise the grid voltage, a function mainly performed by conventional power stations today. Another advantage of this innovative system is its capability of immediate adjusting of the direct current values (i.e. in case of a lightning strike), which would significantly reduce the eventual interruption duration of the HVDC links to an absolute minimum.

All innovative technologies, especially in their early development stages, have been always causing a certain level of social anxiety among the people directly affected. It has been no different also in case of ULTRANET project. Although it is considered as an important milestone for Germany's energy transition it is still lacking broad support and acceptance even though the project developers (Amprion and TransnetBW) have been continuously cooperating with the local communities and authorities in order to work out most convenient solutions. Locally good solutions leading to acceptance can be found such as the adjusted location for the converter in Philippsburg at the former nuclear power site. Despite those considerable efforts and intensive engagement towards public acceptance, ULTRANET still confronts many permitting difficulties resulting in significant project implementation delays.

Even the official PCI label of the undisputable value of the ULTRANET project for the European society as a whole does not seem to have any effect on the project perception.

Both project promoters and developers – Amprion and TransnetBW – are convinced that a strong and transparent European political support complemented by an appropriate legal framework could successfully facilitate the current impediments and accelerate ULTRANET implementation so it could start serving the society as planned.



How the pylons will be modified: In order to utilise the existing pylons for the new direct current connection, only the insulators that hold the cables need to be modified in some sections.

STEP 6 Engineering design and permitting process

After the preliminary design of the project comes the definition of its concrete technical characteristics. What route should the line follow, considering constraints such as the presence of protected areas or of densely populated areas? How to minimise the environmental and social impact of the project?

In parallel to the basic engineering design, the project promoter may also approach local authorities to start the permitting process. Permitting procedures are specific to each country, and even to each local authority involved. Obtaining an administrative permit is a lengthy and complex process, even for PCI projects.

A key step in the permitting process is the public consultation. EU Regulation 2013/347 foresees as least one public consultation during the permit granting process, with the objective to help identifying the most suitable location or route of the project, and any relevant issue that should be addressed in the project's application for permit.

Public consultation at early stage of the project supports the smooth and fast realization of the project and leads to increased public acceptance. It is common for TSOs to involve local communities in the definition of the best route for the project. Even so, local acceptance is very often a challenge and the main reason why 17 % of TYNDP 2020 transmission investments are delayed.

CASE STORY ALEGrO: Record speed thanks to citizen engagement

ALEGrO, which stands for Aachen – Liège Electricity Grid Overlay, is the first power bridge between Germany and Belgium. This 90-kilometre-long connection is a high-voltage DC cable between the Oberzier substation in the Rhineland and Lixhe in Belgium and can transmit about 1,000 MW. It is scheduled for completion by the end of 2020 and will make the European electricity network even more secure and powerful. The ALEGrO interconnector will enhance the market integration by enabling direct power exchanges between Belgium and Germany.

During the revision of the Development Plan and the Planning Permission, Elia and Amprion paid a special attention to the stakeholder's management, developed several accompanying measures for residents near the infrastructure's project and set up mitigation measures. One of these accompanying measures was dedicated, in 2016, during the Development Plan, to the municipality of Oupeye (Belgium). Citizens expressed their concerns about the project's location and felt they did not have the answers to all their questions. The consequence being the willingness of the municipality of Oupeye to lodge an appeal against the project, Elia decided to set up two customised measures. The first measure was the organization of a visit for a group of citizens, representatives from the municipality and experts of Calais (France), where a similar high-voltage line was already underground. The aim of this action was to reassure people about the impact of this high-voltage line on its environment. The second measure was the organization of an exhibition in the town hall where citizens could meet experts, representatives of the municipality and representatives of Elia. These measures resulted in the municipality removing its appeal.

To keep the burdens in the region as low as possible through a process of good planning, Amprion spoke with local residents and representatives of municipal authorities, rural district authorities and trade and professional associations. This happened before the official procedure even started and continued meanwhile. In the process Amprion fulfilled the legal requirements, under which the public must be advised of PCI projects and be given a fair hearing as early as possible. That ensured the most suitable route was selected and allowed to identify the topics that needed to be dealt with in the application documentation. Dialogue with local communities at a very early stage helped in developing the route together with the population, the official bodies and with high acceptance of the communities and Agricultural Associations.

The comprehensive position adopted by Elia and Amprion towards citizens resulted in an outstanding permitting process for such a complex high voltage link. Thanks to this compact approval followed by an equally smooth construction phase, the first direct interconnection between the Belgium and German power grid starts commissioning in 2020.

ALEGrO project (Elia, Amprion)

CASE STORY Greenlink: Going the extra mile with local communities reaps rewards for all

Greenlink is a major infrastructure project to build a 185 km electricity interconnector under the Irish Sea to connect the power grids of Ireland and Great Britain. Benefits include regional investment and jobs, value for money for consumers, and increased energy security and integration of renewables.

Critical to the project's successful development has been that the host communities understand and buy in to these benefits. Greenlink's comprehensive and inclusive approach to public consultation has reaped rewards and helped it reach significant milestones. Landfall for the HVDC power cable is in County Wexford in Ireland and in Pembrokeshire in Wales and engagement activities were focussed on the local residents, organisations, businesses and elected representatives there, with a commitment to open and honest dialogue following key principles:

› Starting early in the development process before detailed environmental work was carried out, meant the developer could draw on the input of local stakeholders, who could watch and understand the complexities of developing a project of this scale as it evolved.

› Tailoring the consultation to the community's needs and interests involved conducting a detailed audit of stakeholders, investing the time to get to know the community and designing events and materials to be accessible and relevant.

› Resourcing the consultation process adequately, with locally-based representatives and the expertise of consultants, ensured questions could always be answered. For example, when health and safety concerns were voiced about Electromagnetic Fields from the cables, the developer commissioned a study on EMF and invited an expert to public exhibitions.

› A suite of consultation tools ensured the widest possible reach into the community and beyond, including four project brochures, exhibitions and meetings, a website, FAQs, telephone and email contact, media (including social media), feedback forms, and visual aids.

› Genuine two-way consultation has encouraged input, and points raised have been helpful in the project's design evolution enabling, for example, Greenlink to choose appropriate cable routes and plan construction to minimise traffic disruption. Concerns raised about the impact on sensitive habitats and beach users at the Welsh landfall resulted in a commitment to using Horizontal Directional Drilling under the beaches on both sides.

GreenLink project

The Greenlink consultation programme has run for more than two and a half years and included four rounds of public exhibitions, held in 8 towns and villages for a total of 24 days. In July 2020 the onshore planning applications in Wales received unanimous consent from the authorities. In Ireland, during the application preparation phase, the project's approach to engagement has been held up as an example of good practice. The PCI process helped ensure Greenlink was developed using inclusive public consultation, but the developers are proud to have gone beyond the TEN-E requirements, resulting in a high quality design with a positive stakeholder response.

In the run up to construction, consultation continues and supplier events are planned for local businesses, helping ensure this significant infrastructure project delivers the benefits promised.

STEP 7 Financing and Final investment decision

Funding may come from public or private investors. Several organisms provide grants, such as the European Investment Bank or the Western Balkan Investment Framework. Projects who are granted PCI status are eligible to receive funding from the Connecting Europe Facility, an EU fund worth € 30 billion supporting energy, transport, and digital infrastructure.

In 2019, a total of € 556 million in CEF grants was allocated to 8 PCI projects, including 6 in the electricity sector, of which 3 transmission projects and 3 storage projects.

Financing the proposed amount of infrastructure investments in the coming decades represents a challenge, considering both the size of the investment needed and its pace. The total CAPEX of TYNDP 2020 projects (transmission and storage) represents 153 billion euro, and the timing to deliver those new investments is challenging as projects due to commission until 2030 represent already 123 billion euro.

CASE STORY Two stories on financing: The Black Sea Corridor and the interconnection Albania – North Macedonia

The Black Sea Corridor project, recognised as Project of Common Interest in the 4th PCI list, aims at allowing the transfer of generation from Western coast of the Black Sea towards consumption and storage centers located in Central Europe and South-Eastern Europe. It consists in a new 400 kV double circuit overhead line Cernavodă-Stâlpu with in / out connection of one circuit in substation Gura Ialomiţei, one new 400 kV circuit OHL Smardan-Gutinas, the upgrade of the substation Stâlpu to 400 / 110 kV in Romania and a new 400 kV OHL Dobrudja-Burgas in Bulgaria.

In 2018 the project received a favorable opinion for grant funding through the financial instrument Connecting Europe Facility (CEF). According to this EU financial support mechanism, the amount of financial assistance from the EU can be of maximum 50 % of the eligible costs of the works. The PCI label and the grant obtained from the CEF positively impressed the public authorities, which eased the granting of the building permits.

The commissioning date for project 400 kV double circuit OHL Cernavodă-Stâlpu with in / out connection of one circuit in substation Gura Ialomiţei is expected to be in 2023 and in 2025 for the new 400 kV double circuit (one circuit wired) between existing substation Smârdan and Gutinaş.

Black Sea Corridor project

Bitola–Elbasan (Albania–North Macedonia) project
(MEPSO, OST)

This connection line between Albania and North Macedonia was launched as part of Corridor 8 which is an integral part of a much larger and important project aiming at the exploitation of energetic resources from the Caspian region and Central Asia. Financing of the project's feasibility study and environmental impact assessment (803,000 €) and project design and tender documentation (2,0750,000 €) were covered by two grants of the Western Balkans Investment Framework (WBIF).

Thanks to good cost-benefit analysis results in every TYNDP from 2010 to 2018, the project was recognised as a project of regional significance and received the status of Project of Energy Community Interest (PECI) in October 2016. Consequently, the project received a befitted loan agreement and significant amount of investment grant. The Macedonian part of the project is estimated at 43.5 M€, and the Albanian part is estimated at 70 M€. In December 2015, North Macedonia signed a financial agreement with the EBRD for a loan of 37 M€. Albania signed a financial agreement with KfW in November 2016 for a loan of 50 M€. In 2016 both countries received an investment grant: North Macedonia 12 M€ and Albania 13.72 M€. The interconnection is currently in construction phase and the project is expected to be commissioned by 2022.

STEP 8 Construction and commissioning

Construction and commissioning covers the civil works, cable laying and, once the construction is over, the testing phase. The building of transmission infrastructure generates economic activity for the promoter's contractors and subcontractors, and for the local community.

During the building of infrastructure or when conducting maintenance work, some equipment may be temporarily unavailable. Project promoters must coordinate with third parties, including with TSOs in neighbouring countries, to obtain planned outages of the relevant equipment and avoid particularly tense situations on the grid. Regional security coordinators support the cross-border coordination of planned outages by testing all possible combinations of upcoming work to see if any will compromise the grid's availability, and suggest corrective solutions such as postponing work on certain lines. Projects with PCI status have priority to obtain planned outages.

CASE STORY Kurzeme Ring – Successful cooperation with local communities

The Kurzeme Ring project forms part of the larger NordBalt project implementation, which includes the subsea interconnection between Lithuania and Sweden and transmission network reinforcements in Latvia, Lithuania and Sweden. In service since 2019, it was one of the biggest transmission network projects in Latvia, that significantly improved security of electricity supply in normal and emergency modes or during storms and critical conditions, and provided possibilities for grid connection for new consumers and producers of electricity (mainly offshore wind) in the Western part of Latvia.

Serious difficulties related to nature protected areas were raised during the building of the 2nd stage of the project, an overhead line located close to the Riga area. Initial plans foresaw the demolition and reconstruction of a 110 KV overhead line near Jurmala city built in 1987 with installation of new pylons (no information is available on studies performed before the construction in 1987). However, it appeared that the ground works and the weight of the new pylons could affect underground sulphur deposits and the surrounding protected area. Additional study and ground assessment confirmed that demolishing and rebuilding new pylons was not possible in these conditions, and a compromise scenario was identified jointly by all involved parties including the Latvian TSO, Latvian Government, and the Municipality of Jurmala. The project route was reassessed and relocated to move around the sensitive areas, and an additional switching point was built due to security of supply reasons. The construction works continued and the cooperation and fast reaction between Latvian TSO, Latvian Government and involved municipalities allowed a timely commissioning.

Completion of the **Kurzeme Ring project** in 2019, with Prime Minister of Latvia, Mr. Krišjānis Kariņš, Mr. Dirk Beckers, Director of INEA and Mr. Varis Boks, Chairman of the AST Management Board.

CASE STORY Crossing the Scheldt: Tallest electricity pylons in the Benelux

Elia's Brabo project is an essential link in strengthening the electrical interconnection with the Netherlands and Western Europe. It will shore up Belgium's electricity grid at a local, national and international level. The project will increase the grid's supply capacity, enabling it to cope with growing electricity consumption in the Port of Antwerp. By upgrading Belgium's north-south axis and bolstering a network of international interconnections, the project will improve international trade opportunities and reduce reliance on Belgian generating facilities.

As part of the Brabo project, Elia had to cross the Scheldt River in the port of Antwerp. For safety reasons, the high-voltage lines had to be at least 100 metres above the surface of the water to leave enough room for ships. Therefore, Elia has erected 192-m high-voltage pylons on both banks of the Scheldt to enable the cables to span the river without disrupting maritime traffic.

The Scheldt crossing is a major technical feat in many respects. To make it possible, a 200-metre-high crane was required to erect the two high-voltage pylons consisting of 584-tons of steel; there are only 11 such machines in the whole of Europe. Elia built a foundation structure comprising of 5,000-ton of concrete to carry the weight of the high-voltage pylons. To guarantee the pressure forces, Elia first made a 3D-print of a scaled model and conducted a wind tunnel test to confirm wind hypotheses.

The conductors cross the Scheldt for a distance of around 911 metres. An extra strong conductor with a steel core was required to support such a crossing. Two ships were sent across the Scheldt River to meet each other in the middle and pass on a nylon rope that Elia used to pull the conductors on the pylons.

Another challenge was to make the pylons fit in the environment, as the mudflats and salt marshes along the Scheldt are a biotope of European importance. 11,000 cubic metres of soil (enough to fill around 110 Lorries) were removed from an area adjacent to the project site so that this part of the left and right banks can flood naturally on a regular basis. This will enable the mudflats and salt marshes to return to their original state, with the help of the river.

Brabo project (Elia)

STEP 9 Operation of the new infrastructure

Once the infrastructure is in operation, analysing its impact on system operations and markets allows to tell whether the benefits anticipated during the planning phase have been delivered. Promoters look at indicators such as, for example, for a cross-border project the price difference on the border before and after the commissioning of the project, the congestion …

The evolution of the amount of electricity exchanged on the border is also a strong indicator of the relevance of a new interconnector, as it shows its usefulness to stakeholders on electricity markets.

Comparing the actual benefits delivered by a project with the benefits anticipated during the CBA phase also allows to gather valuable feedback on the CBA process, and may lead to rethinking the CBA methodology and/or the building process of the scenarios.

CASE STORY Santa Llogaia – Baixas: Benefits identified in the TYNDP surpassed one year into operation

Santa Llogaia – Baixas was a globally pioneering project, connecting France to Spain with a 65-km-long HVDC 320 kV underground cable under the Eastern Pyreneans, with AC/DC converters at both ends. Cost-benefit analysis performed in TYNDPs 2010 to 2014 identified high potential for increase in socio-economic welfare, as the project allows the use of more efficient and cheaper technologies and avoids spillage of RES especially in the Iberian Peninsula. The project was a PCI and benefited from a European coordinator, which help with the smooth implementation of the project.

One year after its commissioning in 2014, the benefits anticipated in the TYNDP were confirmed and even surpassed. It is difficult to draw an exact comparison of the benefits expected with those effectively obtained, because of the horizon year (TYNDP studied the project's benefits in the year 2030), and because some of the variables are not caused only by the new interconnection but by the evolution of the energy mix, climatic conditions, etc. However, other variables used in the TYNDP process provide indications:

- The net transfer capacity has more than doubled since the new interconnection commissioned, reaching expected values.
- There was a rapid uptake for the additional interconnection exchange capacity. This new transfer capacity was swiftly harnessed by the various stakeholders in the electricity market. In fact, physical exchanges increased from 8.02 TWh to 15.17 TWh in just one year, by almost 90 %.
- The increased capacity allowed a higher convergence level of the day-ahead markets. In the hours with congestion from France to Spain the spread was reduced from 17.96 to 12..12 €/MWh, and from Spain to France from 10.98 to 8.13 €/MWh.
- Europe-wide, congestion periods decreased significantly, while maintaining high performance levels. After one year in operation congestion still occurred 75 % of the hours at the French-Spanish border (87 % one year before the commissioning).

The trends obtained in the first year in operation remain in the same range today, with some yearly variations depending mainly on the climatic conditions and network availability. For instance, the spread in 2019 was 11.92 €/MWh from France to Spain and 6.5 €/MWh from Spain to France, the congestion was 65.9 % and the congestion rent 178.4 M€, in a range similar to previous years.

Santa Llogaia–Baixas project (REE, Rte)

1 The TYNDP 2020 project portfolio

The TYNDP 2020 assessed 154 transmission and 26 storage projects. To visualise all projects on a map of Europe and filter per technology, per country, per PCI Corridor or per status, visit our TYNDP 2020 projects page. From there, a detailed description of each project is available, alongside with the projects cost-benefit analysis results and the needs it helps address in the European power system.

To the TYNDP 2020 projects page

Transmission projects

The TYNDP 2020 project portfolio contains 154 transmission projects, representing 323 investments overall, in 37 countries. Among these projects, 8 are "Future projects" addressing power system needs identified in the TYNDP 2020 system needs study.

54 % of investments are overhead line development, with cables – underground and subsea – making up 26 % of the portfolio. Other investments includes substations, reactive compensation devices, phase shifting transformer or converter stations.

In total, the TYNDP 2020 portfolio represents over 46,000 km of potential, additional cables and lines of which 19,000 km (41 %) are AC and 27,000 km (59 %) are DC. In previous TYNDPs, the number of AC projects was typically higher, but the rapid advancement of DC technology has led to improved uptake of this technology and seen its portfolio share grow since TYNDP 2018. Moreover, development of offshore infrastructure will require increased investment in subsea DC cables. Read more on offshore grid development and offshore projects in the TYNDP 2020 in Chapter 4.

In addition, the need to increase public acceptance of transmission projects is driving the transition from overhead lines to cable technology also onshore. In Germany, wide area North-South transmission corridors (see for example projects 254 Ultranet and 130 SuedOstLink) are proposed with an HVDC-cable technology. This offers the advantage of reducing losses when transmitting electricity over long distances, while entailing significantly higher project costs, that must be compensated by the benefits.

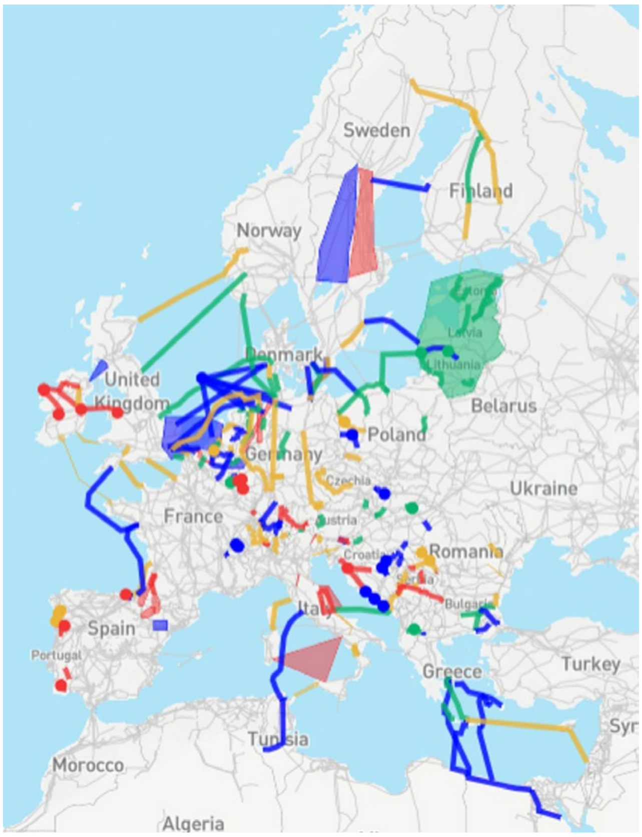


Figure 1.1 – Map of TYNDP 2020 transmission projects. Areas indicate projects for which the route is not yet known. (Green: project under construction, Yellow: project in permitting; Red: Project planned but not yet in permitting, Blue: project under consideration)

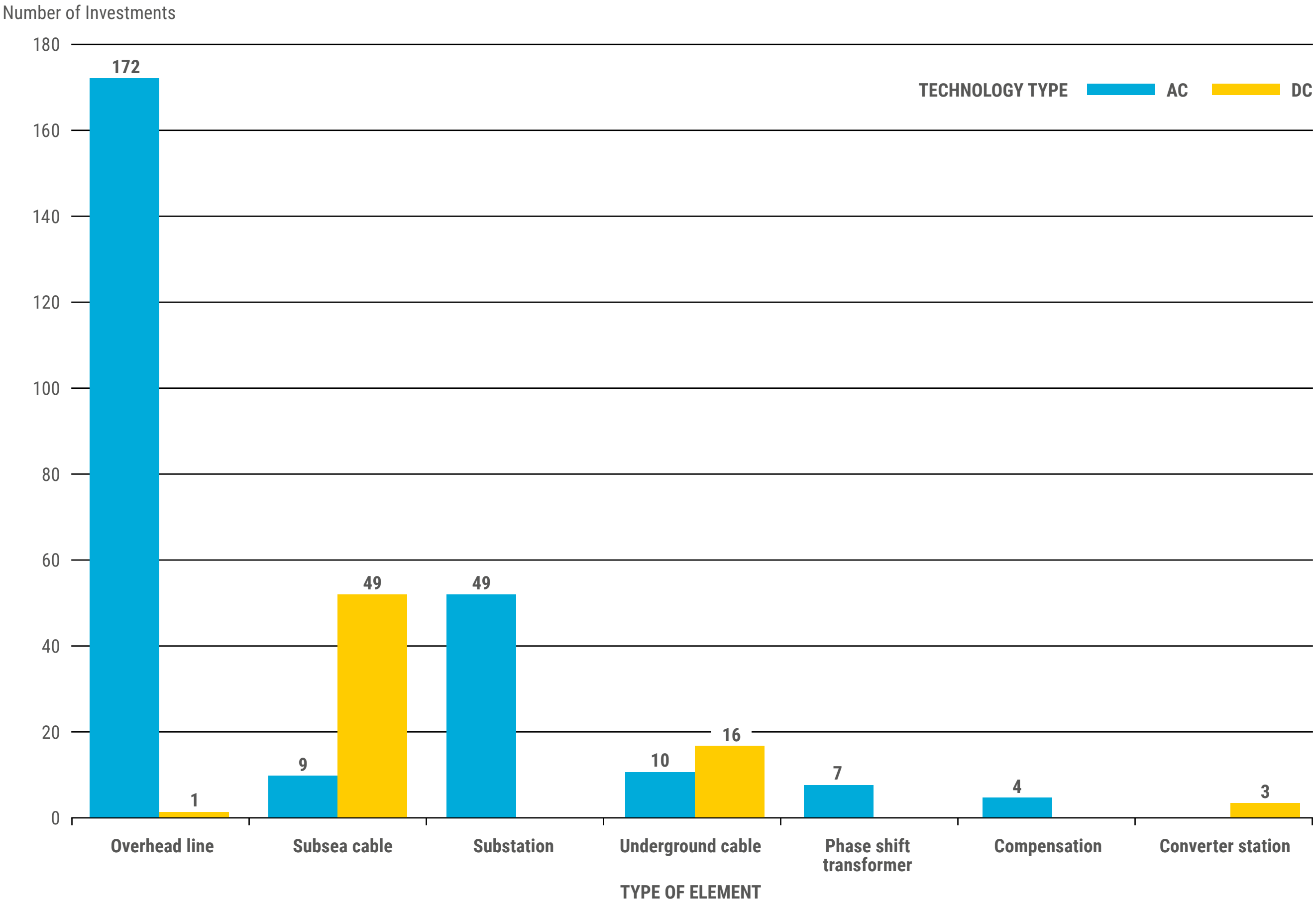


Figure 1.2 – TYNDP 2020 investments per type of element and technology. Note that converter stations are generally included within DC investments, which explains the small number of converter stations reported separately in this Figure.

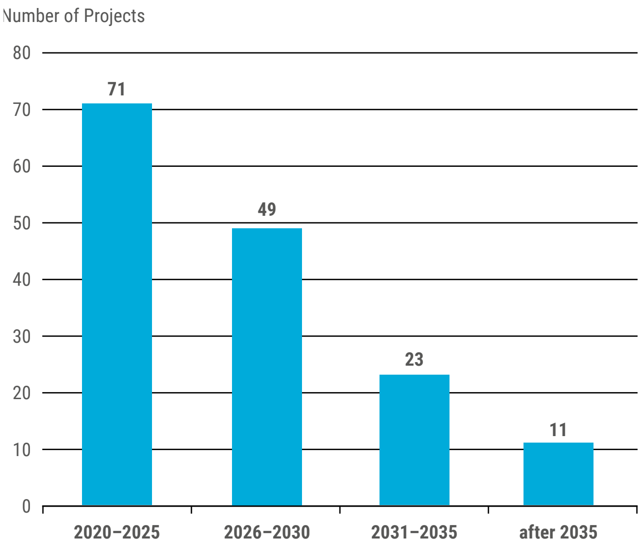


Figure 1.3 – TYNDP 2020 projects per expected year of commissioning, based on the year of commissioning provided by project promoters

Half of TYNDP 2020 transmission projects are expected by their promoters to come in service in the coming five years, while the other half would commission between 2025 and 2035.

The 154 transmission projects are split between the 4 PCI corridors determined by the European Commission: 27 in the North Sea Offshore Grid2, 57 in NSI West, 53 in NSI East and 17 in the BEMIP corridors. The majority of projects (97) is cross-border, involving two or more countries, while 57 projects are internal projects but considered of European relevance. 44 transmission projects in the TYNDP 2020 portfolio are included in the 4th List of European projects of common interest.

2 The impact of Brexit on projects linking the UK to EU countries is not yet known.

Complex implementation of complex projects

32 transmission projects are currently under construction, while 44 are undergoing the permitting process and 27 are included in the National Development Plan but have not yet started the permitting phase. The trend observed in previous TYNDPs is once again confirmed, as 17 % of TYNDP investments suffered delays in the past two years (compared with 17 % in 2018). Of the 44 projects in permitting phase, 39 were already in permitting phase in the TYNDP 2018.

The TYNDP2020 portfolio also includes 64 projects under consideration, of which 30 are new projects in this TYNDP. Many of these projects aim at addressing system needs identified in the 2018 or 2020 system needs study.

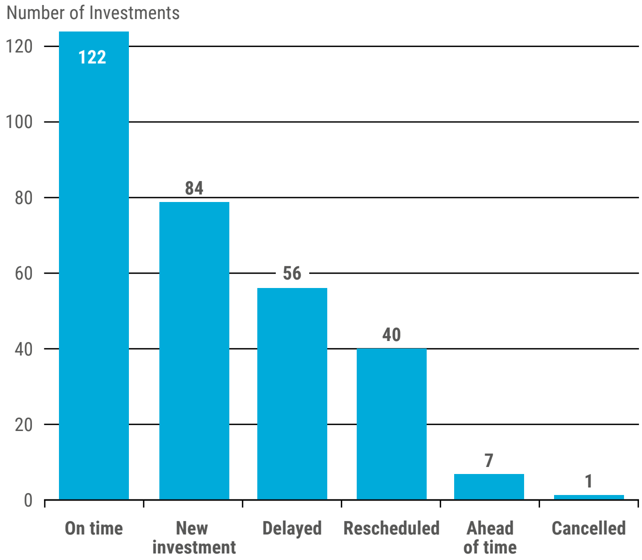


Figure 1.4 – Evolution of TYNDP 2020 transmission investments since 2018. "New investments" are new in the TYNDP 2020.

Storage projects

The TYNDP 2020 portfolio includes 26 storage projects, of which the majority (19) uses pumped hydro technology. Four compressed air energy storage projects and three electrochemical storage projects complete the portfolio.

None of the projects has started the construction phase. 15 projects are either in permitting phase or planned but have not yet started permitting. Seven projects, all pumped hydro, have indicated delays in their implementation in the past two years.

