TYNDP 2022

High-Level Report TYNDP 2022

Final Version · May 2023

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 39 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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Ten-Year Network Development Plan 2022

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

Questions?

Contact us as at **tyndp@entsoe.eu**

Contents

Key numbers 6

Main findings of the TYNDP 2022 System needs study 6

The TYNDP in 11 questions 7

Content of the TYNDP 2022 12

The TYNDP 2022 scenarios 13

The identification of system needs 14

The TYNDP 2022 projects portfolio 15

The CBA framework 20

Benefits delivered by infrastructure projects in TYNDP 2022 22

B1 – Socio-Economic Welfare 22

B2 – Reduction in CO_2 emissions 22

B3 – Integration of Renewable Energy Sources 24

Continuous improvement of the TYNDP 26

Next steps 27

Acknowledgements 28

Key numbers

TYNDP 2022 will assess 141 transmission projects of which 85 cross-border projects, and 23 storage projects. Overall, the TYNDP 2022 portfolio represents 43,000 km of lines or cables.

The development and construction of TYNDP 2022 projects translates into 1.6 Million jobs in Europe. Infrastructure projects also have a positive impact on production, GDP and public administration revenues in the European Union.

Main findings of the TYNDP 2022 System needs study[1]

In 2030

- 64 GW of capacity increases after 2025 on over 50 borders
- 17 TWh of curtailed energy saved each year
- Dependence on gas for power generation decreases by 9 TWh/year
- 14 Mton of CO_2 emissions avoided each year
- Generation costs decrease by 5 billion euro per year
- Existing transmission projects do not cover all system needs, a 15 GW investment gap remains

In 2040

- 88 GW of capacity increases after 2025 on over 65 borders, 41 GW of storage in 19 countries and 3 GW of CO_2-free peaking units in 4 countries
- 42 TWh of curtailed energy saved each year
- Dependence on gas for power generation decreases by 75 TWh/year. That's equivalent to 14 % of the EU gas-based electricity generation in 2021.
- 31 Mton of CO_2 emissions avoided each year
- Generation costs decrease by 9 billion euro per year
- Increased security of electricity supply, with 1,6 TWh of avoided energy-not-served
- There are opportunities for new solutions to address the needs throughout Europe

1 Capacity increases and generation costs are for the whole area covered by the study, which extends beyond ENTSO-E to include Great-Britain, Ukraine, Moldova and Med-TSO countries bordering the Mediterranean Sea. Avoided CO_2 emissions, avoided curtailment, reduction in gas-based power generation and in energy-not-served are for the ENTSO-E area.

The TYNDP in 11 questions

1 What is the TYNDP and why does Europe need a plan for electricity infrastructure?

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

Europe has embarked on an unprecedented societal transformation journey with its Green Deal objective to reach climate neutrality by 2050. The European Climate law sets an ambitious path towards decarbonisation with an intermediate target of reducing net greenhouse gas emissions by at least 55 % by 2030, compared to 1990 levels. The Fit for 55 Package and REPowerEU Plan will fast-forward the energy transition to 'net zero' at a much greater scale with the increase of renewable energy and energy efficiency targets for 2030. The rapid replacement of fossil-fuel generation by renewable energy sources, the greater electrification of other sectors, energy efficiency, and interlinking the various energy sectors will be key. Europe will only reach its decarbonisation objective and the successful deployment and integration of increasing volumes 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, connecting borders, sectors and regions. 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.

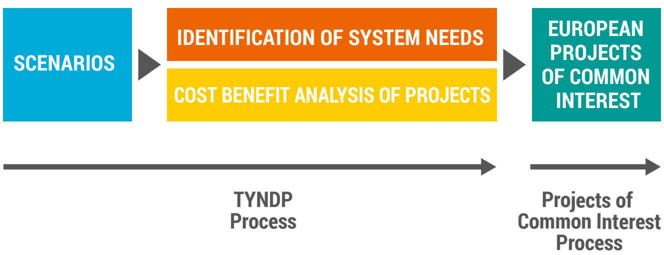
2 How is the TYNDP developed?

Step 1 – the scenarios: At the heart of the TYNDP lays a definition of scenarios indicating how the European power system might look in the future. ENTSO-E and its gas counterpart ENTSO-G have developed the scenarios together with a wide range 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, from an economic viewpoint, 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:

1. Investigating where increasing cross-border electricity exchange, storage or peaking capacity would bring economic benefits in the future energy scenarios considered. This is **Step 2, the System Needs study**.

2. Performing an individual assessment of the performance of every project considered in TYNDP 2022 under the different scenarios (**Step 3: cost-benefit analysis of projects**). TYNDP 2022 assessed 141 transmission projects and 23 storage projects.



3 How are stakeholders involved in the TYNDP?

The development of TYNDP 2022 involved stakeholders via several public consultations and webinars, including:

- on scenarios storylines (Spring of 2020) and on the draft scenarios themselves (October – November 2021). Some stakeholders also contribute directly to scenario building by providing expertise on their specific industry.
- on the proposed improvements to our methodology to identify system needs (October 2021);
- on main components of the TYNDP 2022 implementation Guidelines (December 2021 – January 2022).

In addition, stakeholders have been heavily involved throughout 2018 and 2019 in the development of the Cost-Benefit Analysis methodology (CBA 3.0), which reflects largely the feedback received by the many stakeholders who contributed to the process.

Stakeholders input has allowed to greatly improve TYNDP 2022 overall. The entire TYNDP 2022 package itself is submitted to public consultation from end July to 16 September 2022. A second shorter public consultation on some projects assessment results that are released later will take place in the fall of 2022. In addition, stakeholder webinars