The 2020 portfolio counts 6 more storage projects than in 2018, a sign that future TYNDPs will assess more and more storage projects. For the first time, the TYNDP 2020 portfolio includes a pilot cross-sector project (Project 1042 HYPE), which aims at converting a fleet of 50,000 taxis or taxi-like vehicles to Fuel Cell Electric Vehicles with the development of local stationary infrastructure for the production, storage and distribution of green (hydrogen articulated around a network of semi-centralised units connected to the transmission grid.

Figure 1.5 – TYNDP 2020 storage projects (yellow: in permitting, red: planned but not yet in permitting, blue: under consideration)

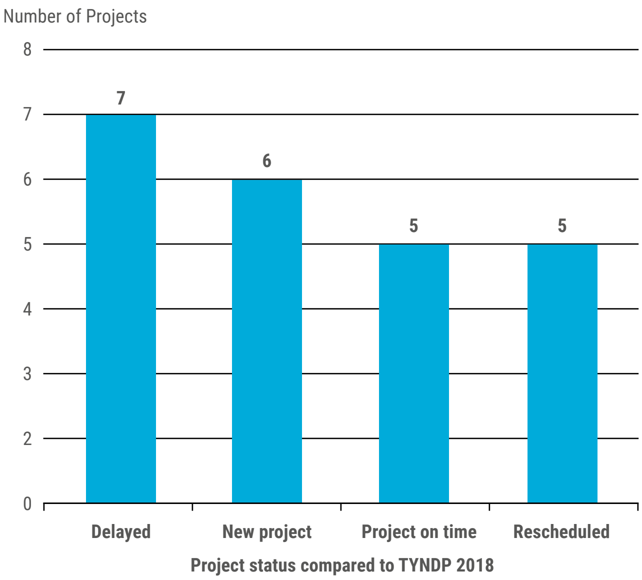


Figure 1.6 – Evolution of TYNDP 2020 storage projects since the TYNDP 2018. New projects are new in the TYNDP 2020.

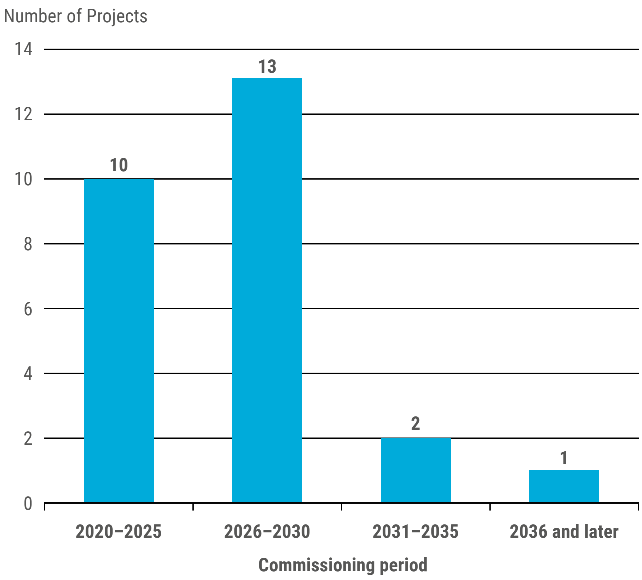


Figure 1.7 – TYNDP 2020 storage projects per expected year of commissioning

TEN YEARS OF TYNDP – Europe is more and more interconnected

Over the last ten years, the European cross-border transmission grid has developed significantly. 10 borders saw the commissioning of their first electric interconnection, joining the 70 European borders terrestrial or maritime that have at least one cross-border line in 2020. New interconnections include for example Denmark and the Netherlands, the UK and Belgium, Italy and Montenegro, and Norway and Germany (project 37 NordLink is expected to be commissioned in Q4 2020). Increased cross-border interconnection goes hand in hand with increased electricity exchanges: from 347 TWh in 2010 to 435 TWh in 2018 in the ENTSO-E area.

The EU Projects of Common Interest (PCI) programme was central to making possible the grid developments of this decade. Beyond its role in the PCI process, he European TYNDP also plays a role by providing information to policy makers, regulators, TSOs or investors to engage on project or to project developers to explore or refine their projects.

Investments[3] assessed in the pilot TYNDP 2010 represented over 42,000 km of lines, of which close to 10,000 km have now commissioned. Some investments have been bundled into other investments, many others have stopped being assessed in the TYNDP but remained in national development plans and have been implemented. Some investments were cancelled. 20 investments of the TYNDP 2010 are still in the TYNDP 2020 portfolio.

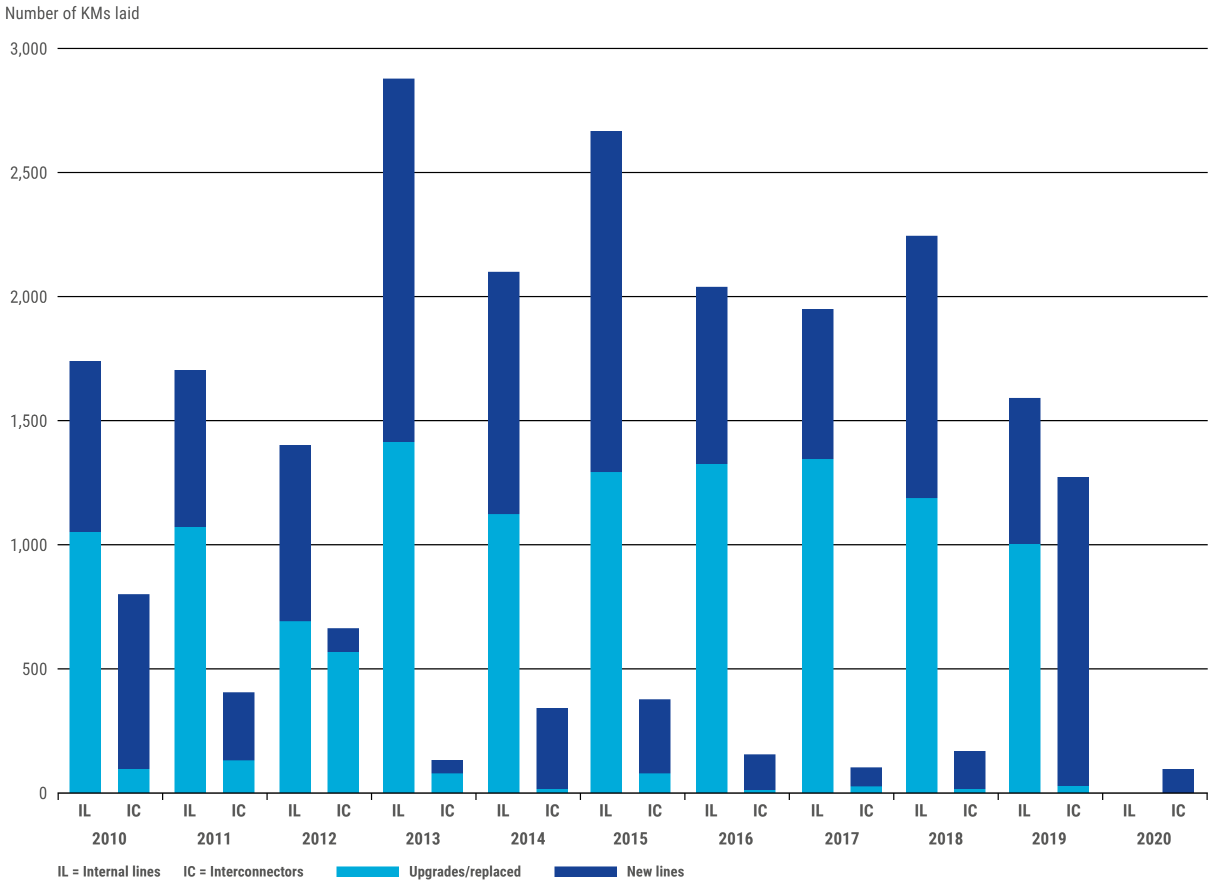


Figure 1.8 – Projects commissioned each year from 2010 to 2020 in km of lines

3 Criteria for inclusion in the TYNDP were different in TYNDP 2010, many projects have not been assessed in following TYNDPs.

Electricity infrastructure will contribute to Europe's economic recovery

As far as the progress of projects in the TYNDP project portfolio allow companies to invest, this progress allows to stimulate the economy and therefore can help the post-pandemic European economy. For the first time in the TYNDP 2020, ENTSO-E has computed the impact of the project portfolio in the European Union economy, during the whole cycle of each project [4]. The analysis considers therefore not only the awardee and direct tenderers of the investments (e. g. companies involved in the construction phase of a project,…), but also the intermediate consumption e. g. goods and services purchased by awardees and direct tenderers, and the final consumption derived from all salary incomes generated at all the steps.

The results show that during the construction and commissioning of the projects in the TYNDP 2020 project portfolio:

- 1,7 Million jobs could be ensured,
- Close to 240,000 M€ could be mobilised in production, understood as the accounting value of payments of the project promoters and their suppliers,
- The European Union GDP could increase by about 100,000 M€,
- And public administration revenues through taxes collection could reach about 45,000 M€, a value that could reverberate in the European society.

These values refer only to European Union countries, and the goods and services generated in European Union countries, while imports from outside EU27 in or out the European continent are not considered.

4 The analysis was based on a sample of representative projects.

2 How can TYNDP 2020 projects benefit Europe?

2.1 The Costs-Benefits-Analysis framework

A project can have various impacts on the electric system. Hence, ENTSO-E has developed for the European Commission guidelines that describe how to assess these numerous impacts. These guidelines define the framework under which each project will be assessed in the TYNDP. The 3rd Costs-Benefits Analysis Guidelines are in the process of validation by the European Commission and will be published by the end of 2020. They will be completed by Implementation Guidelines that describe the concrete application of the CBA Guideline in the TYNDP 2020. These Implementation Guidelines will be published with the TYNDP 2020 package.

In the TYNDP 2020, ENTSO-E has assessed the impact of each project according to several indicators:

› B1. The Socio-Economic-Welfare that computes the reduction of overall generation cost induced by the change in generation mix

› B2. The evolution of CO_2 emissions resulting from the new exchange and the evolution of losses. This evolution is monetised thanks to a societal cost of carbon to take into account climate change.

› B3. The change in the curtailed energy volume induced by the project. This indicator is not monetised because its effect is already fully accounted for within socio-economic welfare.

› B4. The evolution of emissions of several polluting gas induced by the generation mix: nitrogen Oxide (NO_X), ammonia (NH_3), sulfur dioxide (SO_2), particulate matter (PM5 and PM10), Non-Methane Volatile Organic Compounds (NMVOC). This impact is not monetised in the TYNDP 2020.

› B5. The evolution of the volume and the cost of electric losses on the grid due to the change of electrical flow induced by the new infrastructure.

› B6. The support to adequacy allowed by a new project by reducing the loss of load expectancy and decreasing the need of generation capacity.

The CBA guidelines also defined 4 additional criteria which are not assessed by ENTSO-E. For some of them (the so-called "Project Level Indicators"), project promoters were invited to propose an assessment. Reader wishing to know more about the assessment of infrastructure projects should refer to the 3rd CBA Guideline (**version submitted to ACER for Opinion in February 2020**) and the Implementation Guidelines (see Appendix 1 for an overview of the content of both documents).

Compared to the TYNDP 2018, the monetization of the evolution of CO_2 emissions and the quantification of emissions of polluting gas is new, while the assessment of the adequacy impact has greatly improved. For a complete overview of the evolution of the methodology compared to the TYNDP 2018, refer to the 3rd CBA guidelines.

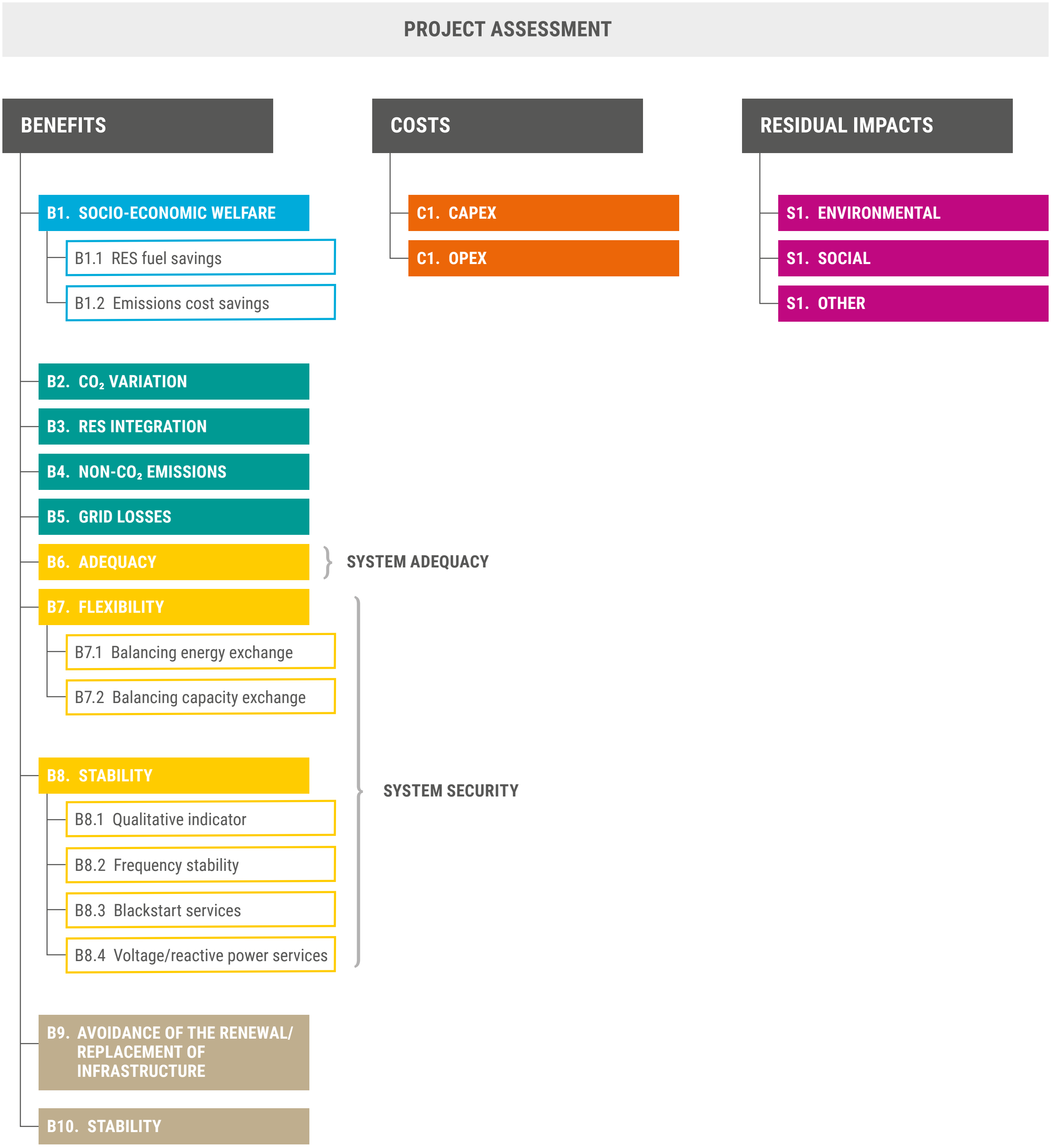


Figure 2.1 – Illustration of the project assessment framework categories

2.2 The TYNDP 2020 scenarios

To help the decision whether to invest or not in the projects, the impacts they have on the electricity system is assessed for future horizons. However, the future of the European energy system is uncertain. Therefore, ENTSO-E uses a scenario-based approach where different futures are defined and used for the analysis. Indeed, the impact of each project can vary according to the envisioned future.

National Trends is the central scenario of the TYNDP 2020, as it is based on National Energy and Climate Plans. A full cost-benefit analysis has been performed for horizon 2025 and 2030 of this scenario. In addition, to take into account uncertainties and illustrate the robustness of the projects, the projects have also been assessed for the 2030 horizon of Global Ambition and Distributed Energy with a subset of CBA indicators.

	National Trends 2025	National Trends 2030	Global Ambition 2030	Distributed Energy 2030
B1 – Socio-economic welfare	✔	✔	✔	✔
B2 – CO_2 emission	✔	✔	Partially	Partially
B3 – RES integration	✔	✔	✔	✔
B4 – Non Direct Greenhouse Emission	✔	✔	✘	✘
B5 – Losses	✔	✔	✘	✘
B6 – Adequacy	✘	✔	✘	✘

Figure 2.3 – Assessment framework for the different scenarios

About TYNDP 2020 scenarios

ENTSO-E has used the **TYNDP 2020 scenarios**, built jointly by ENTSO-E and ENTSOG together with stakeholders and over 80 TSOs, to assess the benefits of each project. The assessment has been performed for the years 2025 and 2030.

The TYNDP 2020 scenarios, published in their final version in June 2020, represent the first step to quantify the long-term challenges of the energy transition on the European electricity and gas infrastructure. We recommend the reader to familiarise themselves with the content included in the Scenarios Report and Data visualisation platform, as these provide full transparency on the development and outcomes of the scenarios serving as basis to assess projects.

TYNDP 2020 scenarios follow three storylines:

National Trends (NT) is the central policy scenario, based on the Member States National Energy and Climate Plans as well as on EU climate targets. NT is further compliant with the EU's 2030 Climate and Energy Framework (32 % renewables, 32.5 % energy efficiency) and EC 2050 Long-Term Strategy with an agreed climate target of 80 – 95 % CO_2-reduction compared to 1990 levels.

Global Ambition (GA), a full energy scenario in line with the 1.5 °C target of the Paris Agreement, envisions a future characterised by economic development in centralised generation. Hence, significant cost reductions in emerging technologies such as offshore wind and Power-to-X are led by economies of scale.

Distributed Energy (DE), a full energy scenario as well compliant with the 1.5° C target of the Paris Agreement, presents a decentralised approach to the energy transition. On this ground, prosumers actively participate in a society driven by small scale decentralised solutions and circular approaches. Both Distributed Energy and Global Ambition reach carbon neutrality by 2050.

While National trend is a bottom-up scenario built via the collection of supply and demand data from gas and electricity TSO, Global Ambition and Distributed Energy are top-down scenario build by ENTSO-E and ENTSOG together with NGOs and stakeholders.

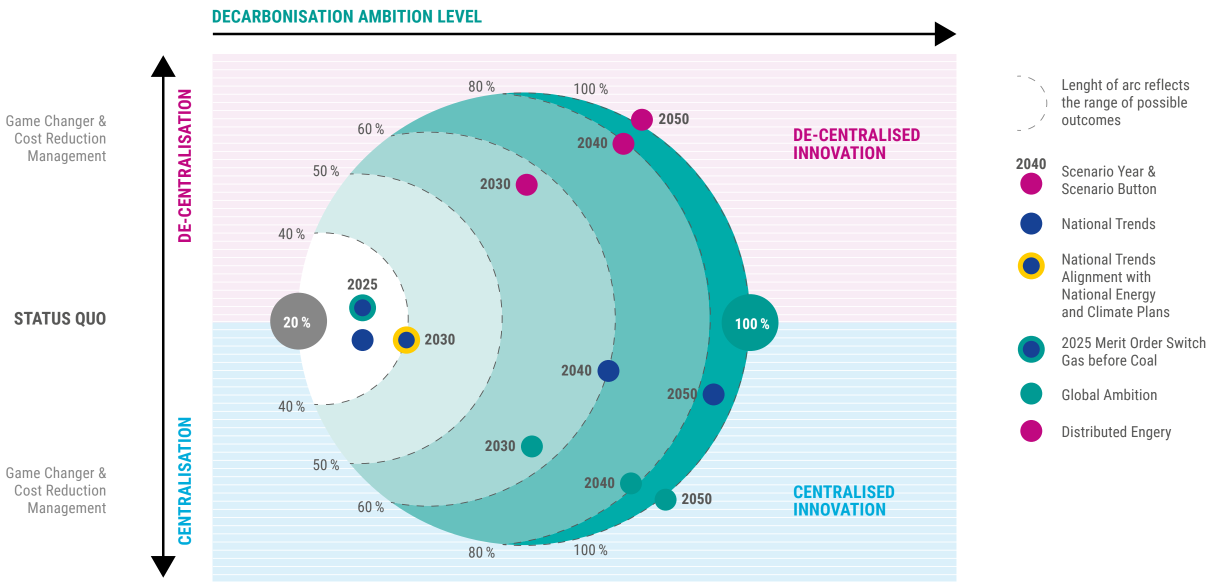


Figure 2.2 – Key drivers of scenario storylines

2.3 CBA results: Benefits delivered by TYNDP 2020 projects

2.3.1 B1 – Socio-Economic Welfare

The better use of cheap generation capacity results in general in the replacement of expensive thermal generation by RES generation (that would have been spilled otherwise) and nuclear. This leads to a decrease of generation cost across Europe.

The hypothesis of the scenario can have a significant effect on the projects' impact on socio-economic welfare. The main drivers are the following:

- Fuel cost and CO_2 costs: the higher the costs, the higher the increase in socio-economic welfare delivered by projects. Indeed, with high costs, the benefit of replacing expensive generation by cheaper one is also bigger.
- RES generation: in general, the higher the RES installed capacities, the higher the increase in socio-economic welfare. This is because high RES generation offers more potential to replace expensive thermal generation.

Socio-Economic Welfare increases with the energy transition

The impact on socio-economic welfare has been computed for every project of the portfolio and in several scenarios. The analyses show that socio-economic welfare tend to increase with time: it is lower in the 2025 horizon compared to the 2030 horizon. The progress of the energy transition across Europe from 2025 to 2030 explains the main part of this increase of of projects' impact on socio-economic welfare..

In the 2030 horizon, projects' impact on socio-economic welfare seem to be higher in Distributed Energy than in Global Ambition and National Trends: in addition to the differences in RES penetration of the scenarios, the ETS CO_2 price plays an important role in the marginal cost of the power plant, and therefore also on socio-economic welfare. For instance, the high CO_2 price used in Distributed Energy 2030 (53 €/ton) compared to National Trends 2030 (28 €/ton) explain a big part of the differences in projects' impact on socio-economic welfare in the two scenarios. Of course, other hypothesis can explain locally other trends and differences that could be observed. Note that the reference grid was the same for all assessments.

In National Trends 2030, the PCI corridor NSOG seems to present slightly higher increase in socio-economic welfare than the other corridors (and higher CAPEX). Indeed, projects in this area tend to be bigger compared to projects in other PCI regions. Their higher Net Transfer Capacity allows more exchanges resulting in a higher increase of socio-economic welfare.

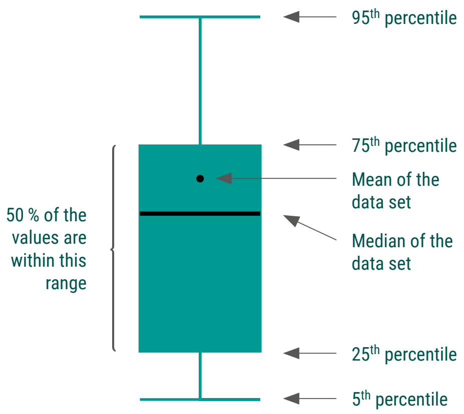
How to read a box plot

The box plot is a method to graphically depict the distribution of a data set.

What is a percentile?

- The Xth percentile is the value to which X % of the values of the data set are inferior.
- For example, 25 % of the values are below the 25th percentile while 75 % are above.

To avoid outliers, the 5th and 95th percentiles have been used to build Figures 2.3 to 2.8.



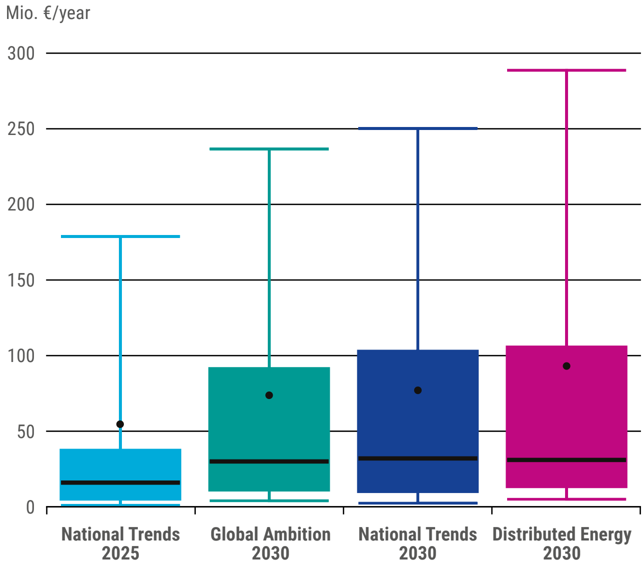


Figure 2.4 – Distribution of the increase of socio-economic welfare due to TYNDP 2020 projects per scenarios

	National Trends 2025	National Trends 2030	Global Ambition 2030	Distributed Energy 2030
Sum of the increase in socio-economic welfare generated by all the projects of the portfolio (M€/year)	7,375	11,481	10,329	13,222

Table 2.5 – Increase of socio-economic welfare generated by the TYNDP 2020 project portfolio in different scenarios

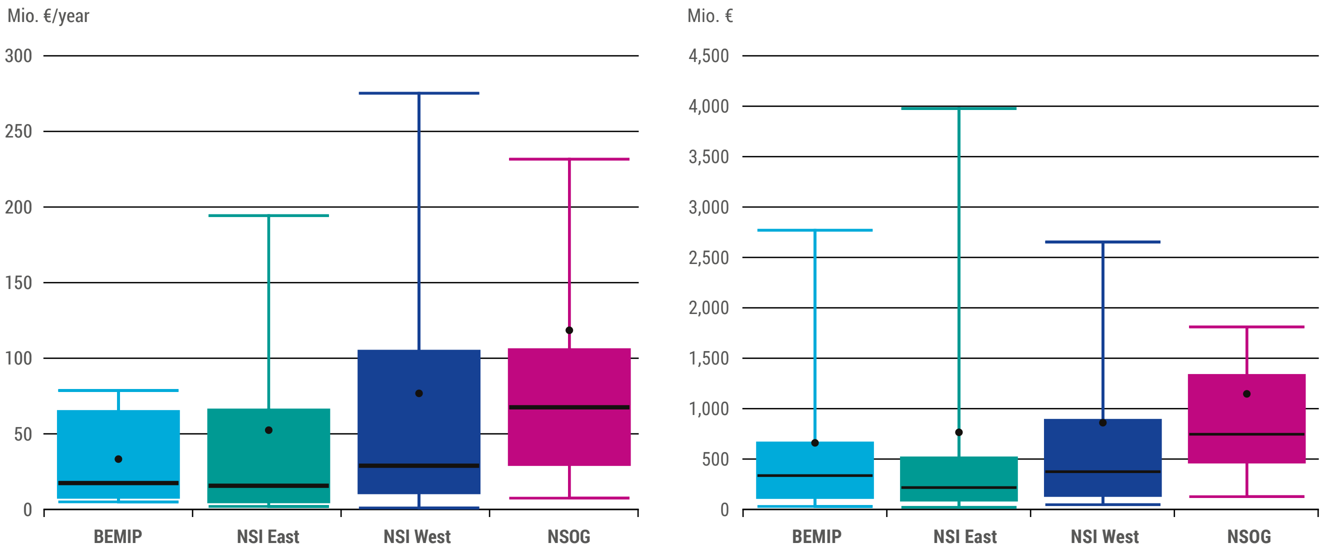


Figure 2.6 – Distribution of the increase in socio-economic welfare in the National Trends 2030 (left) and CAPEX (right) of TYNDP 2020 projects for the four PCI corridors (in M€/year)

About PCI corridors

Four electricity infrastructure corridors were identified as priority by the Trans-European Networks for Energy (TEN-E), which require urgent infrastructure development in electricity in order to connect regions currently isolated from European energy markets, strengthen existing cross-border interconnections, and help integrate renewable energy. The corridors are the following:

- **North Seas Offshore Grid (NSOG)**
- **North-South electricity interconnections in Western Europe (NSI West)**
- **North-South electricity interconnections in Central Eastern and South Eastern Europe (NSI East)**
- **Baltic energy market interconnection plan (BEMIP)**

Evolution since TYNDP 2018

Among the projects of the TYNDP 2020, about one hundred had already been assessed in the TYNDP 2018. While both 2025 scenarios (National Trend for the TYNDP 2020 and Best Estimate for the TYNDP 2018) present on average similar increase in socio-economic welfare, the 2030 horizons show some more contrasted results. The analysis points out that, on average, the impact on socio-economic welfare of the projects in National Trends and Global Ambition from TYNDP 2020 are close to the ones in Sustainable Transition and Distributed Generation from TYNDP 2018. However, socio-economic welfare results in Distributed Energy (TYNDP 2020) are much higher than in other scenarios while results for EUCO (TYNDP 2018) are much lower. Of course, those averages hide some big local differences: some projects' benefits can increase a lot while other have decreased between the two TYNDPs.

These differences have several causes. In addition to the various RES ambition of each scenario, the reference grid is slightly less connected in the TYNDP 2020, where it corresponds to the 2025 horizon, than in the TYNDP 2018 when it represented the expected grid in 2027. On the other hand, the CO_2 cost was higher in the TYNDP 2018, in particular for Sustainable Transition (84 €/ton).

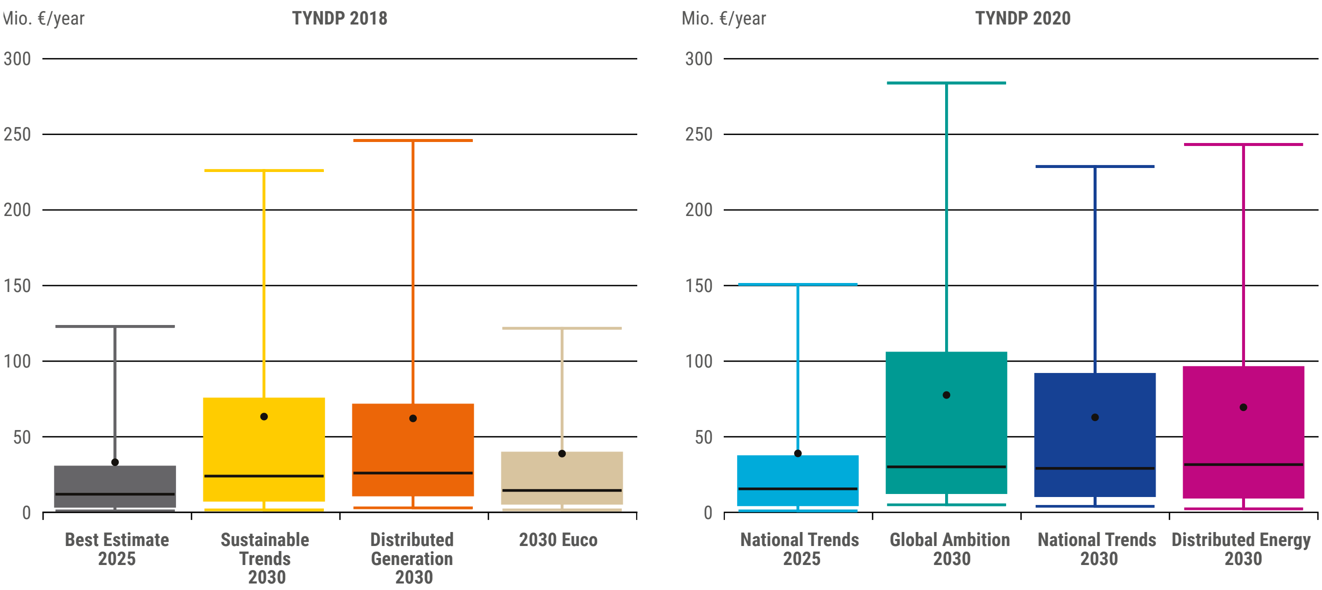


Figure 2.7 – Distribution of increases of socio-economic welfare in the scenarios of TYNDP 2018 and 2020, for projects assessed in both exercises (in M€/year)*

* P335 (North Sea Wind Power Hub) has been removed from the figure due to its very high impact on socio-economic welfare that distorts the comparison.

2.3.2 Other monetised indicators

B2 – CO_2 emissions

New transmission and storage projects allow to replace expensive CO_2 emitting generation by cheaper, low carbon generation, such as RES generation that would have been curtailed otherwise, or nuclear energy. These replacements generate huge CO_2 emissions reductions. However, in some very specific cases, CO_2 emissions could increase with the addition of a new project. Indeed, some coal power plants, and in particular lignite power plants, have lower marginal cost than gas power plant that emits less CO_2. Electricity exchanges favour cheaper generation, which in this rare case would lead to the CBA finding that a project increase in CO_2 emission.

On the other hand, these new exchanges tend to increase electrical losses. The additive generation needed to cover those losses could results in additional CO_2 emission. In the TYNDP 2020, the losses and the CO_2 resulting from them have been computed on NT 2025 and NT 2030. This tend to decrease the total CO_2 reduction allowed by the project, but the global effect remain an important reduction in most of the case.

This effect on CO_2 emission can be monetised with the use of a societal cost of carbon. For TYNDP 2020, the three values proposed by European Commission DG MOVE's Handbook on the external costs of transport (low, median, and high[5]) has been used. CO_2 emission are however already partially monetised within the socio-economic welfare and the cost of losses through the ETS CO_2 price which count for a part of the power plants marginal cost. Consequently, only the additional societal value of CO_2 is included in indicator B2. This indicator can count up to several 10 M€ or even 100 M€ but it strongly depends on the societal value (price of CO_2) used.

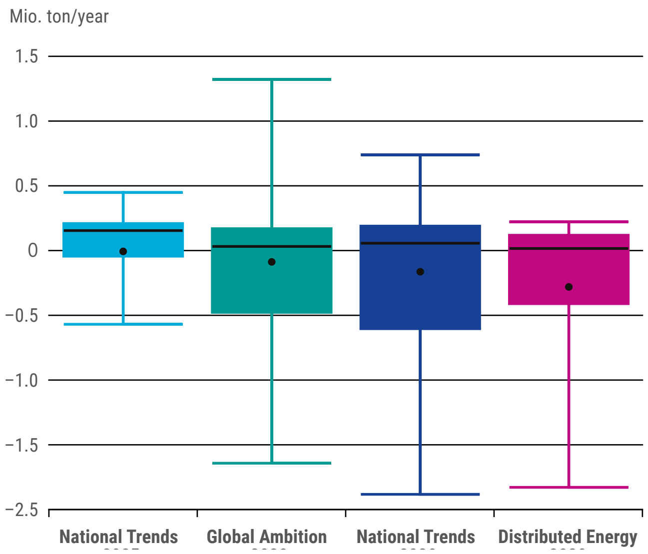


Figure 2.8 – Distribution of CO_2 emissions savings from market substitution of TYNDP 2020 projects (in Mton / year)

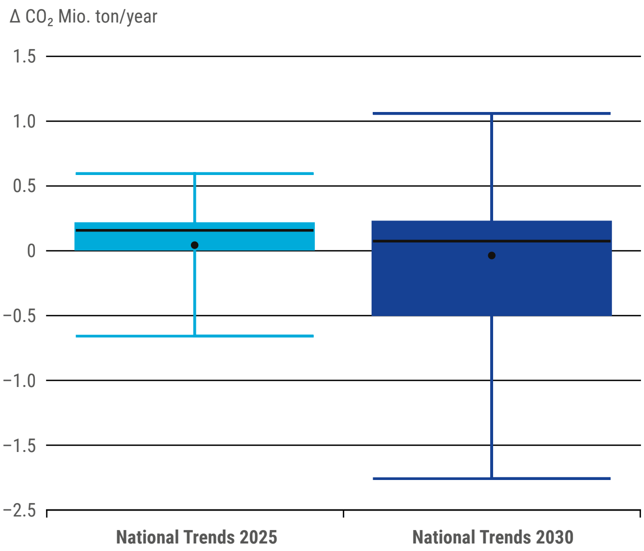


Figure 2.9 – Distribution of global CO_2 emissions savings from market substitution and changes in losses of TYNDP 2020 projects in National Trend 2025 and 2030 (in Mton / year)

5 In the short term (up to 2030) the values are the following: Low value = 60 € / ton; median value = 100 € / ton; high value = 189 € / ton

B5 – Losses

A new project creates in general long-distance electricity exchange across Europe. These new exchanges tend to increase the flow on the lines which results in an increase of electricity losses. The cost of the losses also evolves because of the evolution of the price in each country. Indicator B5 measures the evolution of the cost due to losses induced by the new project. The values are in the order of magnitude of a few 10 M€/year. Compared to TYNDP 2018, some methodology improvements and the reduction of electricity prices have resulted in a small decrease of the values.

B6 – Adequacy

Interconnections help to maintain the adequacy by allowing countries to import electricity during stressful times. With the increase of variable RES generation across Europe, the electricity system could lack flexibility. New interconnectors will bring geographical flexibility by taking advantage of the difference of climate conditions across Europe. They will also allow a better use of the peaking generation units. Therefore, indicator B6 can represent a significant part of the benefits of a project. It has been assessed only for the NT 2030 scenario, and only for projects commissioning before 2035.

In some cases, when the hosting countries of the project have a lot of base and semi-base generation, they might already have no offer and supply balance issue. In such case, the project adequacy benefit is null.

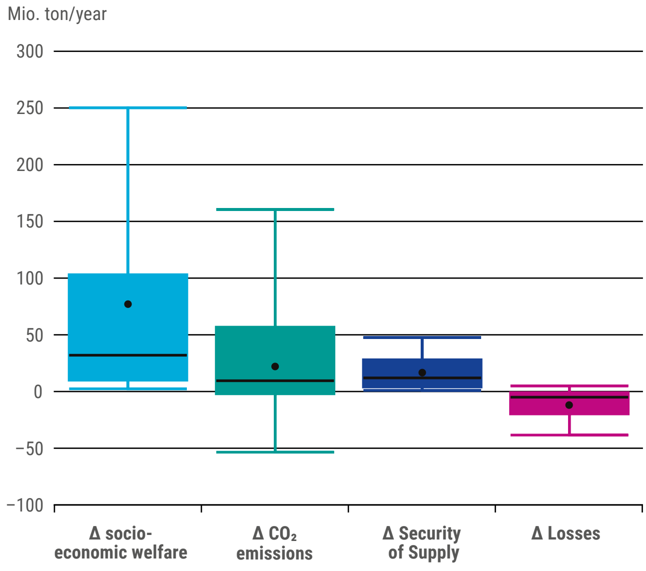


Figure 2.10 – Distribution of the monetised benefits socio-economic welfare, CO_2 emissions*, losses and adequacy in scenario National Trends 2030 for TYNDP 2020 projects (in M€/year)

* From market substitution and change in losses, monetised with the median value (100 €/ton)

3 How do TYNDP 2020 projects address system needs?

Addressing system needs puts Europe on track to realise the Green Deal. This chapter analyses how TYNDP 2020 projects are suitable to accommodate those needs by 2030, as a close and tangible objective horizon. It will be done comparing the results of ENTSO-E's System Needs Study with the project portfolio for 2030, building in the main European boundaries the curves of increase in socio-economic welfare when the transmission capacity increases from the current situation, and checking the fulfilment of the 2030 interconnection target set by the European Commission. This general view must be complemented with the individual project cost-benefit analysis.

In addition, needs may be addressed by a variety of solutions beyond transmission lines (storage, demand management, smart grids, generation). The needs exist beyond the developments foreseen for these technologies in the scenarios, for most of which no concrete projects currently exist. To decarbonise the system while maintaining its reliability at the lowest possible cost requires that all possible solutions are explored.

The project portfolio must be strengthened to meet future needs

The results of the System Needs Study showed that, additionally to the 35 GW of new cross-border reinforcements expected to be built by 2025 in addition to the 2020 grid, 50 additional GW of cross-border reinforcements would be cost-efficient to support the electric system in its path towards decarbonization.

Many projects able to solve system needs by 2030 are already on the table and are assessed in the TYNDP 2020. As anticipated in the System Needs study, only slightly more than half of needs in the 2030 horizon are covered by existing TYNDP projects. The following Figures allow to see this in more detail as they present:

- Cross-border capacity increases of projects in the TYNDP 2020 transmission projects portfolio for which project promoters provided a commissioning year in 2030 or earlier.
- SEW-based needs identified in ENTSO-E's System Needs study for the 2030 horizon (National Trends 2030). These capacity increases are additional to the 2025 network, also included in the Figure in blue, composed of projects under construction or in advanced stage and expected to be in service in 2025. The System needs study investigated the combination of potential increases in cross-border network capacity that minimises the total system costs. As such, it considered needs based mostly on potential benefits in terms of socio-economic welfare. However, there exist many other needs, e. g. improve security of supply, and many other benefits that can be delivered by individual projects. This Figure must then be understood as a partial picture if the needs in the European power system in 2030.
- Comparison of the two figures, identifying where proposed transmission projects correspond to the identified SEW-based needs, where there are projects competing to address the same needs or addressing needs other than SEW-based and where there are unaddressed needs.

To ease the comparison between needs, expressed in terms of cross-border capacity increases, and projects, Figure 3.3 considers only transmission projects. But all options, not only transmission projects as there are here represented, should be considered to address these needs, including storage and cross-sectors solutions.

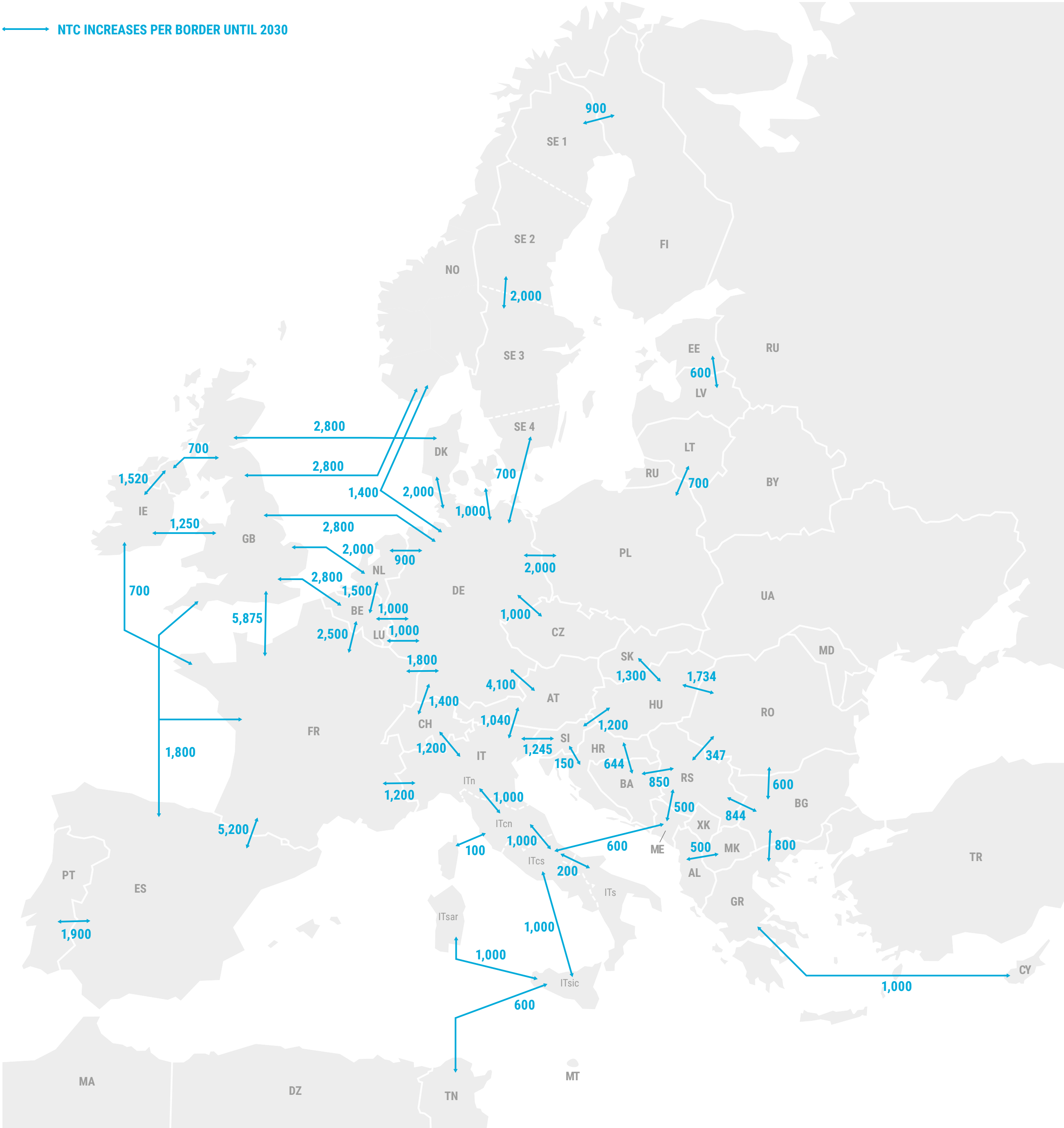


Figure 3.1 – Sum of NTC increases of projects in the TYNDP 2020 portfolio for which project promoters provided a commissioning year in 2030 or earlier (including projects expected to be in service in 2025). Where the NTC increase is not the same in both directions, only the highest value is shown in the map. Some borders have projects competing with each other to address the same need.

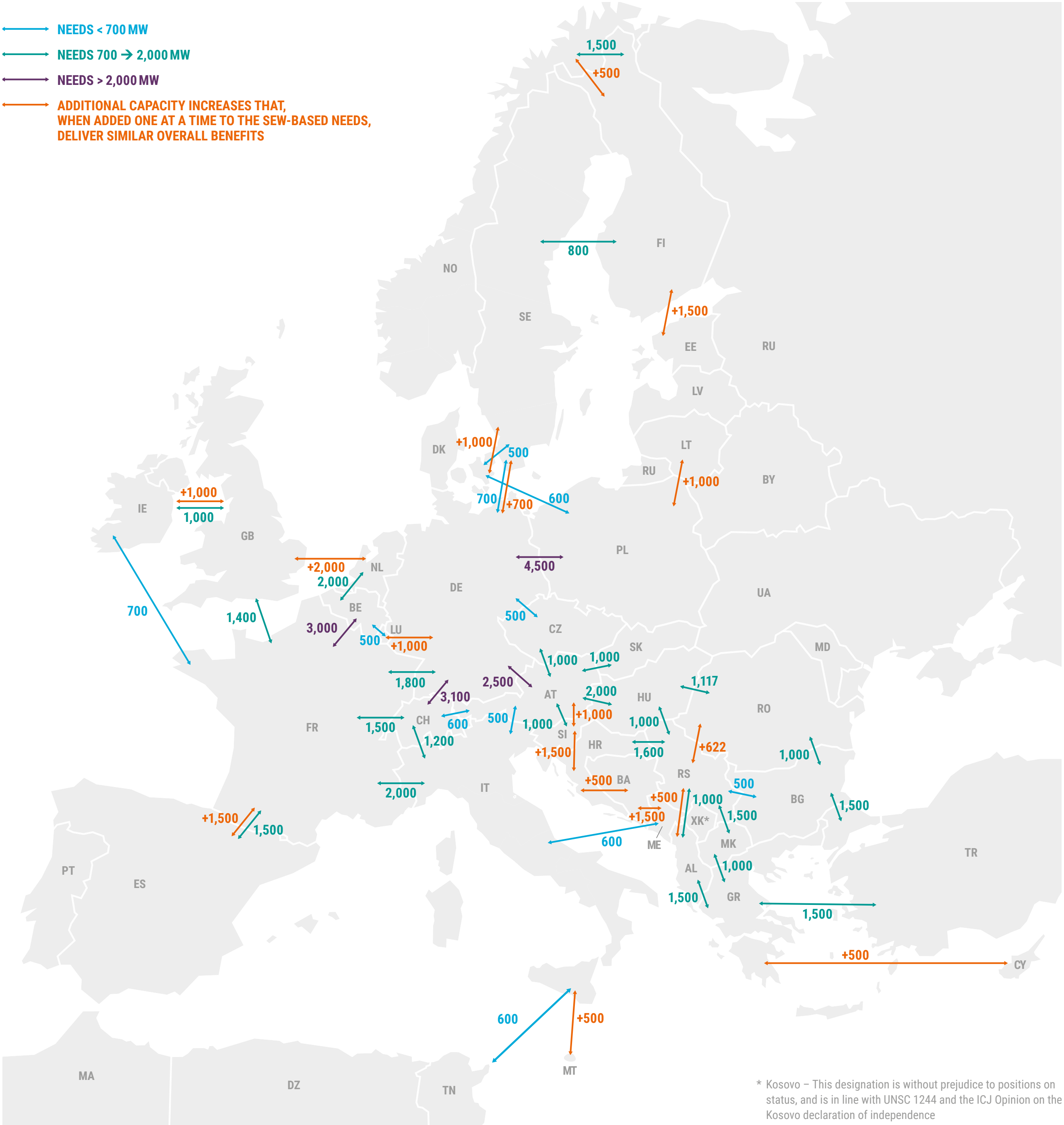


Figure 3.2 – Needs identified in ENTSO-E's System Needs study for the 2030 horizon (National Trends 2030). The study investigated the combination of potential increases in cross-border network capacity that minimises the total system costs. These capacity increases are additional to the 2025 network, composed of projects under construction or in advanced stage and expected to be in service in 2025.

Orange lines correspond to network increases included in grid solutions that were only slightly more expensive than the SEW-based needs solution. These additional capacity increases (presented in more details in ENTSO-E's System needs report page 17 "The SEW-based capacity increases, one solution among others"), if added one or few at a time to the SEW-based needs, would deliver similar overall benefits.

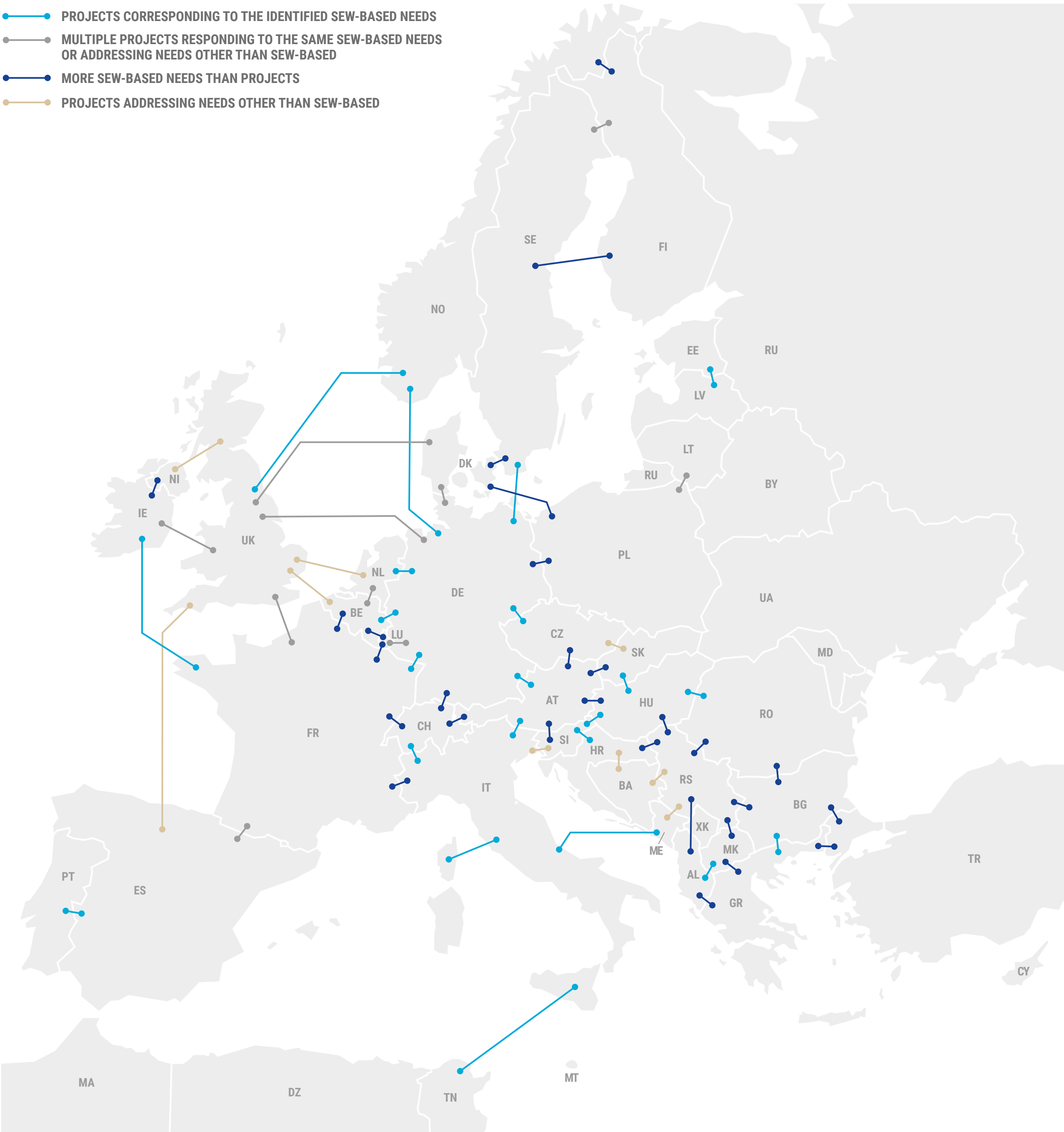


Figure 3.3 – Comparison of the identified needs based on socio-economic welfare and proposed transmission projects for the 2030 horizon

First and foremost, when considering Figure 3.3, CBA results of individual projects have to be considered, because other benefits not fully assessed in the System Needs Study can compensate the cost of the project and make it viable and cost-efficient.

As visible in Figure 3.3, there are areas in Europe (in light blue) where the TYNDP 2020 transmission projects for the 2030 horizon fit the identified SEW-based needs for 2030, such as the north-western border of Germany, the path Slovakia-Hungary-Romania, and several Italian borders (including links with third countries such as Tunisia and Montenegro), among others.

However, in other areas (in dark blue) the identified needs are higher than the capacity increases of existing TYNDP 2020 projects. This lack of projects appears in the Balkans, on the borders Bulgaria–Turkey, Greece–Turkey and Greece–North Macedonia, on the Eastern borders of France, on the corridor between Germany, Switzerland and Italy, on borders between the Czech Republic, Slovakia and Austria, and on several Polish and Swedish borders, among others. This is an indication that some long-term projects currently foreseen to commission after 2030 should perhaps revise their planned commissioning dates and accelerate their development, while some new additional projects could arise.

On the other hand, there are areas (in grey) where the capacity increase of proposed TYNDP2020 projects is higher than the SEW-based needs, or (in brown) areas where there are projects where no clear need was identified based on socio-economic welfare only. In both cases, a case by case analysis has to be performed because the reasons for this discrepancy can be diverse.

- SEW-based needs considered in Figure 3.3 do not include network increases included in grid solutions that were only slightly more expensive than the SEW-based needs. These additional capacity increases, if added one or few at a time to the SEW-based needs, may deliver similar overall benefits. For example, if the additional capacity increase need of 1,500 MW identified on the France-Spain border in the 2030 horizon was considered, then the difference between the SEW-based needs and the project portfolio would be lower.
- Some of those areas may have some projects in competition to address the same need, such as on the Great Britain-France border.
- On the other hand, dark blue lines especially show borders where projects could address combined needs as an alternative solution. For instance, there is a need identified between Serbia and Croatia, but there is no project on that border in the 2030 horizon. As alternative there are projects between Serbia and Bosnia & Herzegovina, and between this last one and Croatia, that could serve for the same purpose and might be more adequate from an environmental and social point of view.
- Lastly, some projects scheduled for the 2030 horizon may be postponed for the next decade if no additional benefits justify their commissioning before 2030.

These findings can help the project portfolio and some of the projects' characteristics adapt to the future power system. They can also serve to guide the development of new projects to perform proper analysis in terms of environmental impact, viability, benefits beyond socio-economic welfare and refined costs.

Comparing Figure 3.4 and 3.5 shows how borders between countries or bidding zones with high price differentials, in the case where Europe would stop all investments in the grid after 2020, turn to colder colours when considering the TYNDP 2020 transmission project portfolio. Most of the higher price differentials higher than 10 € / MWh are reduced, except on some borders in the Baltic Sea, and on a North-South boundary between Eastern and Western Europe.

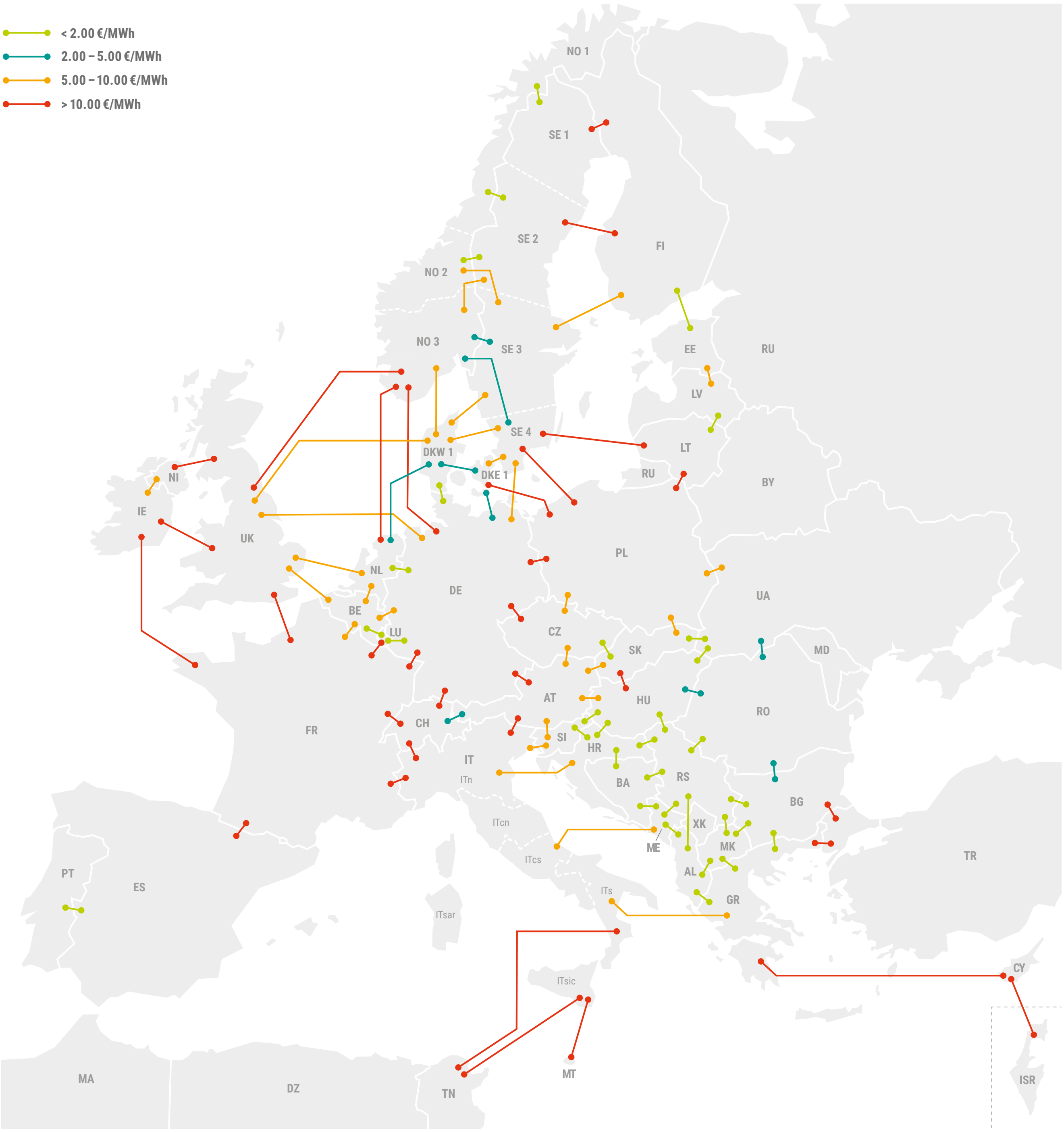


Figure 3.4 – Difference in marginal cost of electricity between neighbouring countries in 2030 (National Trends), in the case where Europe would stop all investment in the grid after 2020

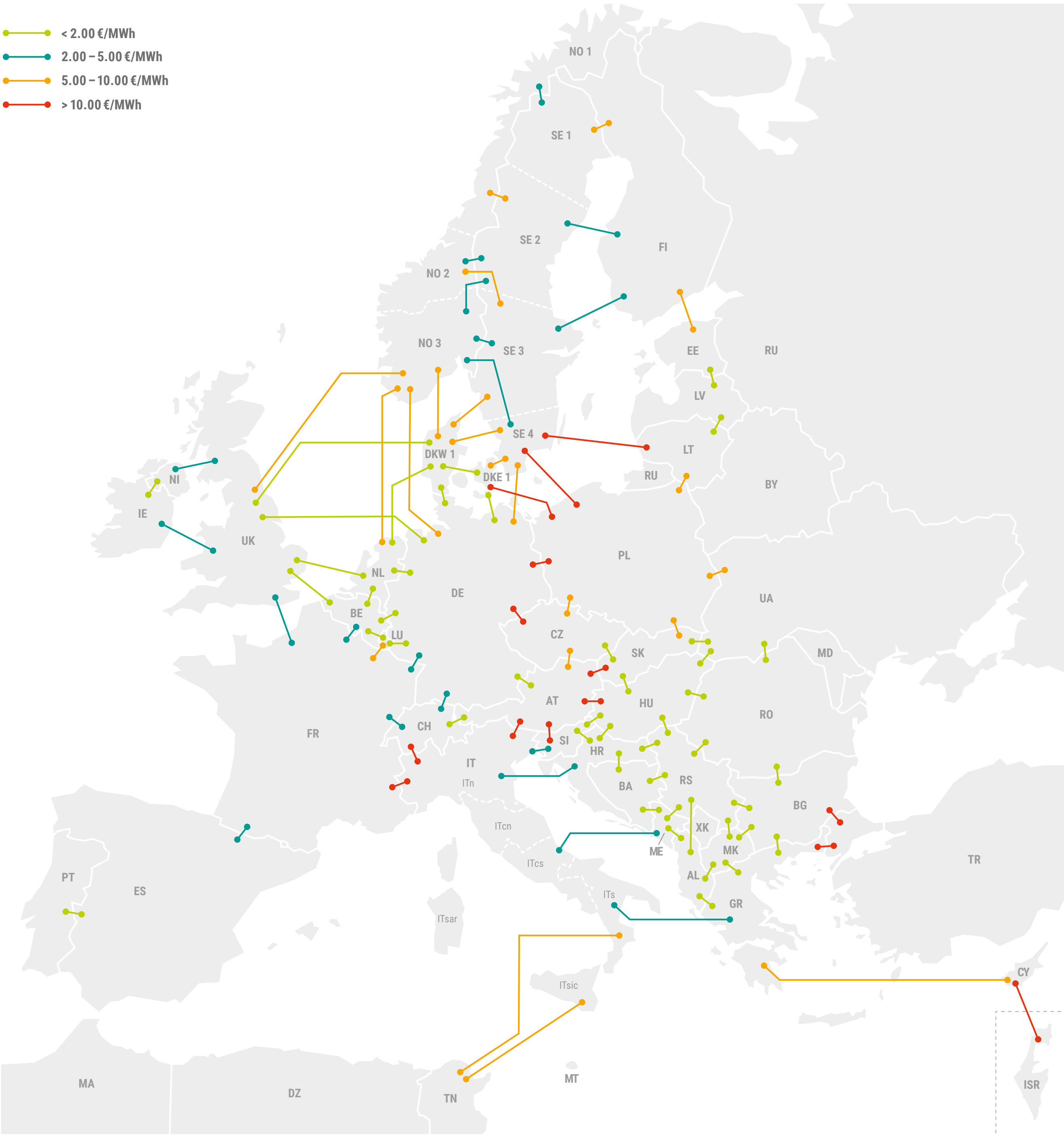


Figure 3.5 – Difference in marginal cost of electricity between neighbouring countries in 2030, with the TYNDP 2020 portfolio for 2030 (all projects with a declared commissioning year in 2030 or earlier)

Unlocking barriers in 2030

For 2030, the analysis of the way the development of the grid can address future system needs focuses on main European boundaries. A boundary is defined as a major barrier preventing optimal power exchanges between countries or market nodes which, if no action is undertaken, leads to high price differences between countries, RES spillage and risk to security of supply. Changes to the generation portfolio – a significant RES increase driving higher power flows across the region – are the main drivers of these boundaries.

The main boundaries identified by ENTSO-E for the TYNDP 2020 (Figure 3.6) are generally between regions where the potential of RES is high and with densely populated and high power consumption areas. The barriers represented by congestion in the power flows appear mostly where geography has set natural barriers such as seas and mountain, which are the most difficult to cross.

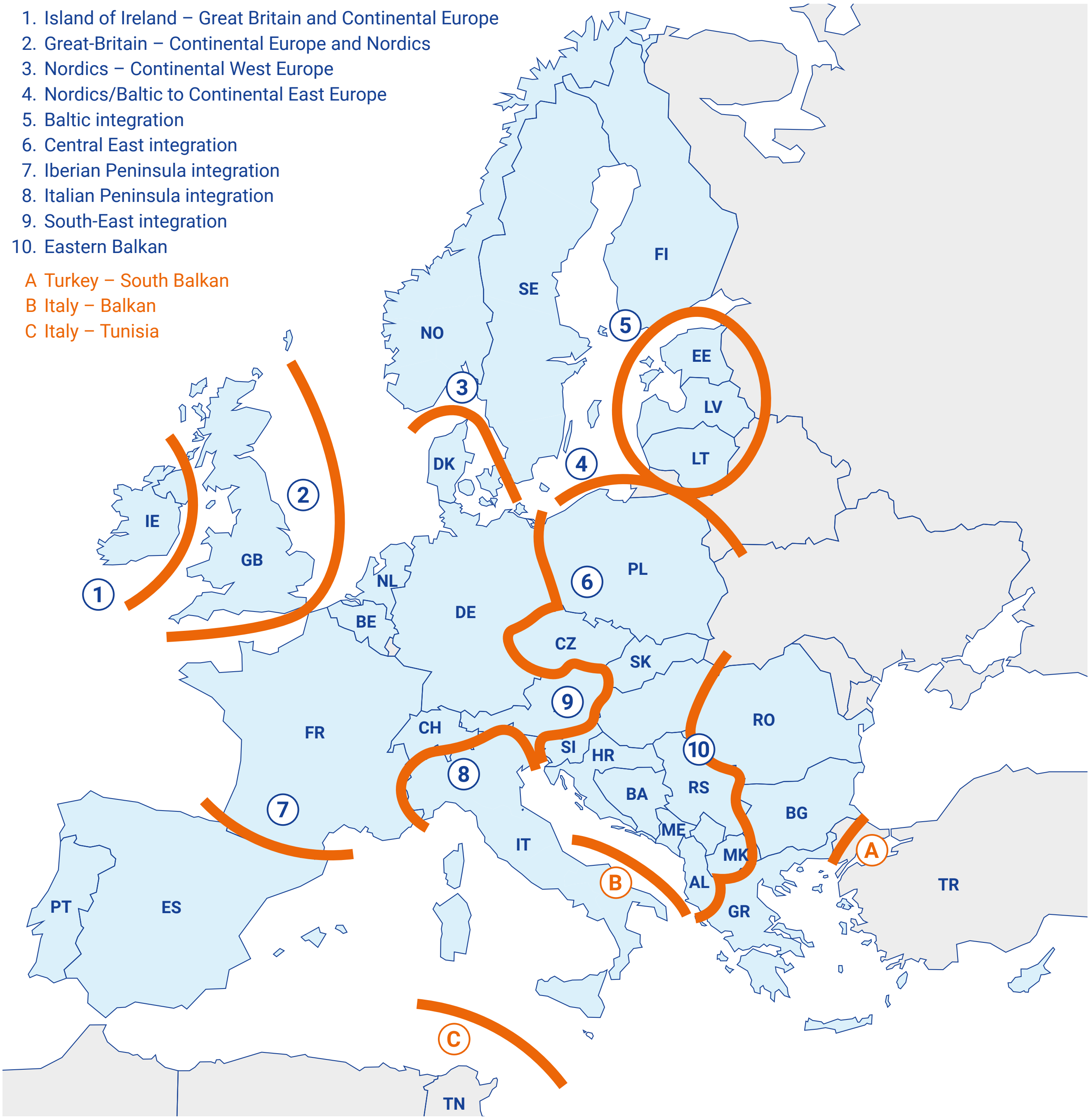


Figure 3.6 – TYNDP 2020 main boundaries identified by ENTSO-E, inside the EU and with neighbouring countries

Figures 3.7 and following figures represent the overall diminution of wholesale market volume (gains in socio-economic welfare) when the total transmission capacity across each boundary increases from the current. situation (first point of the curve represents the 2020 NTC). These curves allow to see rather high potential for positive benefits regarding increased capacity in most of these boundaries, although up to different levels of capacity. Steep curves indicate high needs for further integration of the markets across the boundaries. On the other hand, when the curves turns flat the cost of capacity increases do not compensate anymore the gains in socio economic welfare. Note that the figures only show benefits regarding market integration, not other benefits like decreased CO_2-emissions, increased RES-generation and increased security of supply. Overall, the curves turn flat at rather high capacity values compared to the current situation, which reflects the interest for the European system to address those capacity needs.

The analysis to take out these figures was performed on the ENTSO-E 2030 scenarios using market-modelling tools. Each point of the curves corresponds to the results of a simulation of one scenario, for several climate conditions, with the indicated transmission capacity for the boundary and other grid set to the reference grid. Although this analysis is performed through the perspective of international electricity exchanges, the needs it allows to identify can be addressed by other technological solutions deployed for that purpose (such as generation, storage, demand side technologies).

In general the curves are steeper for the Distributed Energy scenario in Western Europe and in Eastern Balkans, while in Central Europe, from the Baltic area to North Africa the curves are steeper for the National Trends scenario. The only exception being the border between Italy and the Balkans which has its highest values in the Global Ambition scenario, although the curve remains quite close to the National Trends curve. All the boundaries have rather flat curves in the Current Trends sensitivity, implying that this sensitivity has the lower needs in capacity increases and that limited capacity increases would rapidly balance socio-economic welfare and costs.

The highest gains in socio-economic welfare for similar capacity increases are found on the Turkey – South Balkan and on the Great Britain – Continental Europe – Nordics boundaries, followed by the Central East, the Iberian Peninsula and the Nordics-Continental Europe West boundaries.

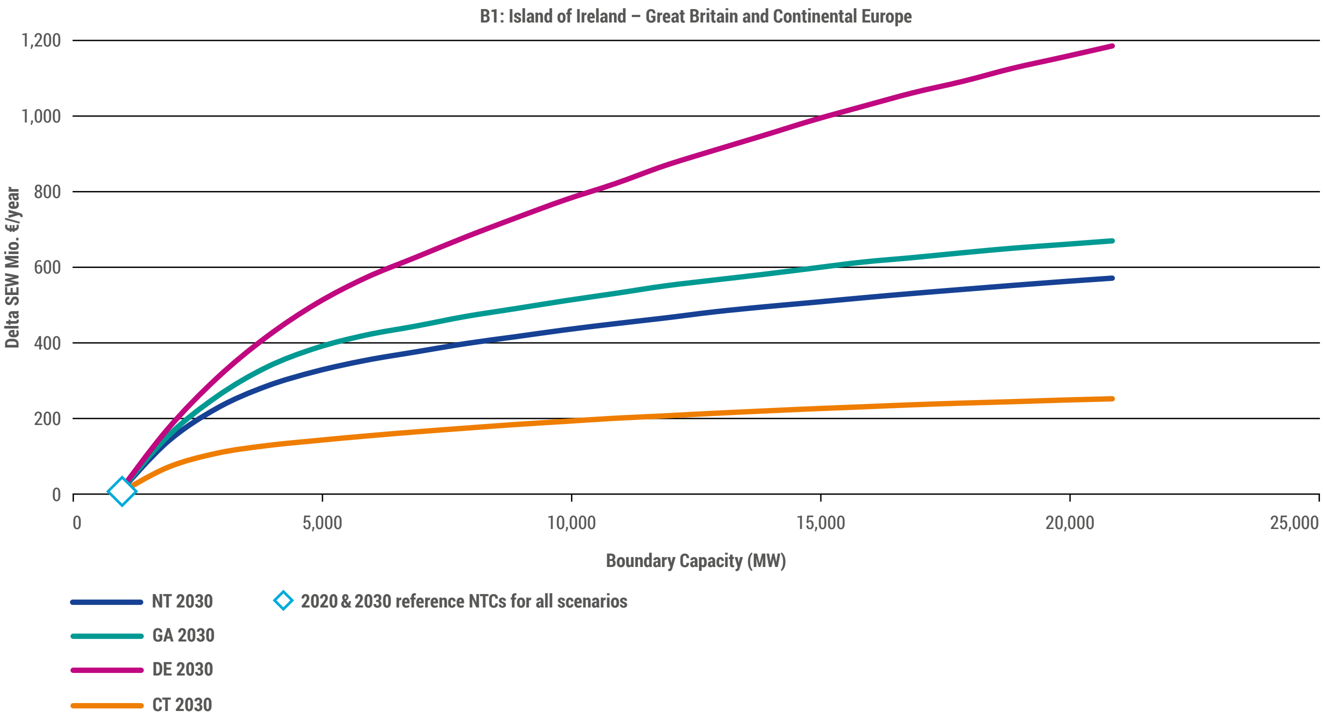


Figure 3.7 – Increase in socio-economic welfare when the transmission capacity increases from the current situation, on Boundary 1 Island of Ireland – Great Britain and Continental Europe, in all TYNDP 2020 scenarios for the 2030 horizon

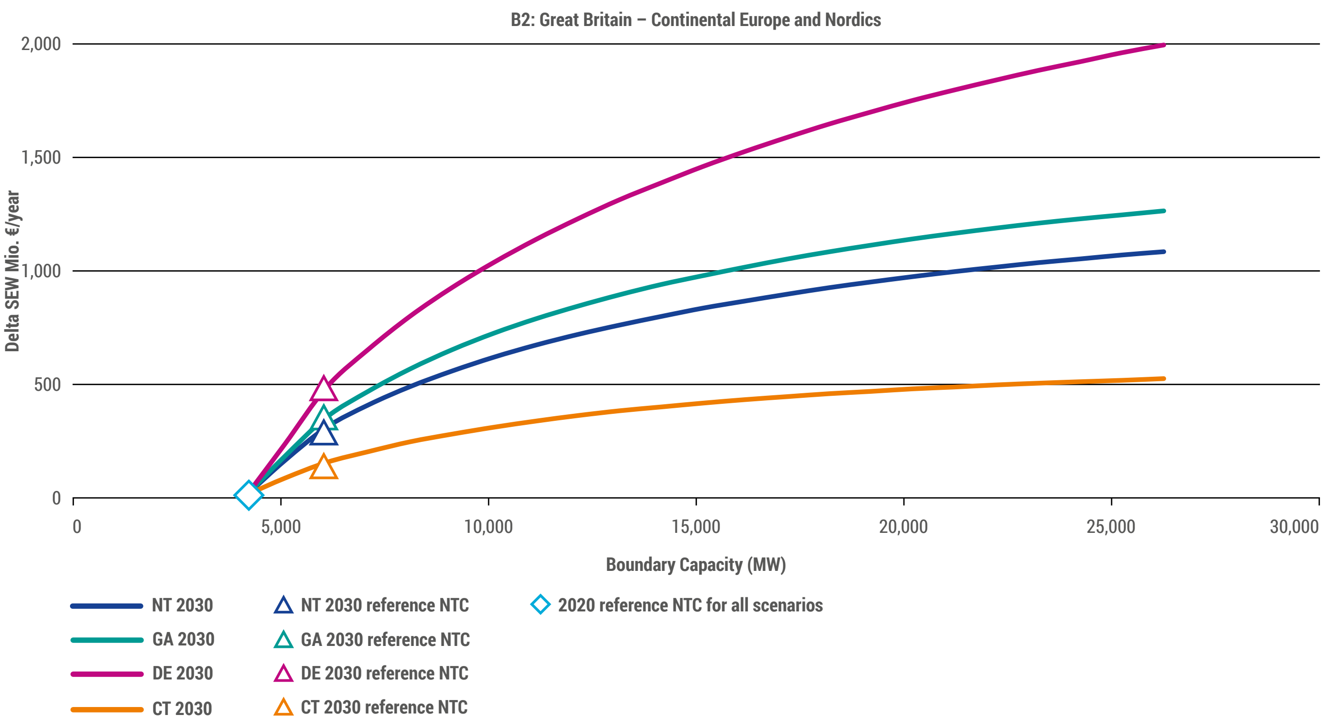


Figure 3.8 – Increase in socio-economic welfare when the transmission capacity increases from the current situation, on Boundary 2 Great-Britain – Continental Europe – Nordics, in all TYNDP 2020 scenarios for the 2030 horizon

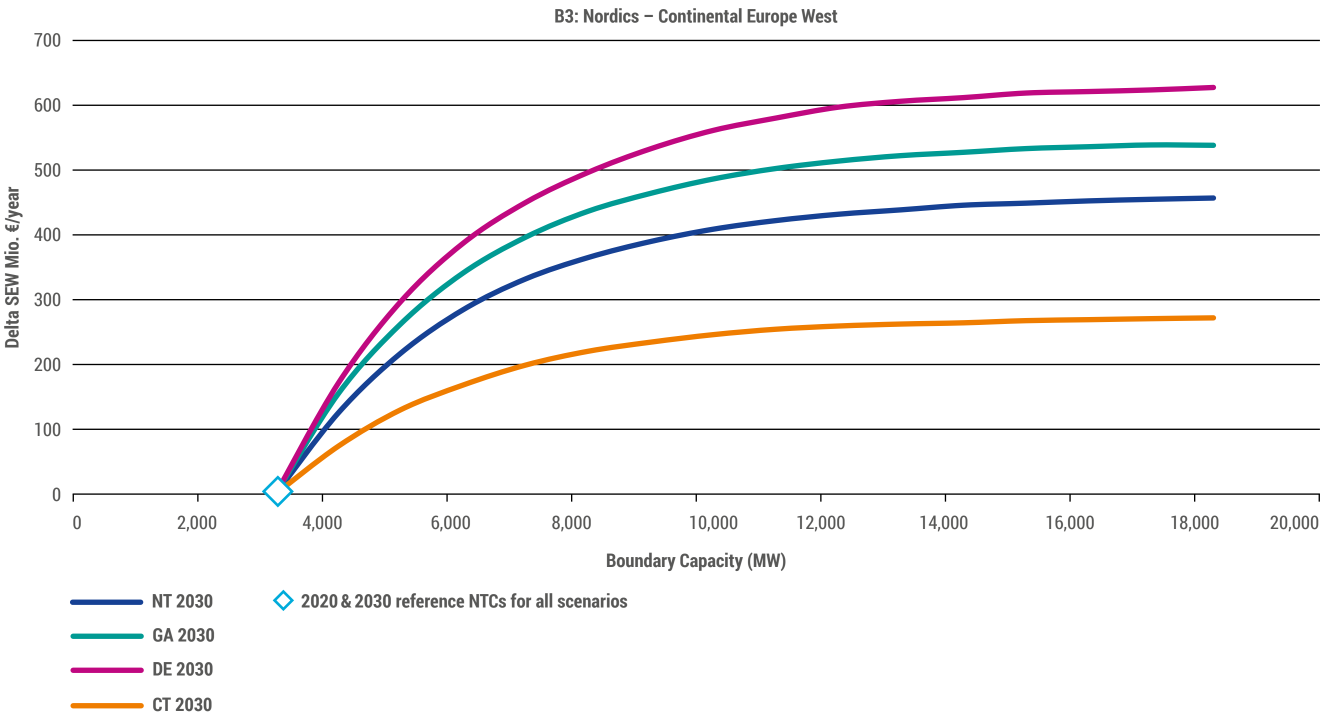


Figure 3.9 – Increase in socio-economic welfare when the transmission capacity increases from the current situation, on Boundary 3 Nordics – Continental Europe West, in all TYNDP 2020 scenarios for the 2030 horizon

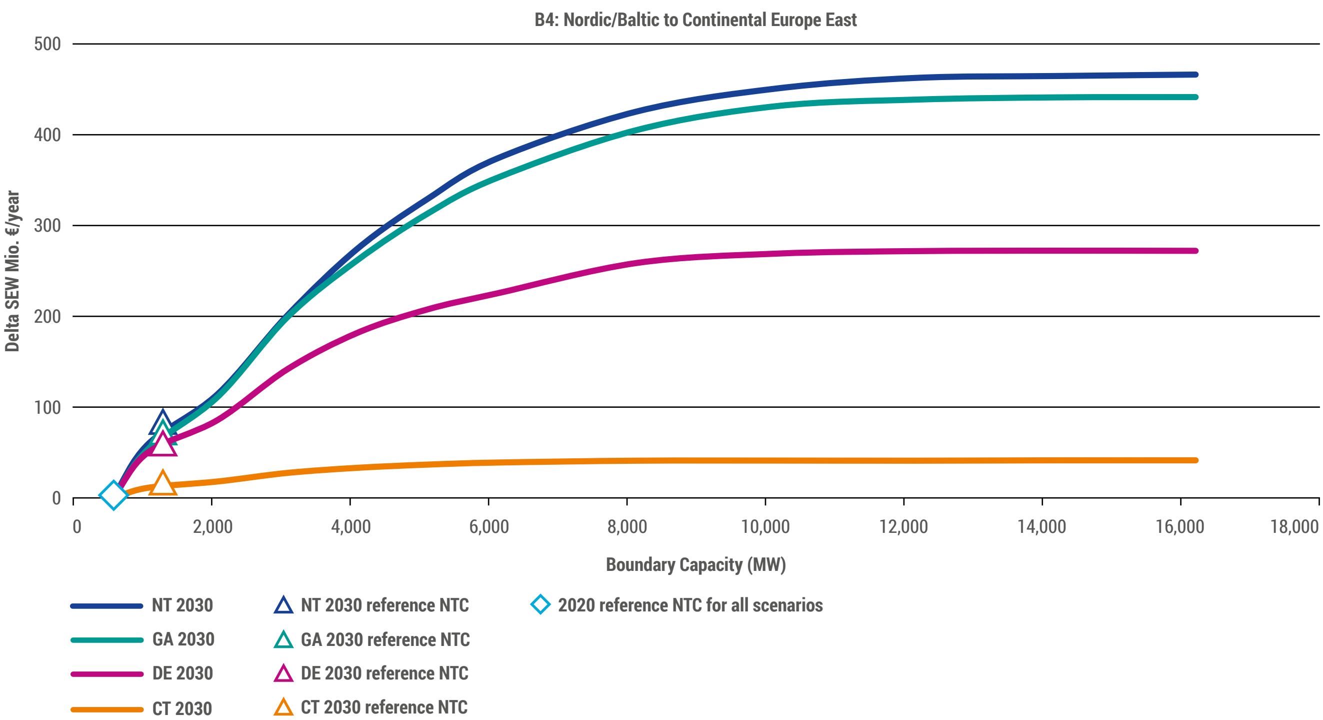


Figure 3.10 – Increase in socio-economic welfare when the transmission capacity increases from the current situation, on Boundary 4 Nordics / Baltics – Continental Europe East, in all TYNDP 2020 scenarios for the 2030 horizon

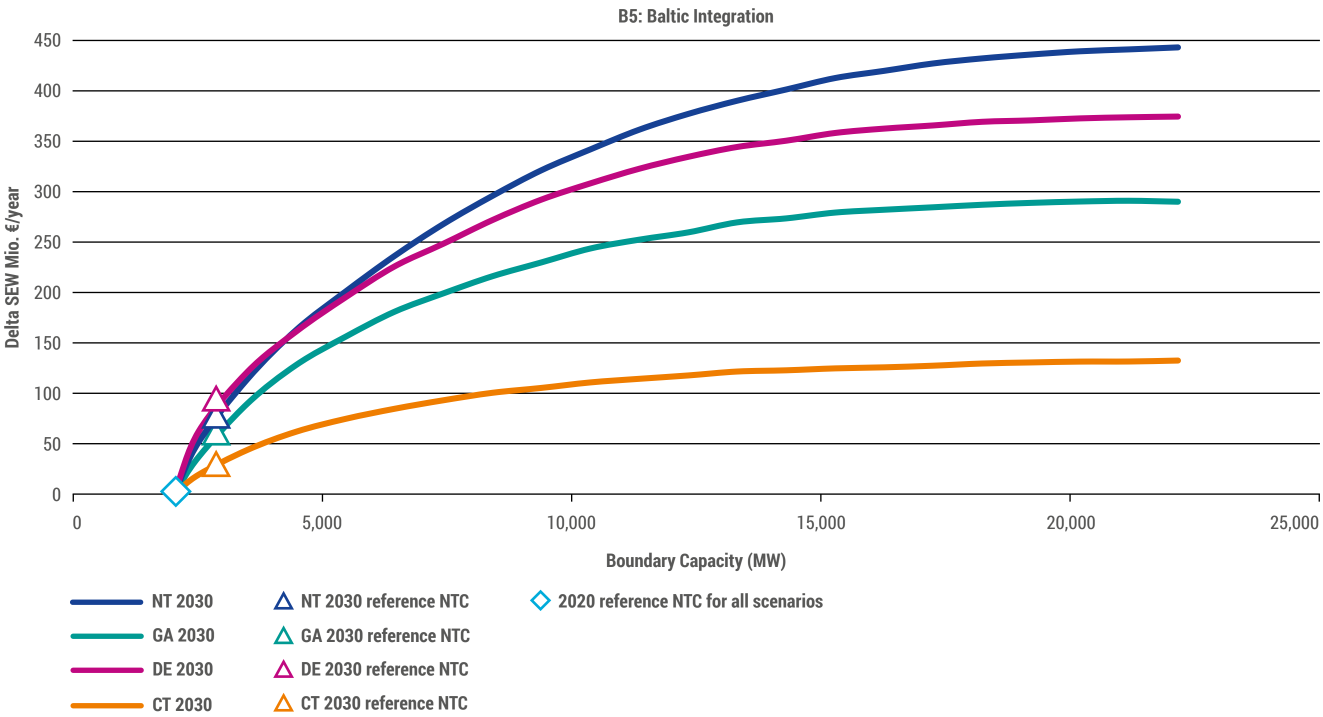


Figure 3.11 – Increase in socio-economic welfare when the transmission capacity increases from the current situation, on Boundary 5 Baltic integration, in all TYNDP 2020 scenarios for the 2030 horizon

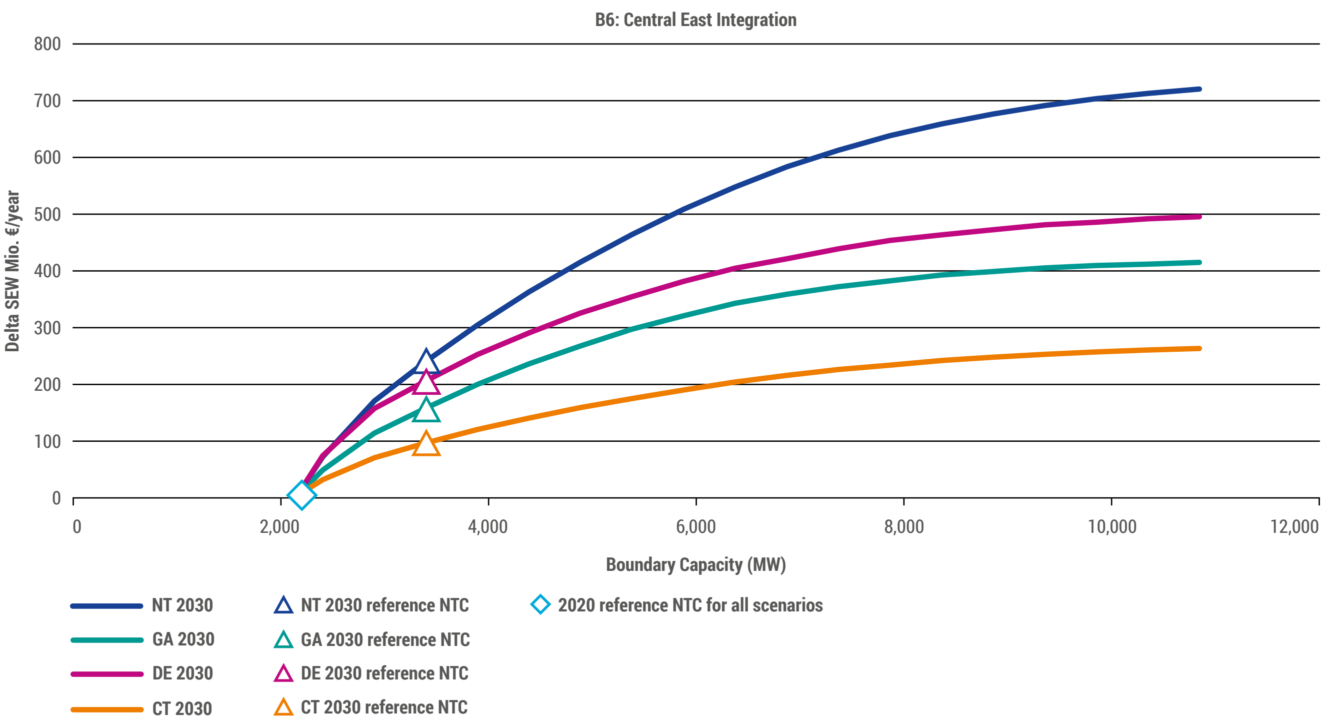


Figure 3.12 – Increase in socio-economic welfare when the transmission capacity increases from the current situation, on Boundary 6 Central East integration, in all TYNDP 2020 scenarios for the 2030 horizon

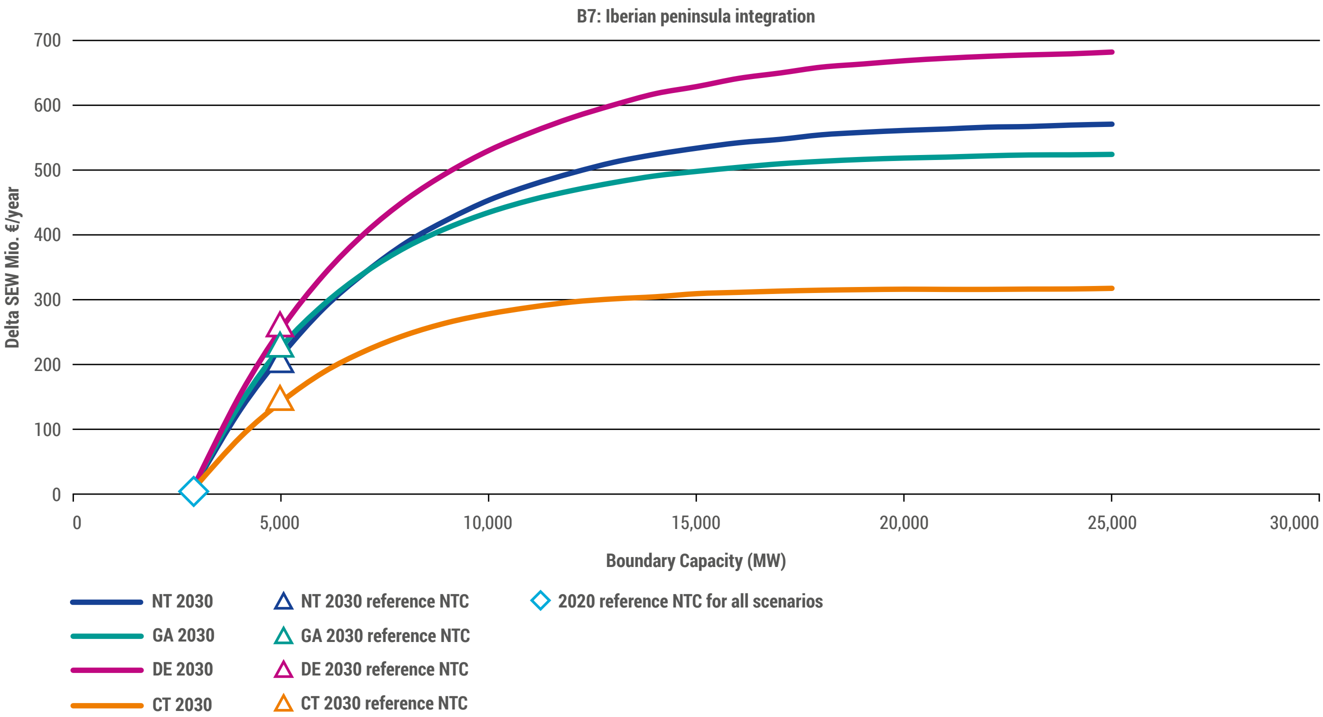


Figure 3.13 – Increase in socio-economic welfare when the transmission capacity increases from the current situation, on Boundary 7 Iberian Peninsula, in all TYNDP 2020 scenarios for the 2030 horizon

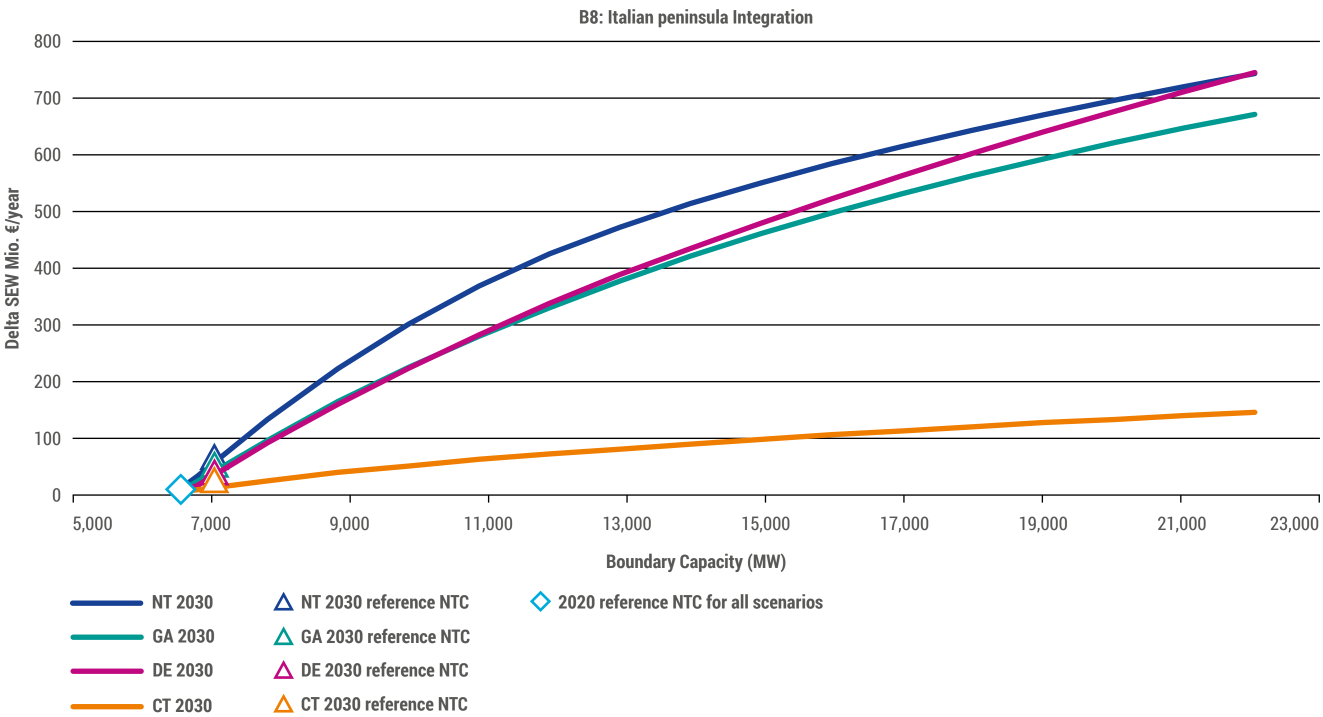


Figure 3.14 – Increase in socio-economic welfare when the transmission capacity increases from the current situation, on Boundary 8 Italian Boundary, in all TYNDP 2020 scenarios for the 2030 horizon

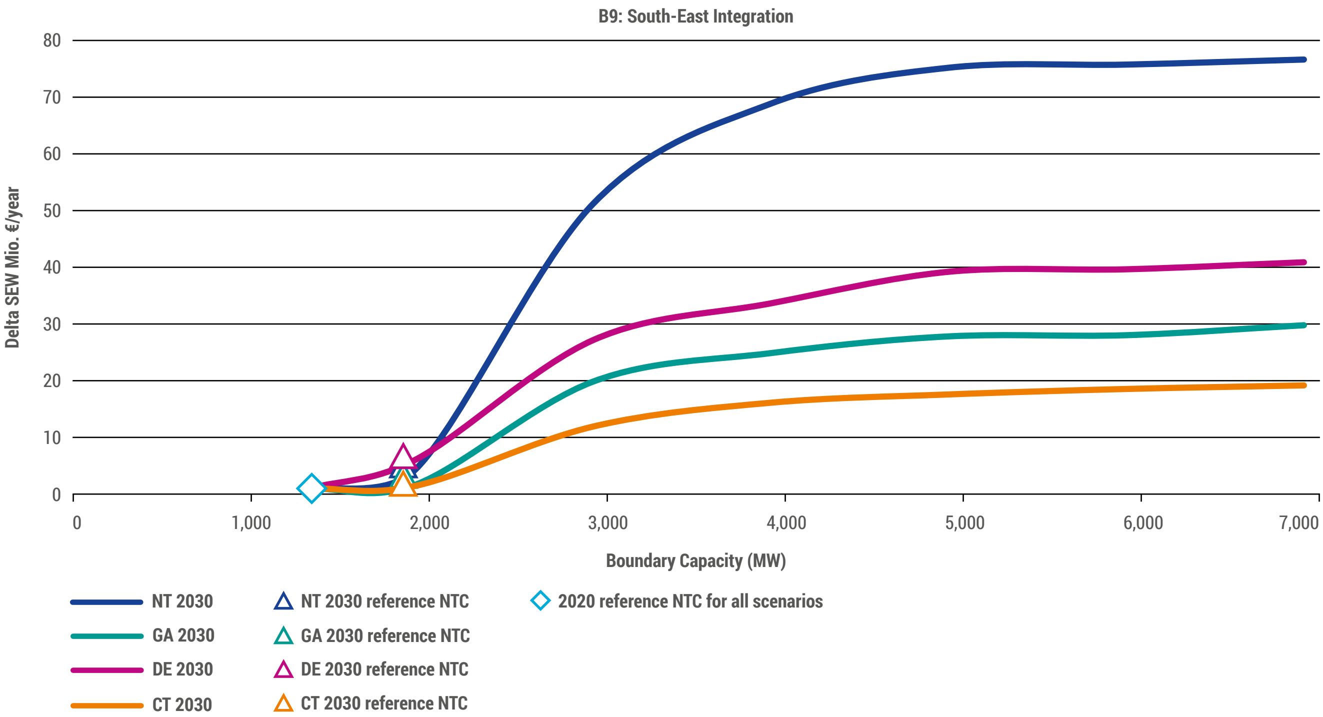


Figure 3.15 – Increase in socio-economic welfare when the transmission capacity increases from the current situation, on Boundary 9 South East integration, in all TYNDP 2020 scenarios for the 2030 horizon

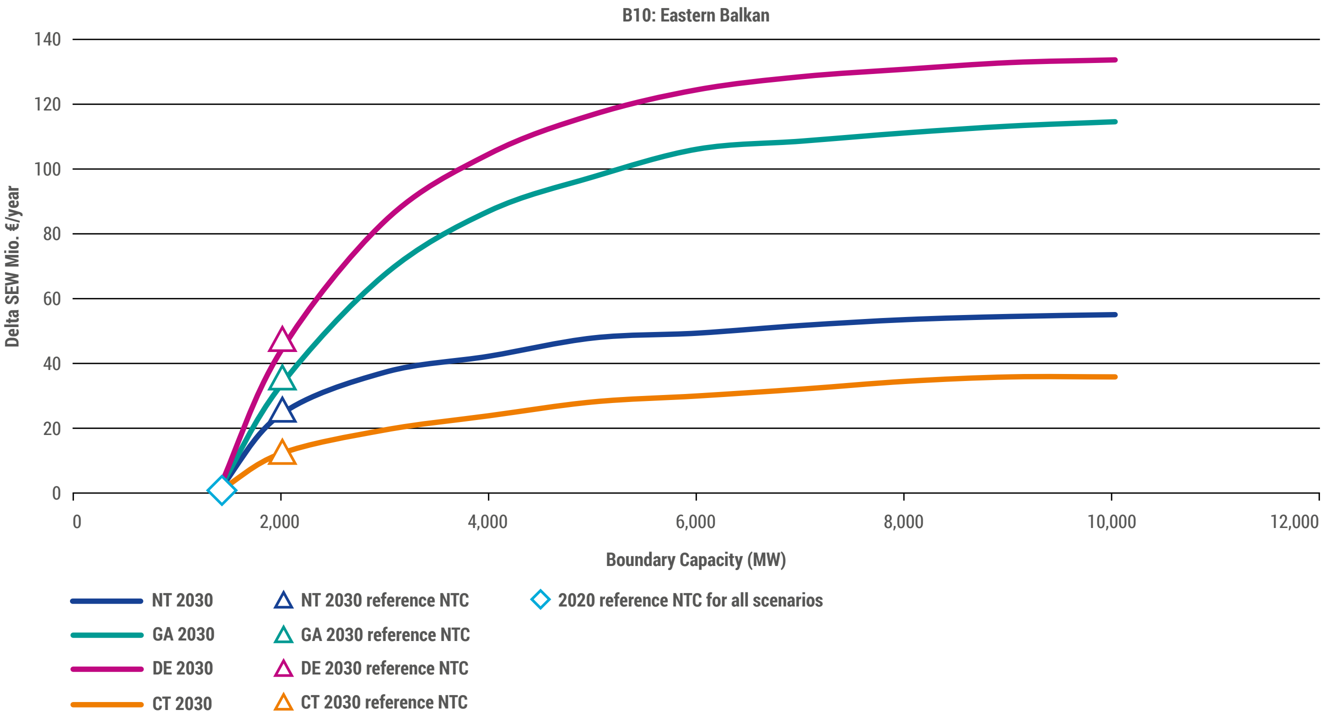


Figure 3.16 – Increase in socio-economic welfare when the transmission capacity increases from the current situation, on Boundary 10 Eastern Balkan, in all TYNDP 2020 scenarios for the 2030 horizon

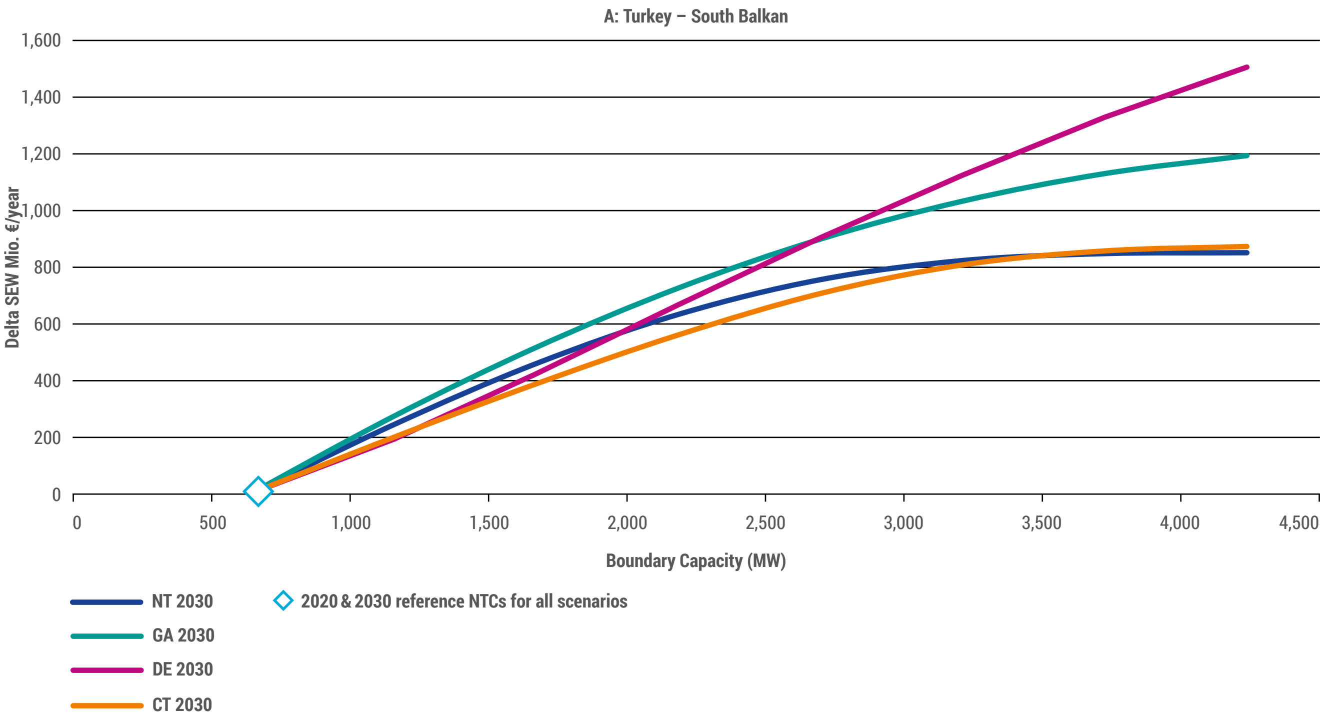


Figure 3.17 – Increase in socio-economic welfare when the transmission capacity increases from the current situation, on Boundary A Turkey-South Balkan, in all TYNDP 2020 scenarios for the 2030 horizon

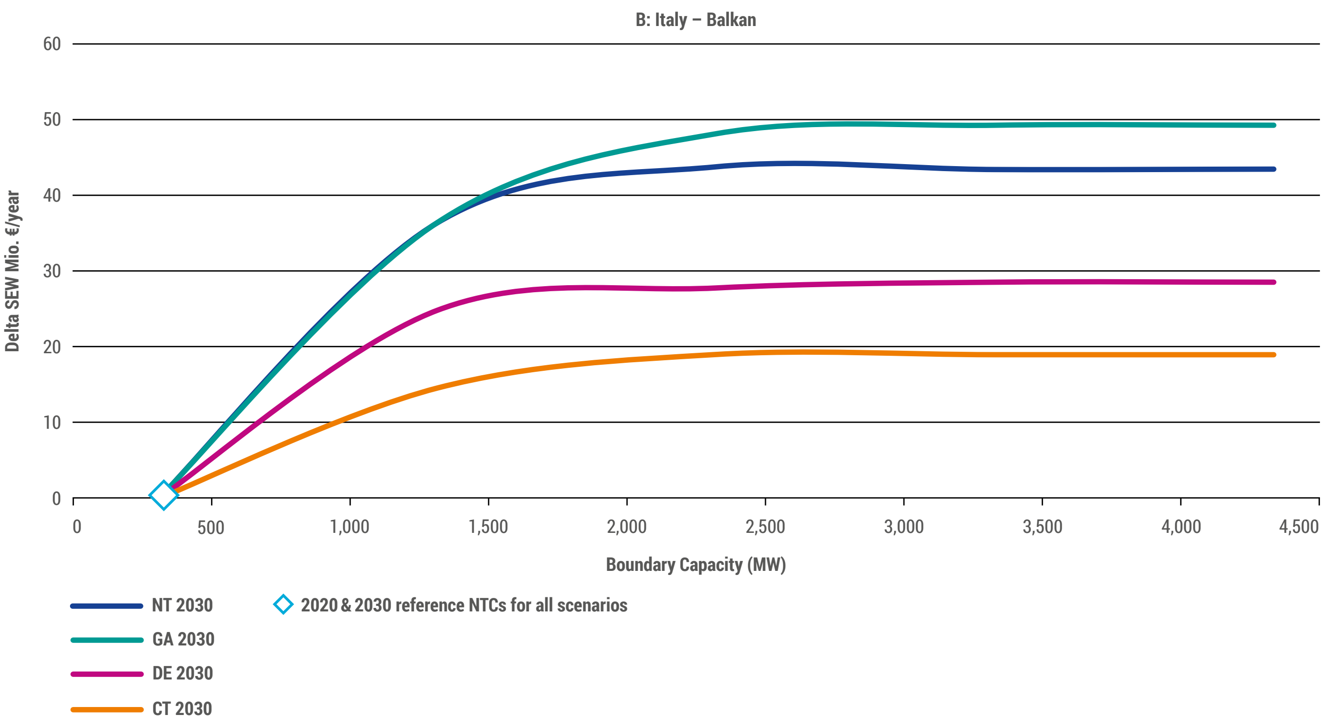


Figure 3.18 – Increase in socio-economic welfare when the transmission capacity increases from the current situation, on Boundary B Italy-Balkan, in all TYNDP 2020 scenarios for the 2030 horizon

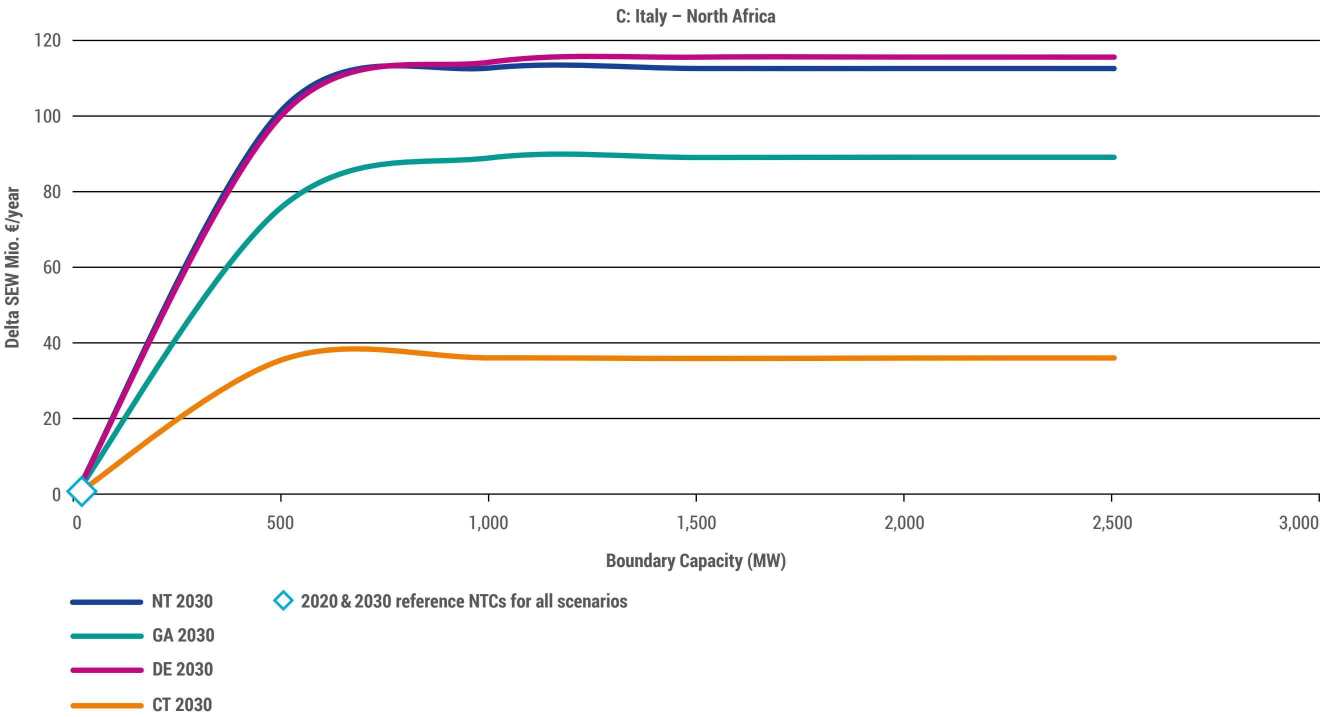


Figure 3.19 – Increase in socio-economic welfare when the transmission capacity increases from the current situation, on Boundary C Italy-North-Africa, in all TYNDP 2020 scenarios for the 2030 horizon.

Fulfilment of EU 2030 Interconnection Targets

In 2017, the European Commission Expert Group on Interconnection Targets (ITEG) proposed that the European Commission complement the existing 15 % interconnection target for every country and electrified island with a new methodology, developed collaboratively between the European Commission, ENTSO-E, ENTSOG, representatives of the industry, universities and other experts. The methodology is based on the TYNDP cost-benefit analysis methodology and is based on three concepts that aim at providing an indication of the urgency of increasing interconnections.

- an efficient internal energy market should translate into competitive electricity prices throughout the EU. Member States should aim at achieving a yearly average of price differentials as low as possible. Additional interconnections should be prioritised if the price difference between relevant bidding zones, countries or regions exceeds 2 € / MWh.
- peak demand will be met through the combination of national capacity and imports for every Member State. In case the nominal transmission capacity of interconnectors is below 30 % of their peak load, Member States should investigate options for additional interconnectors.
- the further integration of renewable energy sources will not be a combination of national capacity and imports for every Member State. In case the nominal transmission capacity of interconnectors is below 30 % of their RES installed, Member States should investigate options for additional interconnectors.

Figures 3.20. 3.21 and 3.22 show the results of the ITEG methodology applied for the TYNDP 2020 scenarios for the 2030 horizon, taking into account the existing grid in 2020. The computation of these indicators is based on a number of assumptions, including:

- the nominal cross-border capacity used to compute the indicators is based on the total physical capacities of all interconnectors, and does not include any restrictions based on system security criteria (such as mitigating possible overloads resulting from N-1 contingencies); and
- price differentials between bidding zones are limited to those for which either an interconnector currently exists or for which projects have been assessed as part of the CBA phase of this TYNDP. Therefore, they are not necessarily fully exhaustive.

Figure 3.20 shows that large price differential (> 2 € / MWh) appear for many European borders in National Trends scenario, which highlights the need for additional interconnection development beyond the existing interconnection grid. Regarding security of supply and RES integration criteria, the existing interconnection grid shows additional needs for interconnection development to be most urgent in Spain, Great Britain, Ireland, Italy, Finland and Norway.

Similar results are obtained for the Global Ambition and Distributed Energy scenarios, including Sweden to the list of urgent countries to analyse in the Distributed Energy scenario and Sweden and Greece in the Global Ambition scenario.

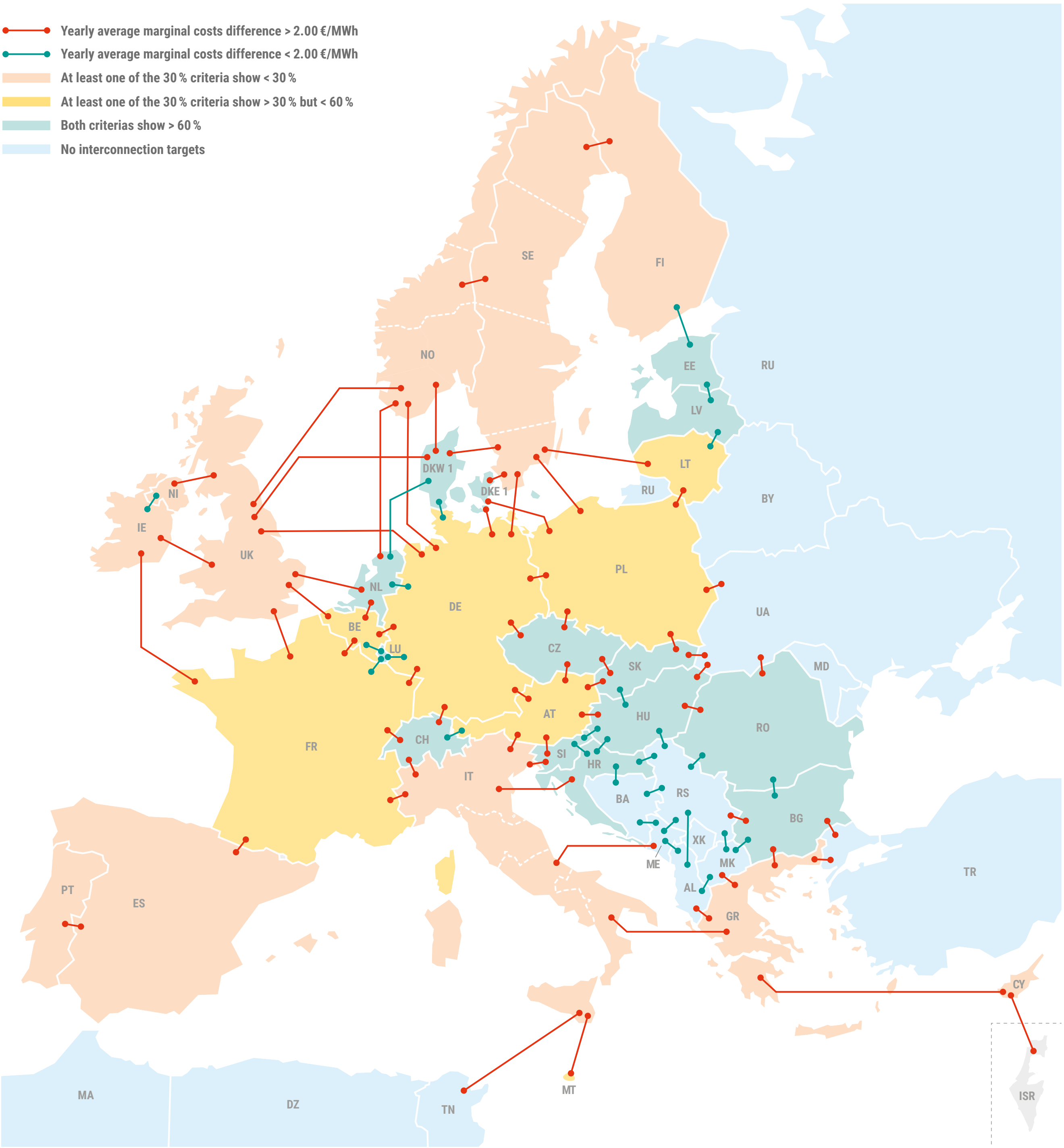


Figure 3.20 – ITEG indicators in 2030 National Trends, if Europe stopped all grid development after 2020

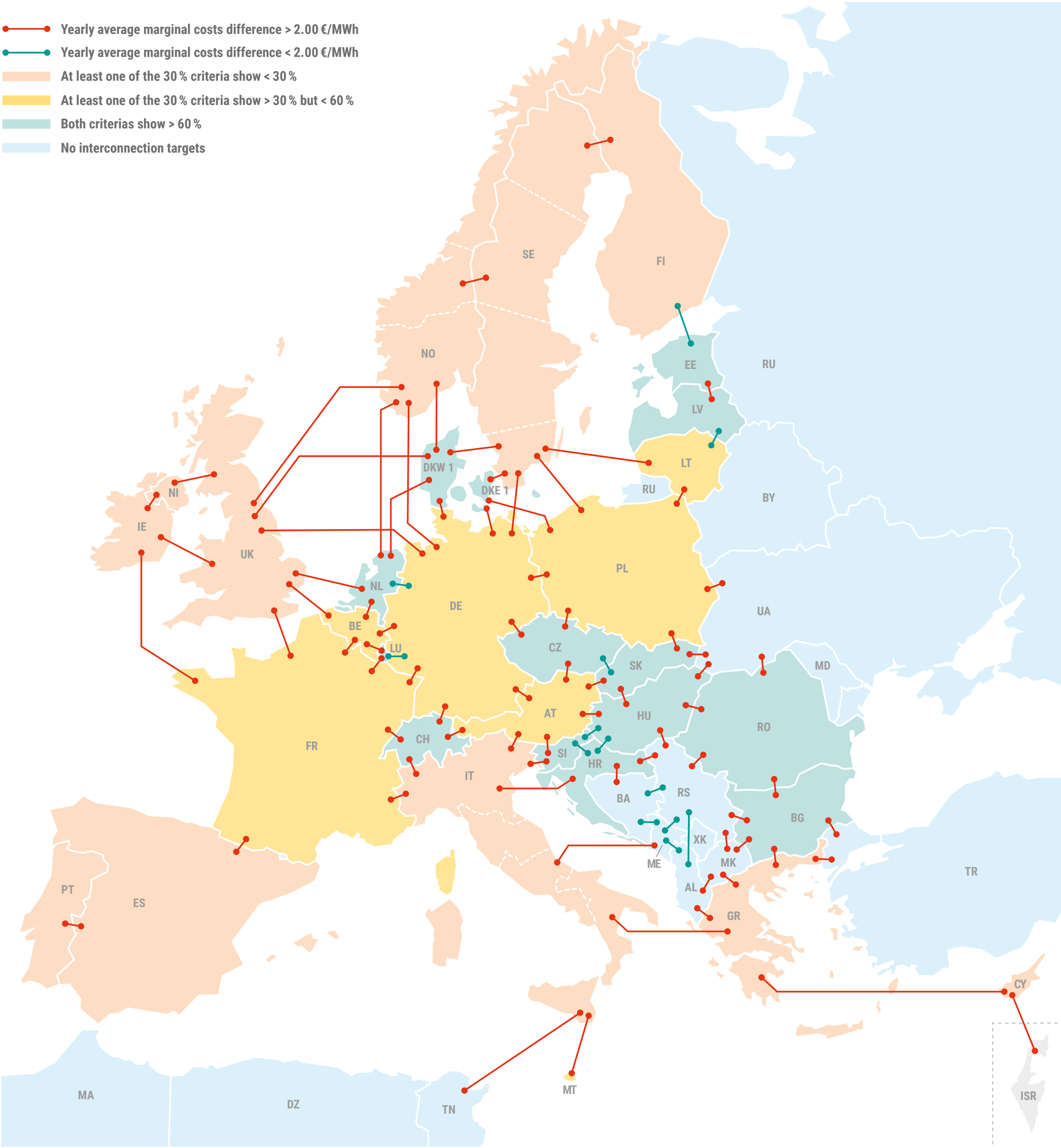


Figure 3.21 – ITEG indicators in 2030 Distributed Energy, if Europe stopped all grid development after 2020

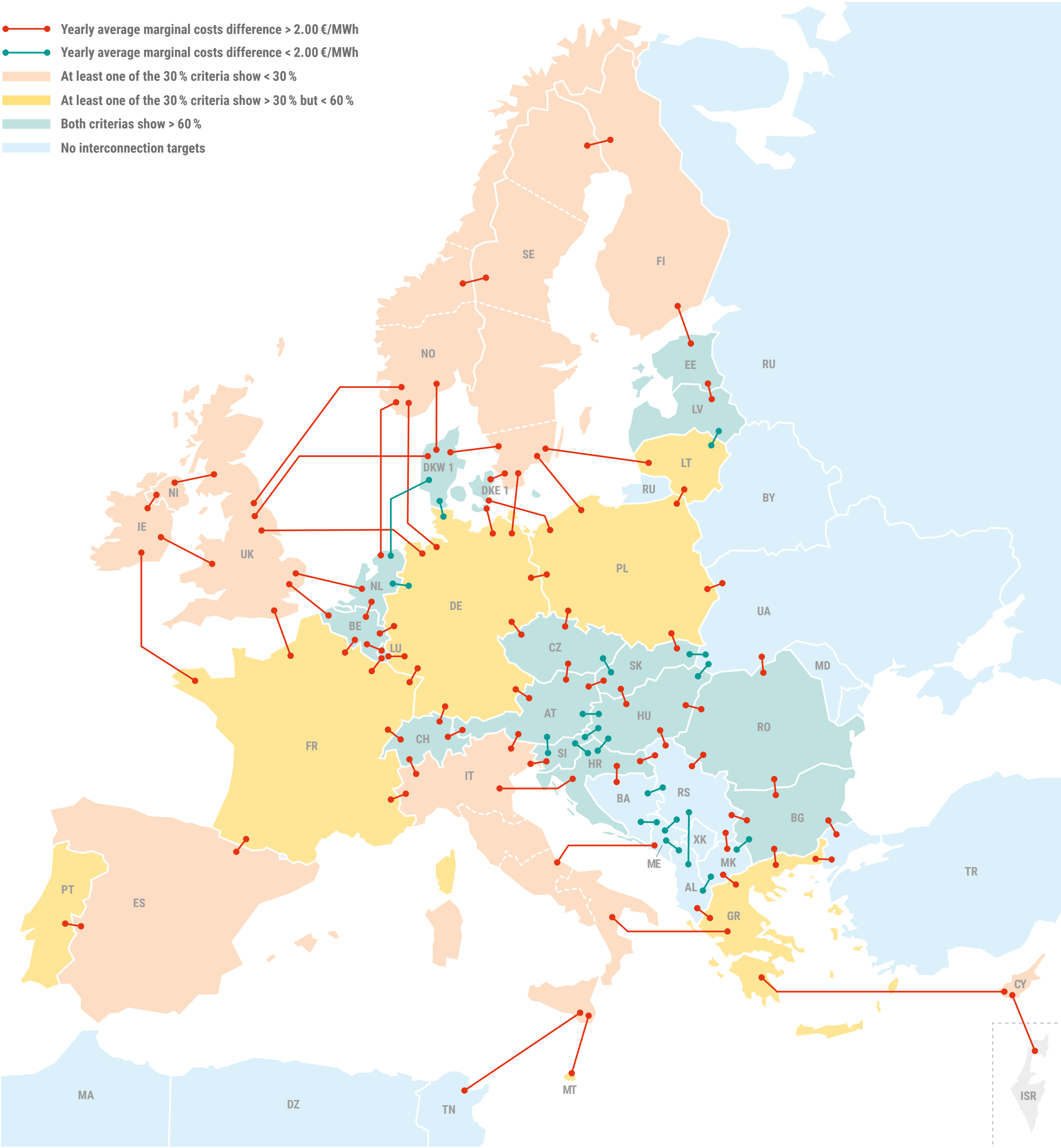


Figure 3.22 – ITEG indicators in 2030 Global Ambition, if Europe stopped all grid development after 2020

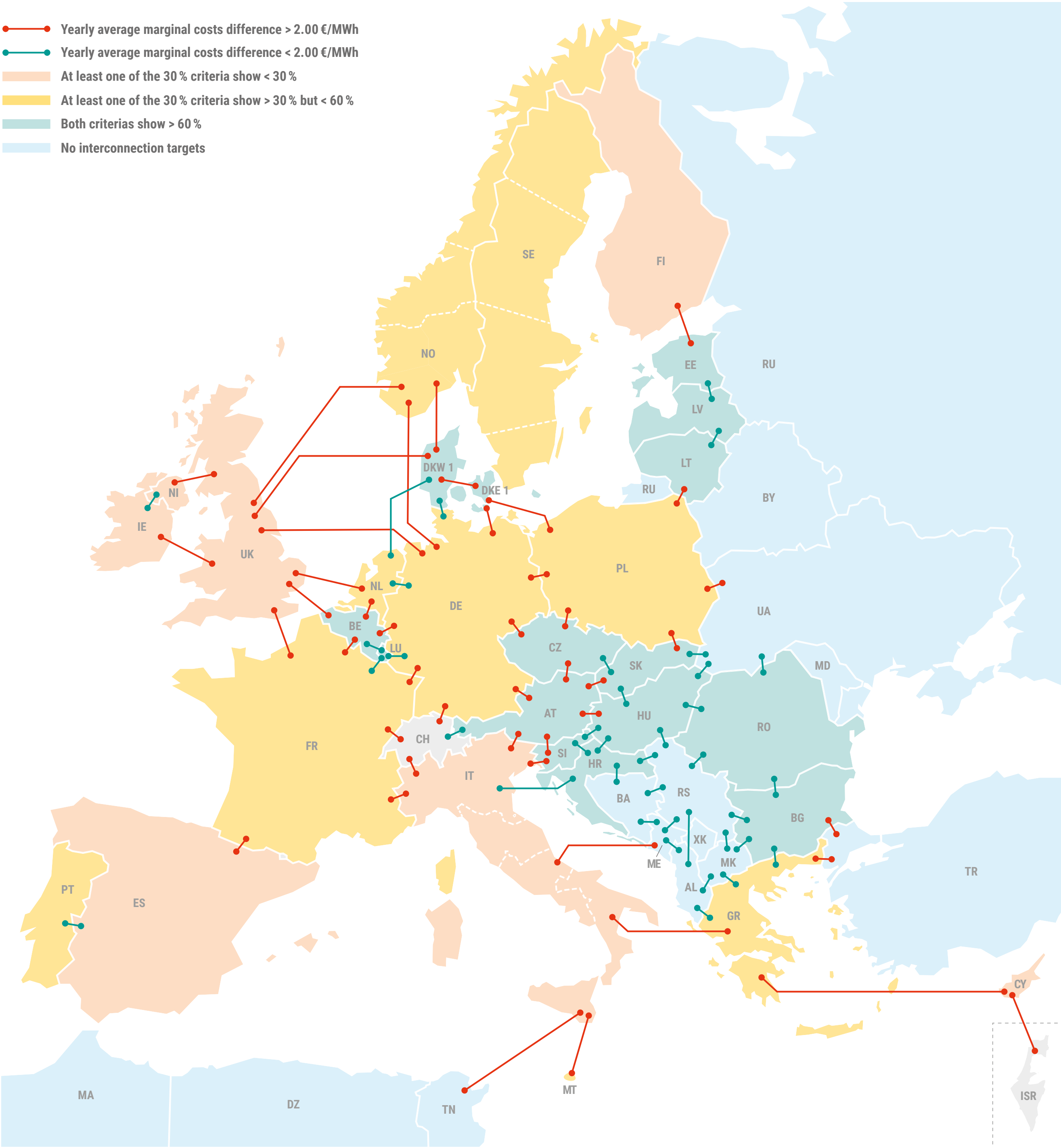


Figure 3.23 – ITEG indicators in 2030 National Trends, if Europe stopped all grid development after 2025

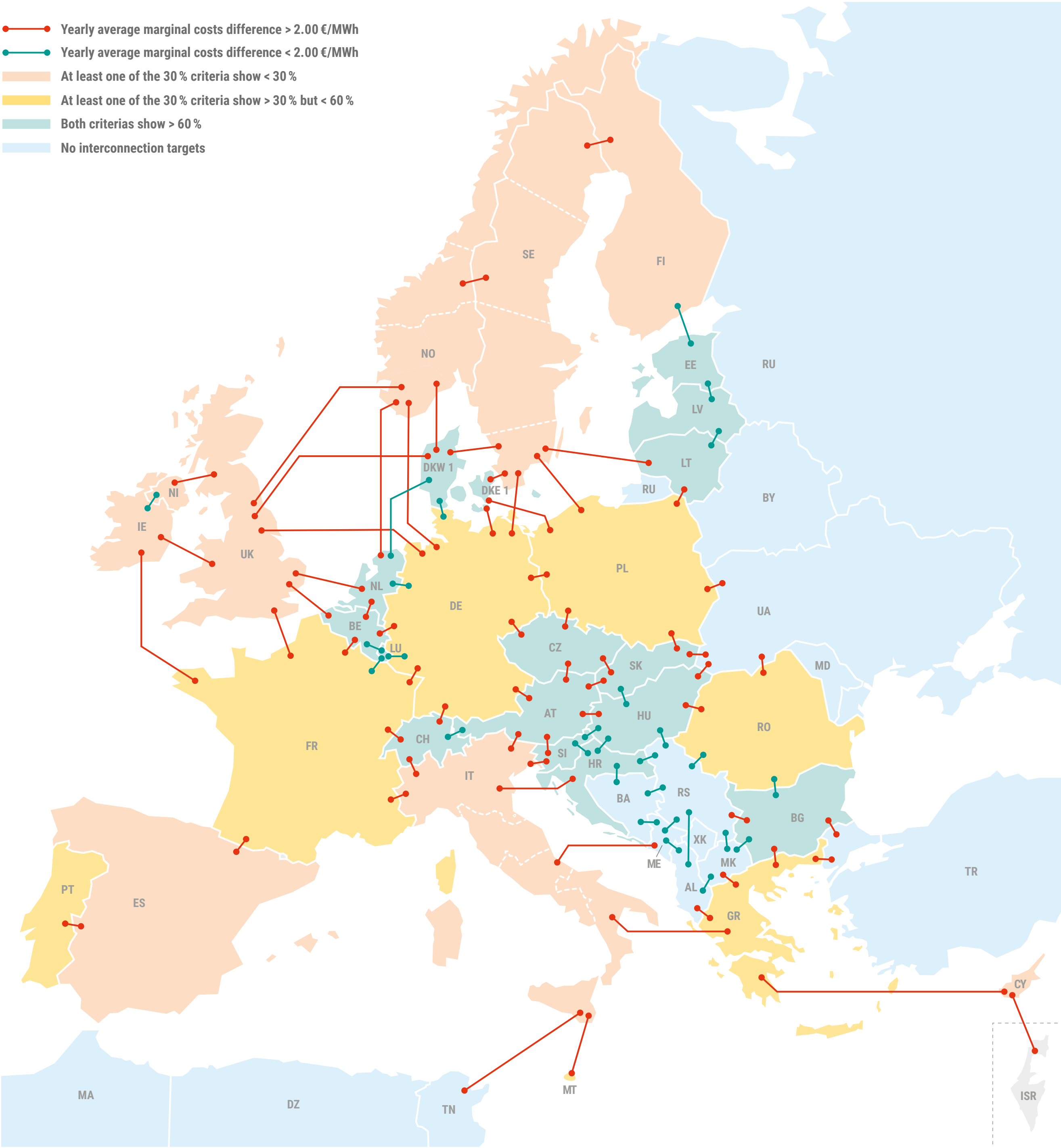


Figure 3.24 – ITEG indicators in 2030 Distributed Energy, if Europe stopped all grid development after 2025

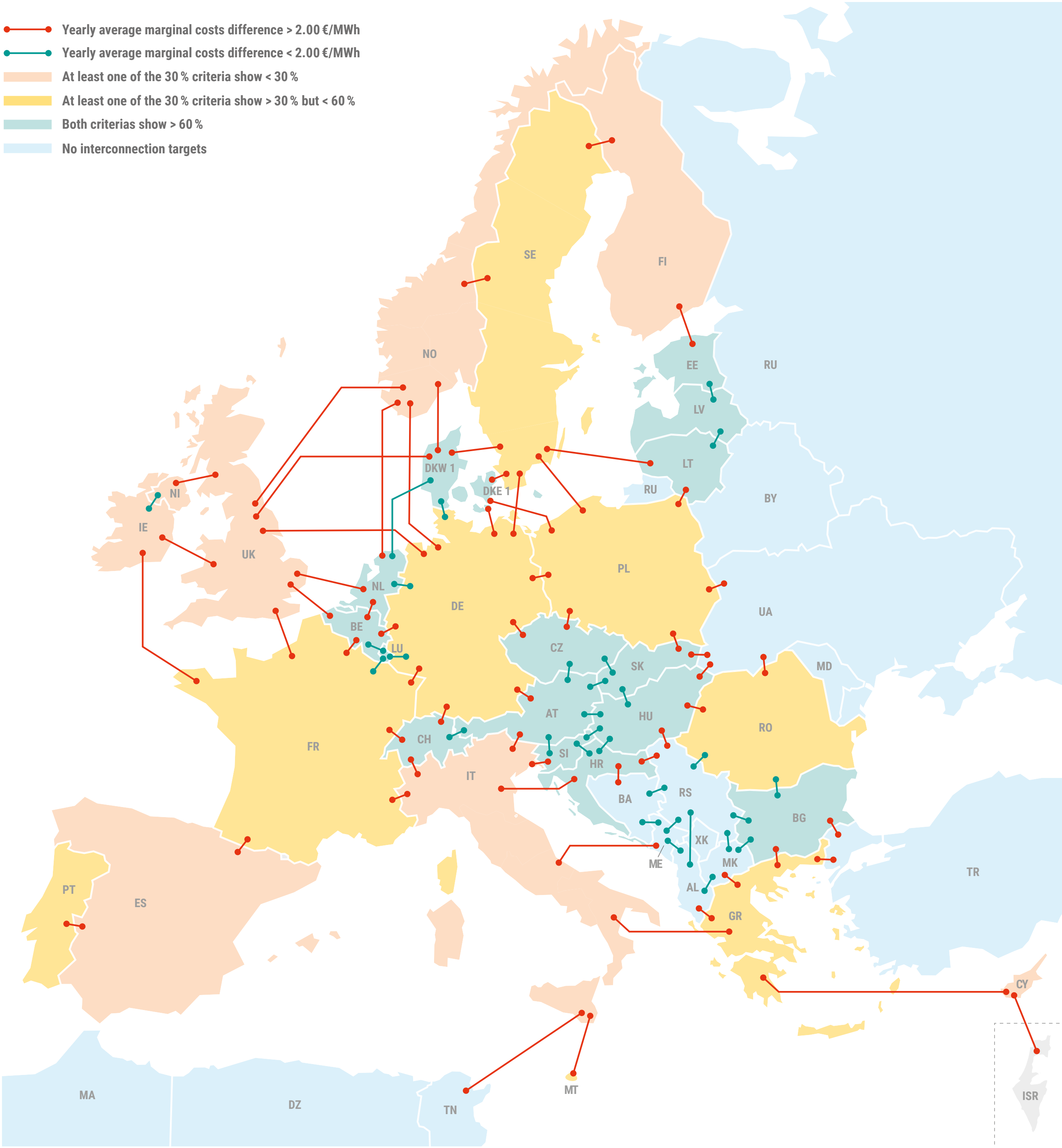


Figure 3.25 – ITEG indicators in 2030 Global Ambition, if Europe stopped all grid development after 2025

Ten years of TYNDP – the main needs addressed so far

Since the first release of the TYNDP, the European transmission system has evolved and many system needs have been addressed, while other needs have appeared for the long term horizon. TYNDP 2010 identified abolishing barriers to market integration and connection of new generation, especially RES, as the two main issues TSOs would have to face for the coming years.

Looking at the evolution of net transfer capacities and of import and export values of electricity since 2010 gives an idea of the barriers that have fallen so far.

2010

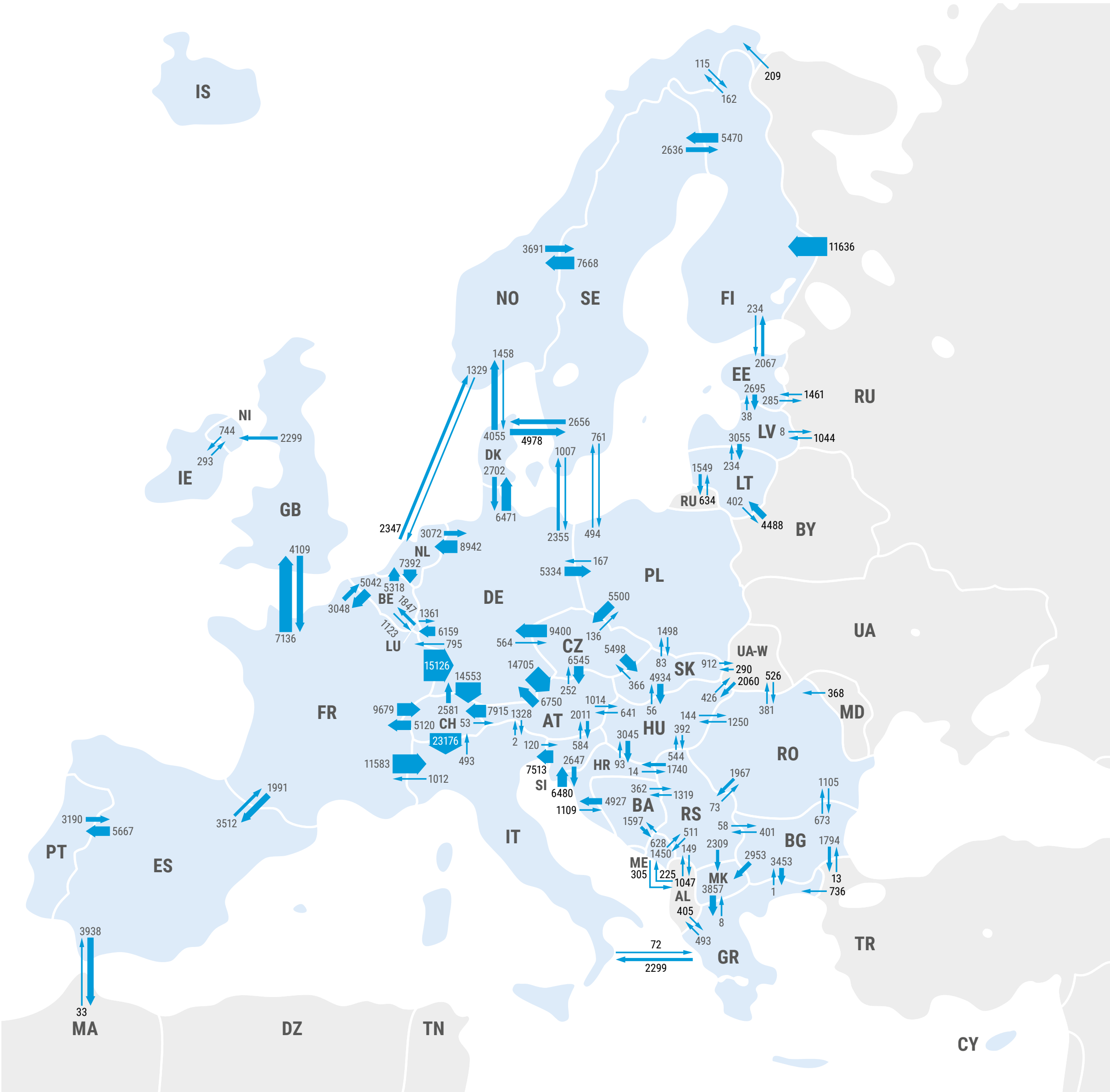


Figure 3.26 – Physical energy flows in GWh in 2010

2018

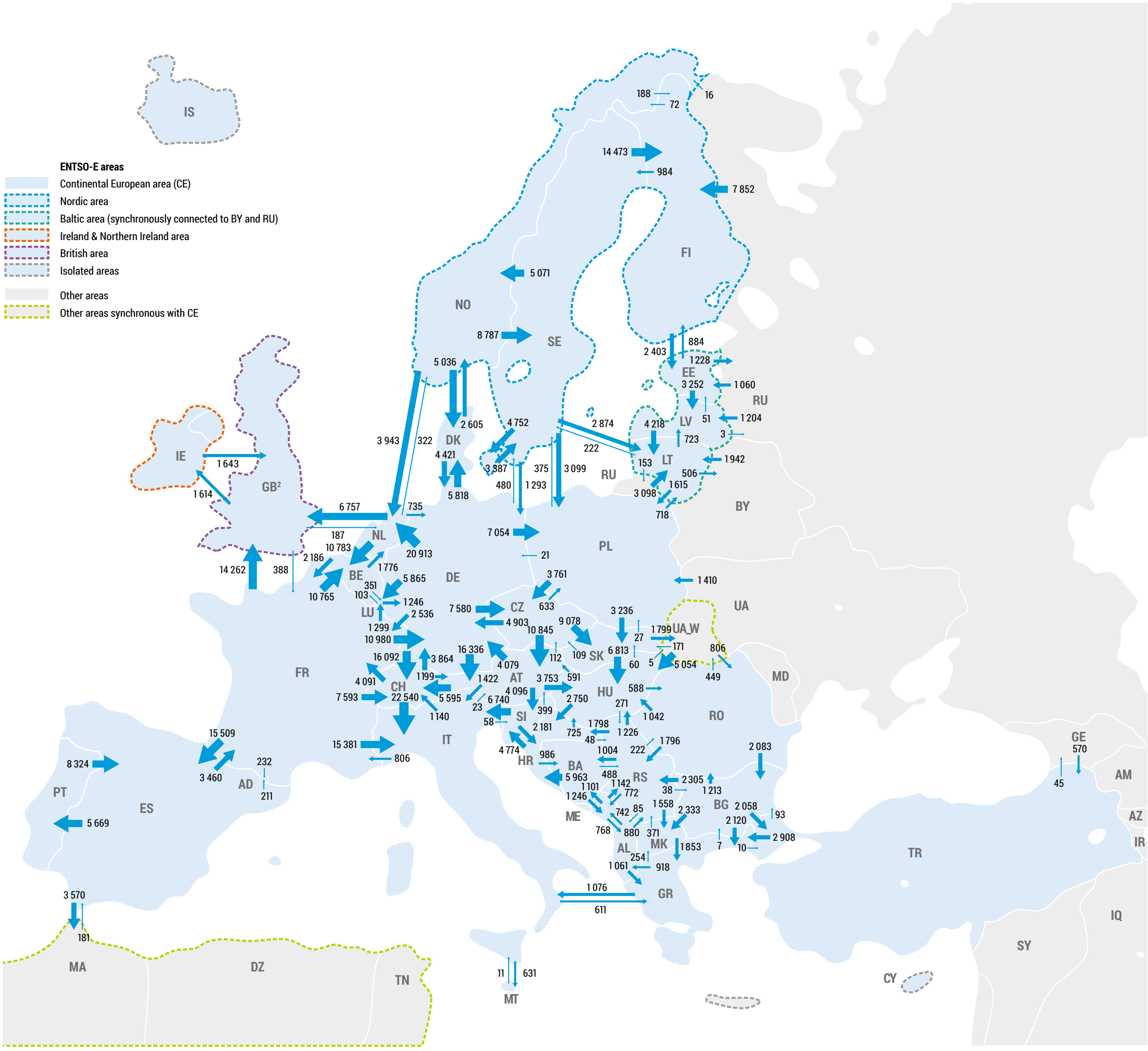


Figure 3.27 – Physical energy flows in GWh in 2018

- The exchange capacity between Great Britain continental Europe was expanded. The need to address major expected power flow between GB and the Continent was already identified in the TYNDP 2010, which pointed out the insufficiency of the transmission capacity on this boundary. Not visible in Figure 3.27, a new interconnector linking the UK to Belgium that commissioned in 2019 further expands capacity.

- Lithuania's connection to Poland via the LitPol link, a PCI included in the first list in 2013, allowed the Baltic states to begin closing a gap in the European transmission network and taking the first steps to achieving energy independence from Russia and synchronization with the Continental Europe area. The interconnection between Lithuania and Poland was identified as a short- and long-term investment need in the TYNDP 2010.

- The flows through the Pyrenees have increased almost 5 times from France to Spain. The Eastern Interconnection, a PCI included in the first list in 2013 and part of the TYNDP 2010, allowed to increase transfer capacity and reduce partially the isolation of the Iberian Peninsula. However, needs still remain in this border.

- Needs on Northern Italian borders have been in part addressed since TYNDP 2010, reinforcing cross-border connections and increasing energy import to the North of the Italian peninsula. However, further interconnections will be necessary for the integration of the Italian Peninsula interconnection of the main islands (Sicily, Sardinia and Corsica) with the mainland.

- Power flows across Germany's border to all neighboring countries increased substantially in both directions, as Germany was and still is the primary transit corridor of continental Europe. In Germany alone, 34 TYNDP investments have commissioned since 2010 to either connect RES generation, strengthen Germany's internal network or, for three investments, reinforce exchange capacities to France, the Netherlands and Belgium.

- Power flows with North Africa has been quite stable as the only interconnection between Spain and Morocco has not evolved and flows remain from North to South with similar values. However, in future, to achieve EU climate goals, investments on this boundary can be effective means to promote the energy transition, integration of renewables, security of supply, as well as regional and local socio-economic welfare and economic cooperation.

4 A closer look at offshore grid infrastructure

The EU's energy system is currently undergoing an unprecedented transition at an unprecedented time. To achieve European energy targets and the Paris Agreement, decarbonisation of the electricity sector by 2040 and climate neutrality by 2050 are required. This chapter provides some information related to the currently planned offshore infrastructure projects, comprising the projects submitted to the TYNDP2020.

Today, 22.1 GW of offshore wind capacity is installed in European waters. A huge boost in investment is needed: 2030 estimates reach 100 GW, while 2050 estimates vary between 230 to 380 GW (EC) and 450 GW (WindEurope). The bottom-up scenario based on the National Energy and Climate Plans foresee 78 GW – 131 GW in 2030 and 2040 respectively together in all European waters, with most installations being expected in the Northern Seas[6]. These investments come with their own set of challenges regarding regulatory frameworks, market design and research and Innovation, which must all be addressed to accelerate the integration of offshore renewable energy generation.

Offshore wind will play a major role in decades to come, as it has high availability rates and higher public acceptance than onshore wind, together with falling cost-curves. However, time pressure is high, as not providing the offshore wind generation and necessary infrastructure will lead to missing the European carbon-neutrality targets.

In response to the aforementioned challenges, TYNDP 2020 assessed 43 offshore transmission projects (including interconnectors, offshore generation connection and hybrid projects), which represent almost a third of the total transmission project portfolio. It also assessed one offshore storage project. As illustrated in Figure 4.1, the submitted offshore transmission projects vary in their scale and year of commissioning, adding up to 65.6 GW of transmission capacity to be commissioned in the period 2020 to 2035[7].

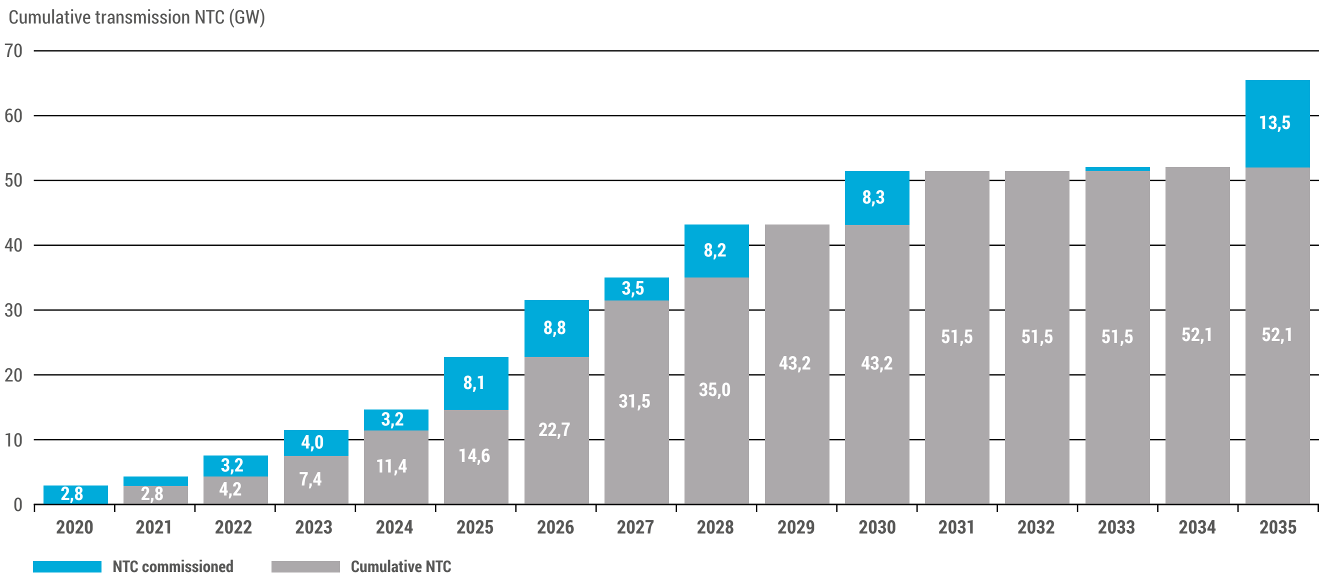


Figure 4.1 – Figure 1 NTCs of offshore transmission projects accounted in the TYNDP 2020. The grey bars represent the cumulative NTC (GW) while the blue bars account for NTC commissioned in the observed year.

6 The Northern Seas comprise the Irish Sea, The English Channel, The North Sea, Skagerrak and Kattegatt.

7 The following project IDs have been considered: 36; 110; 309; 167; 219; 247; 286; 190; 293; 153; 170; 284; 176; 283; 16; 1040; 120; 121; 1048; 179; 260; 267; 1034; 1042; 234; 239; 37, 1051, 1050, 1049, 285, 172, 349, 107, 296, 16, 299, 339, 29, 28, 338, 1041, 1055

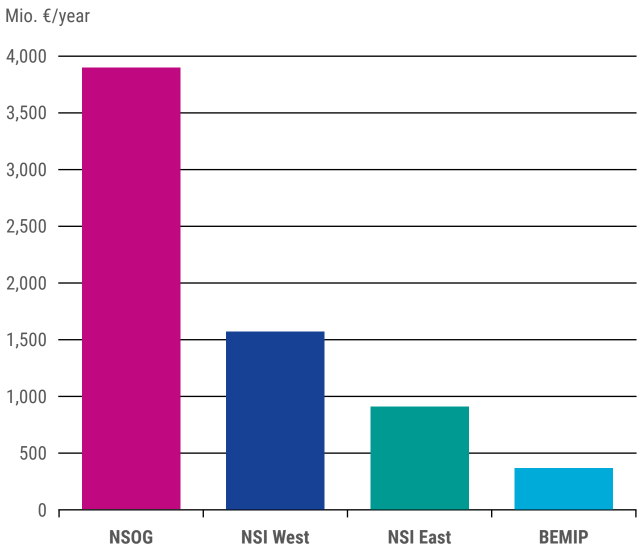


Figure 4.2 – Distribution of the increase in socio-economic welfare (Mio. € annually) among the four PCI corridors

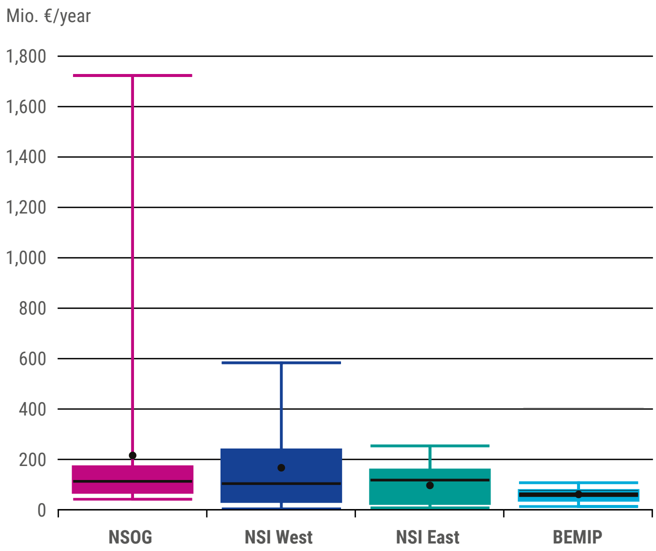


Figure 4.3 – Whisker chart to illustrate the SEW distribution among the four PCI corridors

These 65.6 GW translate into an increase in socio-economic welfare of 6,180 Mio. € [8]. Allocating these projects to the EC's PCI corridors results in Figure 4.2, indicating that most of the projects are in the Northern Seas, which is compliant with the expected development of offshore wind generation. Further investigating these four corridors leads to Figure 4.3.

For further information about the offshore grid, readers may consult the 2020 Regional Investment Plan of the Northern Seas region. This is the region with highest expected offshore development covering between 85 % and 88 % (2030/2040) of all European offshore capacities in the NT scenario, 95 % and 85 % for Distributed Energy Scenario (2030/2040) and 88/72 % for the Global Ambition scenario (2030/2040) respectively. Chapter 5 of that report covers the developments per country and scenario, describes potential basic design concepts and describes the limitations of the current methodology for hybrid project identification. Additionally, operational challenges are described, which already are seen today in some areas such as the Island of Ireland, will be seen sooner or later in the bigger systems as well, as the relation of variable-RES to peak load increases in all countries. A CBA analysis of all projects currently in the pipeline by 2030 and crossing the Northern Seas waters is provided in that report. The main results are:

- Economic benefits between 1.4 bn and 1.6 bn annually (total CAPEX of 65 bn €)
- Additional Res integration between 13.5 TWh and 19.2 TWh per year.
- Reduction of CO_2 emissions between 12,260 Mt and 15,900 Mt.

8 The 6,180 Mio Euros increase in socio-economic welfare is an average of the scenarios National Trends, Global Ambition and Distributed Energy

5 The Current Trends sensitivity

Requested by ACER, the Current Trends sensitivity considers a future with low economic growth, which leads to restrictions in meeting EU climate targets. In this context, national subsidies are limited and not a viable alternative due to financial pressures. There is scarcity of global financing for new RES developments because there is not a strong Emission Trading System price or subsidies available, and delays occur in many projects. In essence, society has less money to contribute to the energy transition.

Current Trends is built based on TSOs data. The lowest ranges for variable renewables are used, whereas the highest are taken for thermal. Hydro, Other RES, Other non-RES, DSR and Batteries remain all consistent with the National Trends 2030 scenario. Furthermore, new demand profiles were created by using the lower trajectories for electric vehicles and heat pumps. The evolution of technologies is also assumed to stagnate, therefore data from 2018 is used for wind and solar load factors.

What does Current Trends mean for the energy sector?

Transport sector

Oil and hybrid technologies are still used in passenger transport because gas and electric vehicle uptake is slow and subsidies are not sufficient. Heavy goods transport and shipping relies on oil and gas using internal combustion engines. However, domestic biogas and biofuels production as well as imports of carbon-neutral gases and liquid fuels increase, which allows moderate decarbonisation of the transport sector. The total energy demand is only slowly decreasing.

Residential and Commercial sectors

Due to its low economic growth, Current Trends considers limited renovation and insulation rates or efficiency measures in the building stock. Hybrid heat pumps and gas-condensing boilers are the main technologies used in renovated or new dwellings, replacing inefficient gas or oil boilers. The heat sector will still reach considerable reduction of CO_2 emissions due to the high decarbonisation of the power sector and, to a lesser extent, to the introduction of green gases in the gas sector.

Industrial sector

Industrial energy demand is stable due to the low economic growth combined with some energy efficiency gains. Both electricity and gas replace fossil fuels emitting high emissions and therefore experience low growth.

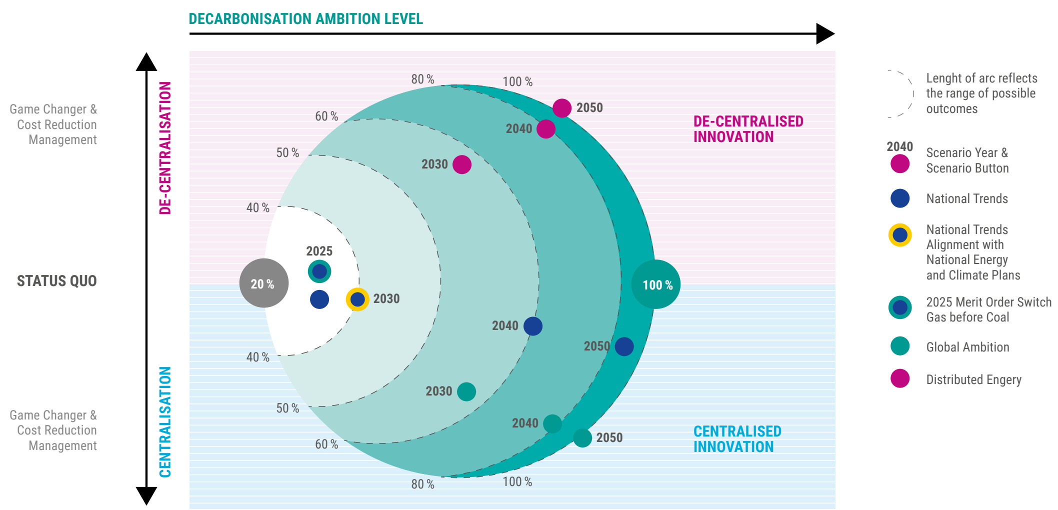


Figure 5.1 – Key drivers of scenario storylines, Current Trends appears in grey

Electricity and Gas Supply

Solar and wind still have the highest growth in generation, however national policies restrict the geographical location of technologies. The decreased funding for electricity transmission projects or their delayed implementation also holds back the potential for wind and solar generation development. Electricity storage sees low growth, and battery production and capability grow slower than anticipated. Thermal power generation continues at higher levels to compensate, with a slow policy-driven coal phase out and the extension of nuclear plant lifetime to maintain adequacy.

Development of renewable gases is restricted, with limited support for biomethane and a lack of renewable generation to support synthetic gas production. Power-to-Gas is slow to develop at scale and is mainly used for storage. Still, the gas supply experiences some level of decarbonisation by the substitution of natural gas by carbon-neutral gases such as biomethane, synthetic gases or hydrogen from Power-to-Gas and imported green gases.

The increase in socio-economic welfare achieved by TYNDP 2020 projects in Current Trend 2030 is in general lower than in the other 2030 scenarios, because of the less advanced energy transition. The lower RES generation reduces the opportunity to replace expensive marginal generation by cheaper one and therefore reduces the economic benefit from infrastructure projects.

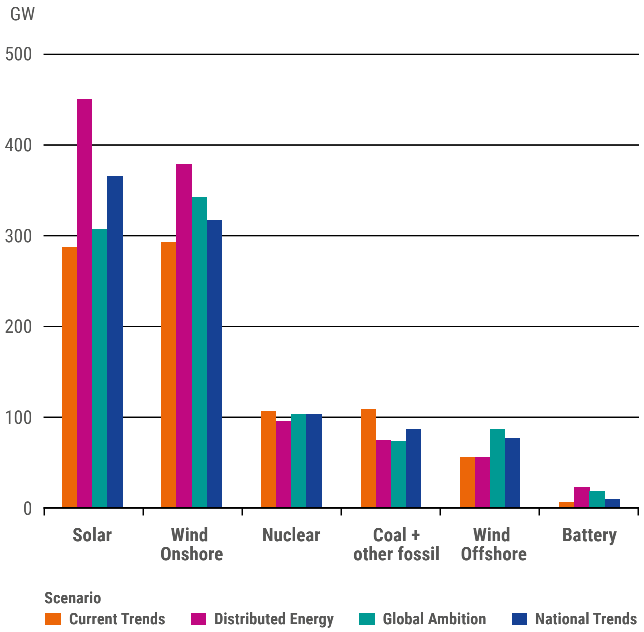


Figure 5.2 – Installed capacities in GW for Current Trends 2030 per generation technology

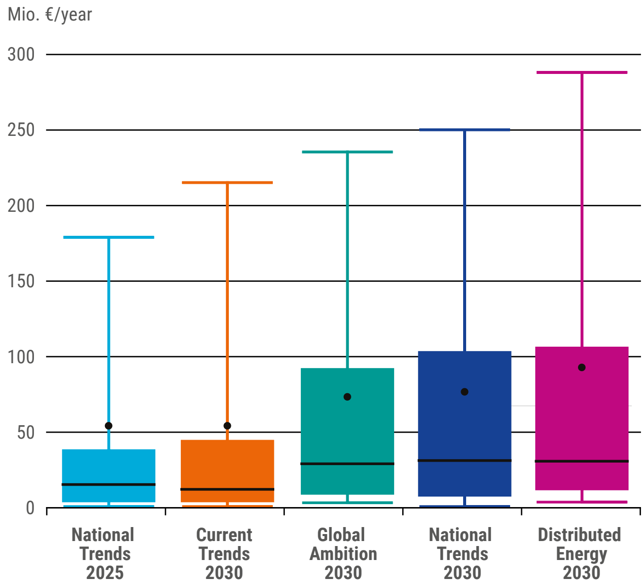


Figure 5.3 – Distribution of the increase in socio-economic welfare of all projects in the TYNDP 2020 scenarios including Current Trends (in M€/year)*

* The lowest bar represents the 5th percentile, the bottom of the box the first quartile, the black line the median, the top of the box the 3 quartile, and the highest bar the 95th percentile. The dot is the average.

6 Perspectives for 2050

The year 2050 seems a long way off. Yet, the mid-to long term economic and environmental consequences of not investing in our energy system, exposed in the System Needs and Scenarios reports, leave no doubt that the energy system of tomorrow is a priority of today.

Since the endorsement of the Paris Agreement in 2015 and recent communication of the European Green Deal, the discourse on the energy transition has grown more ambitious. The target to keep the increase in the global average temperature below 2 °C and achieving climate neutrality by 2050 will require EU member states to deliver more ambitious National Energy and Climate Plans. Indeed, based on current trends, a considerable share of the EU's remaining carbon budget would be worn out in the next 10 years.

The path towards decarbonisation

As scenarios Distributed Energy and Global Ambition show in Figure 6.1, a competitive, secure and decarbonised EU is possible and there is no silver bullet to get there. However, this objective places further demands on the speed of decarbonisation the energy system should reach.

Distributed Energy and Global Ambition show that both a centralised or decentralised evolution of the energy system can achieve carbon neutrality by 2050. The scenarios also show that, considering different development of technologies – and starting from 2018 onwards – the energy system can limit its emissions to reach not more than 64.2 $GtCO_2$ at EU level until 2050 in Global Ambition, and not more than 61.4 $GtCO_2$ in Distributed Energy. What implications does carbon neutrality have in the transition towards a fully decarbonised European energy system in 2050?

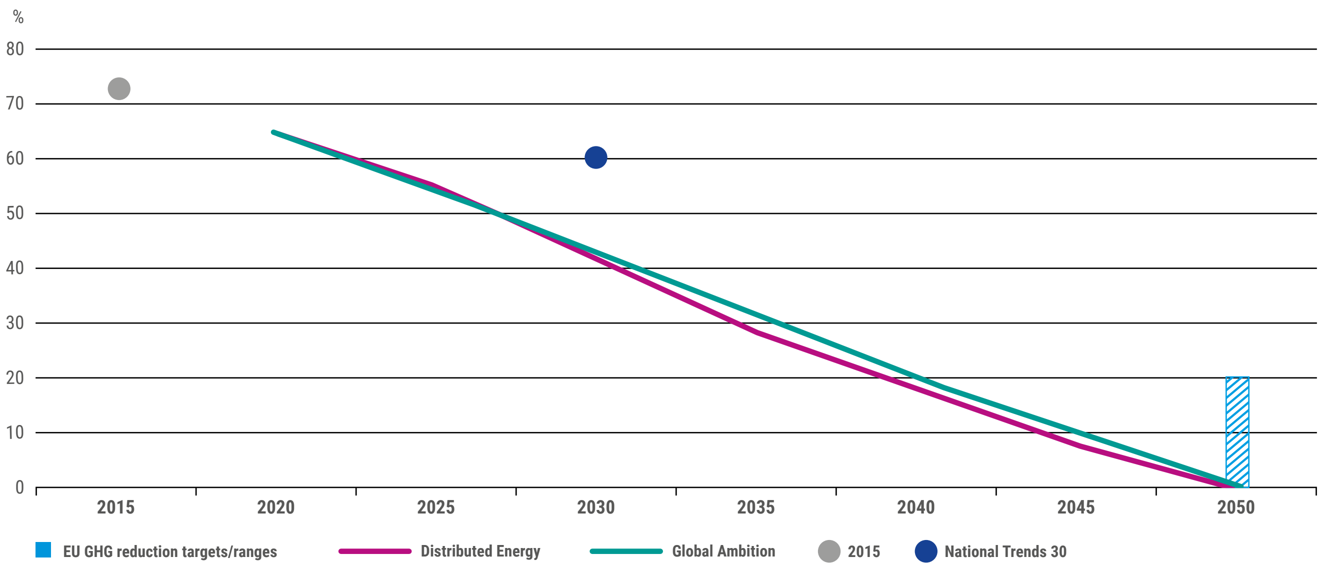


Figure 6.1 – GHG emission reduction pathway until 2050

The energy system in 2050

The vast majority of energy stems from renewables. In 2050, wind, solar and hydro cover roughly 52 % of primary energy demand in Europe within the scenario Distributed Energy and about 34 % in Global Ambition, while nuclear contributes between 6 and 9 %. Biomass and energy from waste materials contribute significantly – in Distributed Energy they cover 22 % and in Global Ambition 28 % of the primary energy mix.

The speed of decarbonisation runs even faster in the electricity sector, achieving 100 % decarbonisation in 2040 for both scenarios. Distributed Energy is the scenario with the highest investment in generation capacity, driven mainly by the highest level of electrical demand. Distributed Energy mainly focuses on the development of solar PV. This technology has the lowest load factor, as a result installed capacity of solar PV will be higher compared to offshore or onshore wind to meet the same energy requirement. The scenario shows a larger growth in onshore wind after 2030. Global Ambition has a lower electricity demand, with a general trend of higher nuclear and reduced prices of offshore wind. Consequently, the capacity required for this scenario is the lowest as more energy is produced per MW of installed capacity in offshore wind.

Biomass can be directly used in industrial processes, or as feedstock to produce biofuels or biomethane – both can be used in all sectors, with a main focus in power generation, transport and heating. Because coal is assumed to be phased out in Europe by 2040, the remaining demand is covered by oil, nuclear and gas imports. The increase in renewable energy production results in declining "all-energy" import shares, from 55 % to 60 % nowadays, to ca.18 % in Distributed Energy and 31 % in Global Ambition.

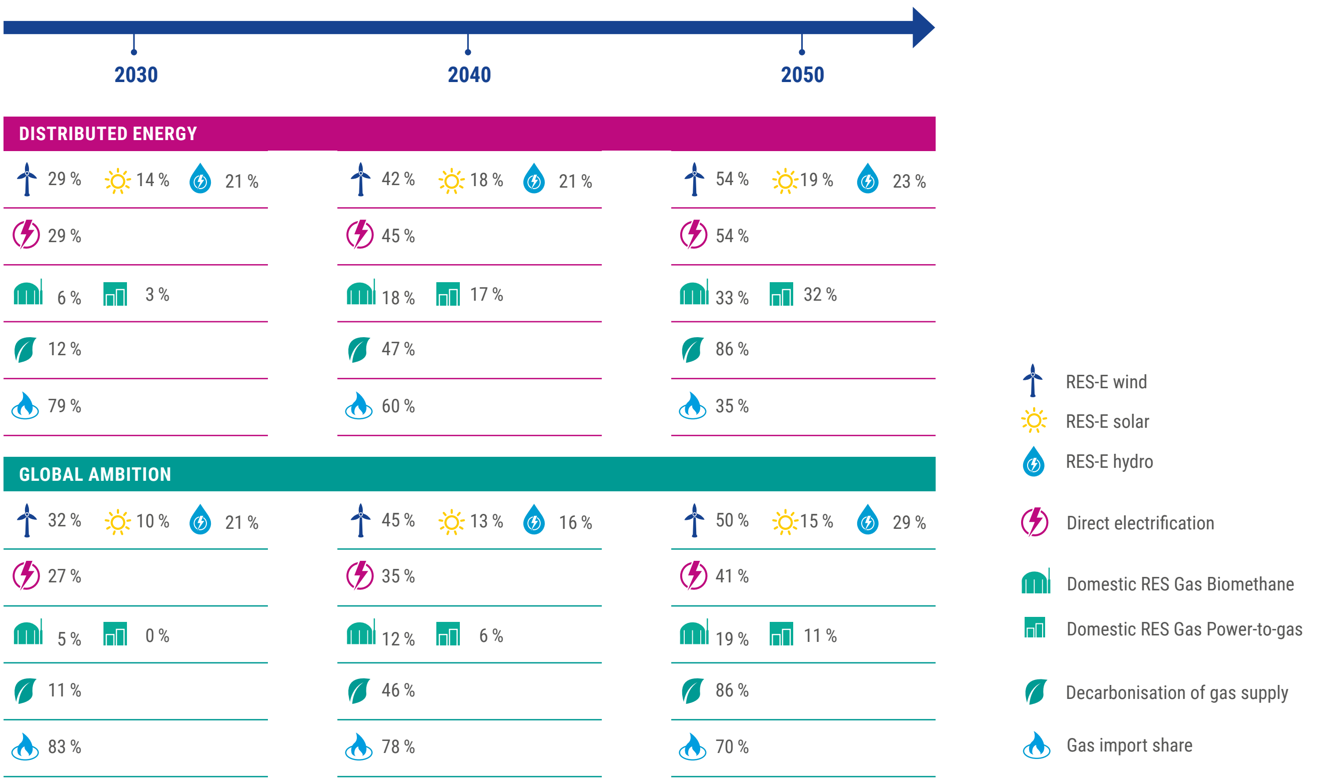


Figure 6.2 – Key parameters of the scenarios Distributed Energy and Global Ambition

The role of smart sector integration

Sector integration enables a link between energy carriers and sectors, thus it becomes key in achieving the decarbonisation target. In the long-term, Power-to-Gas and Power-to-Liquid will play a key role in the integration of electricity from variable renewables and in decarbonising the supply of gas and liquid fuels. This would require close to 800 GW of dedicated wind and solar in 2050.

Coordinated multi-sectorial planning and operation is in line with a one energy system view, a view of all sectors in the European economy in order to ensure an affordable, effective, and efficient transition. To be able to fulfil the requirements of coordinated planning under a one energy system view, ENTSO-E released in 2020 its Roadmap for multi-sectorial Planning Support.

The Roadmap will serve as an umbrella for infrastructure planning activities, ensuring consistency in the pathways for decarbonisation and finally contributing to efficient decision-making for policy makers and actors in the European economy.

This will ensure consistent pictures of possible futures between sectors, by providing consistent scenarios / pathways for decarbonisation, including an overall set of assumptions considering cost assumptions, before infrastructures and assets are planned in detail. The use of the same and consistent scenarios across sectors is a key factor to maximise economic efficiency while avoiding stranded assets or infrastructure deficits.

After defining the scenarios, detailed investigations of individual energy systems are still to be performed sector-independently, taking into account their specificities, see Figure 6.3. This means, for example, that during the "identification of system needs" phase, corridors where energy is transported from one node to another node will be identified. After this phase, project promoters could submit their projects to ENTSO-E or ENTSOG's respective TYNDP processes. Afterwards, projects enter further project assessment phases.

ENTSO-E is convinced that, through the implementation of this roadmap, it will deliver a more comprehensive overarching view on the energy system scene that will translate into improved quality of results delivered to decision-makers.

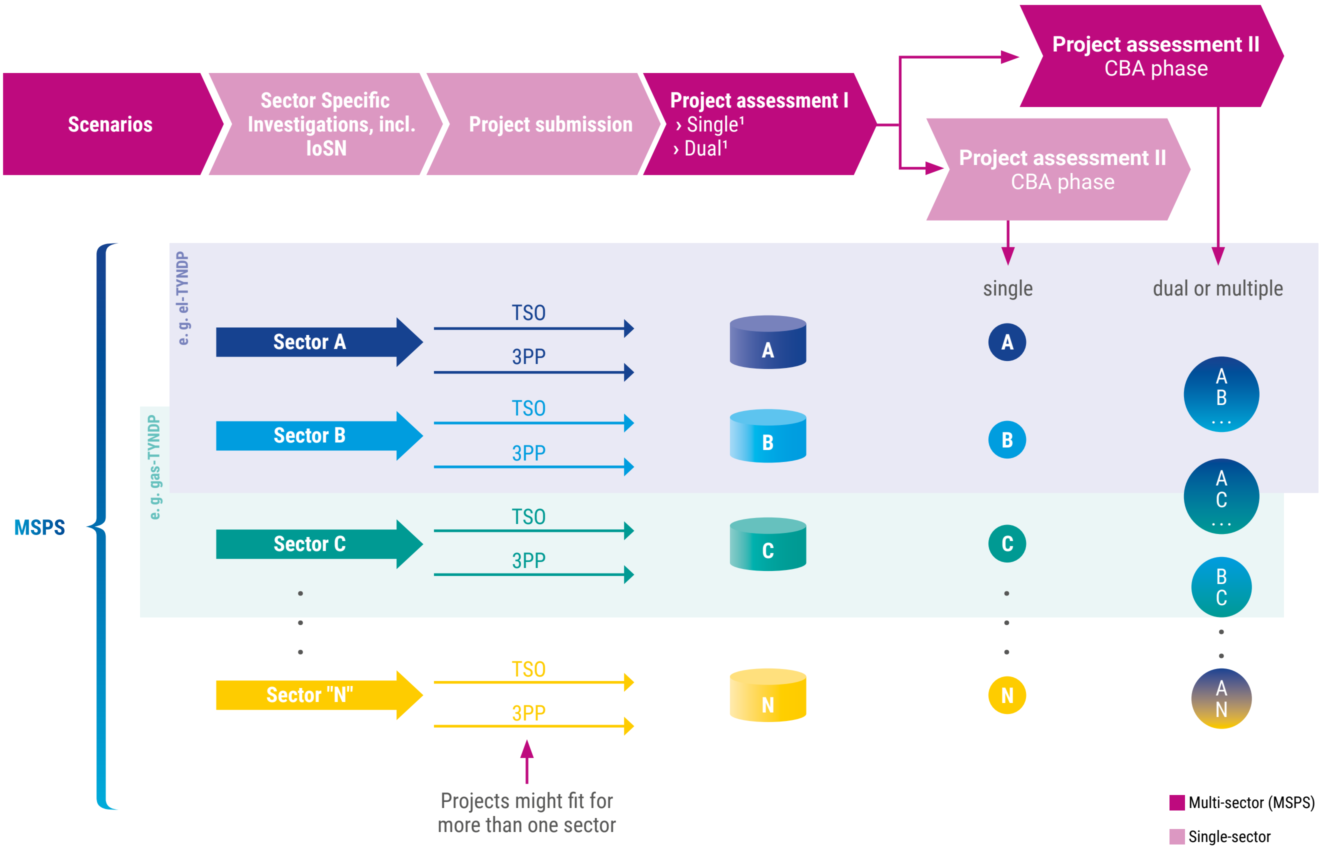


Figure 6.3 – Multi-sectorial planning support – various sectors under the MSPS umbrella

7 Continuous improvement of the TYNDP

The development of the TYNDP is a living and constantly developing process with the aim of better preparing Europe for an uncertain and complex electricity future. The main changes compared to TYNDP 2018 include:

- The methodology and scope of the System needs study have greatly improved compared to the previous System needs release, with the use of a zonal model for the 2040 horizon allowing for increased granularity of the results and the expansion of the scope to the 2030 horizon with a Net Transfer Capacity model.

- The CBA 3.0 was applied for the first time in the TYNDP 2020. Co-developed with stakeholders, it builds on CBA 2.0 and implements a number of improvements. For the first time in the TYNDP, the guidelines also formally consider project-level benefits i.e. benefits that cannot be computed at the pan-European level because there is no agreed-upon methodology. The guidelines outline methodological principles that promoters need to follow. This ensures consistency between promoters' various assessment tools and pathways. These benefits have been computed by project promoters and are published in the project sheets.

- Like in 2018, scenarios were developed jointly with ENTSOG and co-constructed with stakeholders. Improvements in the TYNDP 2020 scenarios include:

  a) the introduction of a carbon budget as an input to the COP21 scenarios Distributed Energy and Global Ambition;

  b) the development of an in-house energy model tool called the "Ambition Tool" allowing to better map the sectoral coupling and the associated interdependence between gas and electricity sector and to improve the methodologies to capture all GHG emissions and their development within a time period and thus ensure that the scenarios are in compliance with the Paris Agreement targets;

  c) several improvements to the modelling of electricity and gas generation and demand, and of Power-to-X

  d) the creation of an online platform to visualise scenarios data.

- The readability and user-friendliness of project sheets have been improved. New functionalities allow to filter projects per status, country, PCI Corridor, type of element of the main investment (for transmission projects), and storage technology.

Preparation of the TYNDP 2022 is already ongoing. Stakeholders comments during the public consultation phase will feed into discussion on the definition of the scope of the TYNDP 2022 and where to improve compared to the 2020 exercise. Possible improvements concern the assessment of needs for offshore infrastructure, especially hybrid infrastructure.

ENTSO-E is also working towards a multi-sector approach. The Multi-Sectorial Planning Roadmap released in July 2020 aims at improving the consideration of smart sector integration in the infrastructure planning process. The Roadmap will serve as an umbrella for infrastructure planning activities, to ensure coordination and consistency between pictures of possible futures developed by different sectors. It will be the starting point for system and sector development plans and focus on even more comprehensive and consolidated scenarios compared to today's joint scenarios of ENTSO-E and ENTSOG. The MSPS also identifies needs for dual or multiple-sector assessment of infrastructure projects, via a screening process. Projects that have relevant interactions with other sectors, or that compete with projects of other sectors addressing the same needs, will be compared through a transparent cost-benefit analysis. Implementation of the Roadmap will begin in the TYNDP 2022 and continue in future editions.

Appendices

Appendix 1 – About the CBA methodology

The CBA Guidelines[9] contain principles and high-level guidance on how ENTSO-E and project promoters assess project benefits at the European level. They do not provide specific methodological steps but are instead drafted such that entities performing the CBA (ENTSO-E or project promoters themselves for project-level benefits) can follow an approach that is consistent with pan-European assessment principles.

The Guidelines include terms and definitions, principles on how project benefits are assessed and also some specific methodologies used to compute, for example, the change in NTC a project offers or how redispatch calculations are performed.

The third Guideline is the result of the learning-by-doing principle ENTSO-E has employed in its broader TYNDP process development. The CBA Guideline ensures that there is consistency between all project assessments and dictate the inputs to the European Commission's Projects of Common Interest selection process. However, the CBA Guidelines can also be used by anyone interested in assessing transmission and storage investments slated for long-term grid development.

The CBA Guidelines utilised in this TYNDP cycle are largely based on the second edition, released in 2018 and is another step towards a more consistent TYNDP CBA methodology that should ensure more comparable results leading into the future.

TYNDP 2020 Methodology – Key documents

3rd CBA Guidelines
(Latest version: For ACER opinion, February 2020)

CBA implementation Guidelines
(Forthcoming)

TYNDP 2020 Implementation Guideline for project-level indicators

Power system Needs report – Chapter 7 Identification of system needs methodology

TYNDP 2020 Scenario Building Guidelines
(Final version June 2020)

For more information, the reader is encouraged to refer to the actual CBA Guidelines. For more detailed information on how to apply the CBA Guidelines in actual project assessment interested readers should read the Implementation Guidelines, that are published alongside this document.

CBA Implementation Guideline

2020 marks the first year ENTSO-E is releasing "CBA Implementation Guidelines," that provide detailed, technical explanations of the methodology ENTSO-E employed to assess projects in the TYNDP 2020. Whereas the CBA Guidelines provide principles and high-level guidance on the approach parties should take when assessing their transmission assets, the implementation guidelines can be used as a manual to replicate the exact approach ENTSO-E took to arrive at the results published at the end of the TYNDP 2020.

The implementation guidelines present how methodological principles outlined in the CBA Guidelines are applied directly to the project types the TYNDP 2020 has had to assess. Some projects obviously differ from others and their specific circumstances need to be fairly accounted for in their assessment. In addition, the implementation guidelines give a detailed account of how each indicator is calculated. Readers interested in replicating the studies done by ENTSO-E are therefore referred directly to the implementation guidelines. Please note that the Implementation Guidelines and CBA Guidelines should be read as companion documents to each other.

Readers interested in understanding the specifics of the NTC calculations, how benefit indicators were calculated or redispatch calculations were performed are therefore encouraged to read the Implementation Guidelines.

9 The link provides readers with access to the current CBA Guidelines, the previously approved edition and lets readers gain an insight into the CBA Guidelines process.

Improvements in CBA Guideline 3.0 (compared to 2.0)

Following the release of the second guidelines, the feedback ENTSO-E received from stakeholders and internal studies, improvements were made to address specific weaknesses found in the second Guidelines.

1. Including a benefit indicator to represent how a project contributes to reducing non-greenhouse emissions. Non-greenhouse gas emissions were missing from the last CBA Guidelines. Projects can emit gasses and particles that are not CO_2 but still cause either direct environmental damages (for example, NO_X) or can accumulate in the atmosphere where they will contribute heavily to climate change (also, NO_X). ENTSO-E has included an indicator to capture the benefits that projects can deliver to the system in reducing the emission of these particulates. The saved emissions result from the market models that ENTSO-E has at its disposal that simulate hourly dispatches for the entire European electricity market. This includes a per unit representation of the generators included in each country's generation pool. With the known efficiencies and hourly MWh output of each dispatched generator for each hour of the target year and applying a calculated emission factor to this generation, ENTSO-E can estimate how many emissions are generated with and without the assessed project.

2. Address the case for missing benefits: stakeholder feedback received during the public consultation of the TYNDP 2018 indicated that ENTSO-E was missing certain benefits that projects could provide. An internal study on what kind of indicators could be reasonably assessed and how was conducted by ENTSO-E based on this feedback. As a result, the 3rd CBA Guidelines include so-called project-level benefits that were drafted to target the missing benefits identified in the previous publication. These indicators do in fact have pan-European impacts but the methodologies that are required to assess these have not been tested by ENTSO-E at this time and are thus left to the project promoters to calculate and submit. However, the 3rd CBA Guidelines does provide guidance on how promoters are to calculate these benefits to ensure consistency between submissions. The missing benefits that are included as project-level benefits in the current CBA Guidelines are:

(a) **B7.1 – Balancing Energy Exchange:** designed to capture the socio-economic welfare benefit that the commissioning of the project would incur. For transmission projects, this is reflected in the energy exchange between integrated balancing markets.

(b) **B8 – Frequency stability (8.1):** qualitatively assesses the general benefit the projects offers to the system in maintaining the frequency within the nominal band. This indicator includes the following sub-categories:

i. **B8 – Focus on Frequency quality targets (energy aspect):** for HVDC interconnectors between synchronous areas (8.1.1): this benefit evaluates the change in frequency drop in a synchronous area with and without a HVDC interconnection to or from it.

ii. **B8 – Synchronisation with Continental Europe (for Baltic States):** the risk associated with operating as a near-island system while being also strongly reliant on the IPS / UPS system is one linked to the total blackout of a Baltic State's system. This indicator quantifies the socio-economic benefit generated by a project's ability to reduce periods of blackout in the Baltic system(s).

(c) **B8 – Blackstart services (8.2):** blackstart services refer to a project's ability to allow a system undergoing a blackout to re-energise the network. Interconnections may allow the network to recruit cheaper or more effective generating units in connected markets to provide blackstart services or directly support the re-energisation by offering direct active power generation (in the case of storage systems).

(d) **B9 – Avoidance of the renewable / replacement costs of infrastructure:** this benefit captures the economic benefits incurred by projects that effectively replace the need for either existing lines or storage projects to be replaced, upgraded or maintained, besides the main benefits the project can offer the system or region.

(e) **B10 – Reduction of necessary reserve for re-dispatch power plants:** this captures the socio-economic benefit the project offers to the European grid in reducing the necessary reserve capacity required when re-dispatching, either as a result of increasing border capacity or by providing localised energy exchange from a storage unit instead of an existing reserve unit.

CBA keywords

This section includes definitions of key words found in the CBA Guidelines. The CBA Guidelines contain a section on Definitions (Section 6.1) and Abbreviations (Section 6.2).

Socio-economic Welfare (SEW): the benefit of a project is quantified by calculating the social economic welfare that this project contributes to the grid. This benefit is calculated, by ENTSO-E as the difference in total system generation cost between the cases where the project is active vs inactive in the reference grid, see below.

Need: a system Need as is it used by ENTSO-E, is a system issue that needs to be addressed. For example, a network with known congestion issues has a congestion need a project could alleviate by offering to improve available net transfer capacity either through internal reinforcement (building a new line or upgrading an existing one's capacity) or by directly installing a new interconnection at the country's border. Needs also include redispatch problem areas, a substantial increase in generation volume that will have to be integrated in the network or could be as simple as addressing ageing infrastructure. All projects assessed by the TYNDP have the possibility to state what the system need is that they address. Additionally, ENTSO-E performs its own study on future grids that deliver a host of system needs identified across the European network. The system benefits from alleviating these system needs is quantified in SEW. Interested readers are encouraged to refer to the System Needs study 2020: Completing the Map.

Boundary: A boundary defines a barrier to power exchanges between network areas. These barriers are also known as transmission corridors. These boundaries are drawn to distinguish network areas in Europe that aggregate significant transmission power flows but lack the capacity to distribute these effectively across the European network. A boundary can:

- Be the border between two bidding zones or countries;
- Span multiple borders between multiple bidding zones or countries or,
- Be located inside a bidding zone or country dividing the area into two or multiple subareas.

Boundaries can serve as a means of identifying potential investment areas in the European grid and these investment opportunities are broadly assessed by determining how the socio-economic welfare changes as the aggregate capacity in both directions of the drawn boundary increases. A map of the boundaries studied in the TYNDP 2020 is included in Chapter 3.

Reference grid: the reference grid establishes the baseline system state against which all benefits and indicators from the cost-benefit analyses are compared. The reference grid was established for the reference year 2025, and is based on ENTSO-E's Mid-Term Adequacy Forecast 2019 reference grid. For a detailed explanation on how the reference grid was built please refer to the Power System Needs report Chapter 7.

Take Out One at the Time (TOOT): Projects who are in the reference grid are assessed with the TOOT method. The reference case reflects a future target grid situation in which all additional network capacity is presumed to be realised and projects under assessment are removed from the forecasted network structure (one at a time) to evaluate the changes to the load flow and other indicators.

Put IN one at the Time (PINT): Projects who are not in the reference grid are assessed with the PINT method. The reference case reflects an initial state of the grid without the projects under assessment, and projects under assessment are added to this reference case (one at a time) to evaluate the changes to the load flow and other indicators.

Investment vs. project: investments are the smallest set of assets that together can be used to transmit electrical power and that effectively add transmission infrastructure capacity. An example of an investment is a new circuit, the necessary terminal equipment and any associated transformers. A project on the other hand can be either a single investment or a cluster of investments that together are required to reach an intended goal. Only transmission projects contain can be clusters of several investments while storage projects contain only a single investment.

Appendix 2 – Glossary

Term	Acronym	Definition
Agency for the Cooperation of Energy Regulators	ACER	EU Agency established in 2011 by the Third Energy Package legislation as an independent body to foster the integration and completion of the European Internal Energy Market both for electricity and natural gas.
Baltic Energy Market Interconnection Plan in electricity	BEMIP Electricity	One of the four priority corridors for electricity identified by the TEN-E Regulation. Interconnections between Member States in the Baltic region and the strengthening of internal grid infrastructure, to end the energy isolation of the Baltic States and to foster market integration; this includes working towards the integration of renewable energy in the region.
Bottom-Up		This approach of the scenario building process collects supply and demand data from Gas and Electricity TSOs.
Carbon budget		This is the amount of carbon dioxide the world can emit while still having a likely chance of limiting average global temperature rise to 1.5 °C above pre-industrial levels, an internationally agreed-upon target.
Carbon Capture and Storage	CCS	Process of sequestrating CO_2 and storing it in such a way that it will not enter the atmosphere.
Carbon Capture and Usage	CCU	The captured CO_2, instead of being stored in geological formations, is used to create other products, such as plastic.
Combined Heat and Power	CHP	Combined heat and power generation.
Congestion revenue / rent		The revenue derived by interconnector owners from the sale of the interconnector capacity through auctions. In general, the value of the congestion rent is equal to the price differential between the two connected markets, multiplied by the capacity of the interconnector.
Congestion		Means a situation in which an interconnection linking national transmission networks cannot accommodate all physical flows resulting from international trade requested by market participants, because of a lack of capacity of the interconnectors and / or the national transmission systems concerned.
	COP 21	21st Conference of the Parties to the United Nations Framework Convention on Climate Change, organised in 2015, where participating states reached the Paris Agreement.
Cost-benefit analysis	CBA	Analysis carried out to define to what extent a project is worthwhile from a social perspective.
Curtailed electricity		Curtailment is a reduction in the output of a generator from otherwise available resources (e. g. wind or sunlight), typically on an unintentional basis. Curtailments can result when operators or utilities control wind and solar generators to reduce output to minimise congestion of transmission or otherwise manage the system or achieve the optimum mix of resources.
Demand side response	DSR	Consumers have an active role in softening peaks in energy demand by changing their energy consumption according to the energy price and availability.
e-Highway2050	EH2050	Study funded by the European Commission aimed at building a modular development plan for the European transmission network from 2020 to 2050, led by a consortium including ENTSO-E and 15 TSOs from 2012 to 2015 (**to e-Highway2050 website**).
Electricity corridors		Four priority corridors for electricity identify by the TEN-E Regulation: North Seas offshore grid (NSOG); North-south electricity interconnections in western Europe (NSI West Electricity); North-south electricity interconnections in central eastern and south eastern Europe (NSI East Electricity); Baltic Energy Market Interconnection Plan in electricity (BEMIP Electricity).
Energy not served	ENS	Expected amount of energy not being served to consumers by the system during the period considered due to system capacity shortages or unexpected severe power outages.
Grid transfer capacity	GTC	Represents the aggregated capacity of the physical infrastructure connecting nodes in reality; it is not only set by the transmission capacities of cross-border lines but also by the ratings of so-called “critical” domestic components. The GTC value is thus generally not equal to the sum of the capacities of the physical lines that are represented by this branch; it is represented by a typical value across the year.
Internal Energy Market	IEM	To harmonise and liberalise the EU’s internal energy market, measures have been adopted since 1996 to address market access, transparency and regulation, consumer protection, supporting interconnection, and adequate levels of supply. These measures aim to build a more competitive, customer-centred, flexible and non-discriminatory EU electricity market with market-based supply prices.

Term	Acronym	Definition
Investment (in the TYNDP)		Individual equipment or facility, such as a transmission line, a cable or a substation.
Mid-term adequacy forecast	MAF	ENTSO-E's yearly pan-European monitoring assessment of power system resource adequacy spanning a timeframe from one to ten years ahead.
Net transfer capacity	NTC	The maximum total exchange programme between two adjacent control areas compatible with security standards applicable in all control areas of the synchronous area and taking into account the technical uncertainties on future network conditions.
N-1 criterion		The rule according to which elements remaining in operation within a TSO's responsibility area after a contingency from the contingency list must be capable of accommodating the new operational situation without violating operational security limits.
National Energy and Climate Plan	NECP	National Energy and Climate Plans are the new framework within which EU Member States have to plan, in an integrated manner, their climate and energy objectives, targets, policies and measures for the European Commission. Countries will have to develop NECPs on a ten-year rolling basis, with an update halfway through the implementation period. The NECPs covering the first period from 2021 to 2030 will have to ensure that the Union's 2030 targets for greenhouse gas emission reductions, renewable energy, energy efficiency and electricity interconnection are met.
North Seas offshore grid	NSOG	One of the four priority corridors for electricity identified by the TEN-E Regulation. Integrated offshore electricity grid development and related interconnectors in the North Sea, Irish Sea, English Channel, Baltic Sea and neighbouring waters to transport electricity from renewable offshore energy sources to centres of consumption and storage and to increase cross-border electricity exchange.
North-south electricity interconnections in central eastern and south eastern Europe	NSI East Electricity	One of the four priority corridors for electricity identified by the TEN-E Regulation. Interconnections and internal lines in north-south and east-west directions to complete the EU internal energy market and integrate renewable energy sources.
North-south electricity interconnections in western Europe	NSI West Electricity	One of the four priority corridors for electricity identified by the TEN-E Regulation. Interconnections between EU countries in this region and with the Mediterranean area including the Iberian peninsula, in particular to integrate electricity from renewable energy sources and reinforce internal grid infrastructures to promote market integration in the region.
Power to gas	P2G	Technology that uses electricity to produce hydrogen (Power to Hydrogen – $P2H_2$) by splitting water into oxygen and hydrogen (electrolysis). The hydrogen produced can then be combined with CO_2 to obtain synthetic methane (Power to Methane – $P2CH_4$).
Project (in the TYNDP)		Either a single investment or a set of investments, clustered together to form a project, in order to achieve a common goal.
Project of common interest	PCI	A project which meets the general and at least one of the specific criteria defined in Art. 4 of the TEN-E Regulation and which has been granted the label of PCI project according to the provisions of the TEN-E Regulation.
Put IN one at the Time	PINT	Methodology that considers each new network investment/project (line, substation, PST or other transmission network device) on the given network structure one by one and evaluates the load flows over the lines with and without the examined network reinforcement.
Reference grid		The existing network plus all mature TYNDP developments, allowing the application of the TOOT approach.
Reference capacity		Cross-border capacity of the reference grid used for applying the TOOT/PINT methodology in the assessment according to the CBA.
Scenario		A set of assumptions for modelling purposes related to a specific future situation in which certain conditions regarding electricity and gas demand and supply, infrastructures, fuel prices and global context occur.
Take Out One at the Time	TOOT	A set of assumptions for modelling purposes related to a specific future situation in which certain conditions regarding electricity and gas demand and supply, infrastructures, fuel prices and global context occur.
Ten-Year Network Development Plan	TYNDP	The Union-wide report carried out by ENTSO-E every other year as (TYNDP) part of its regulatory obligation as defined under Article 8, para 10 of Regulation (EC) 714/2009.
Top-Down		The "Top-Down Carbon Budget" scenario building process is an approach that uses the "bottom-up" model information gathered from the gas and electricity TSOs. The methodologies are developed in line with the Carbon Budget approach.
Trans-European Networks for Energy	TEN-E	Policy focused on linking the energy infrastructure of EU countries. It identifies nine priority corridors (including 4 for electricity) and three priority thematic areas.

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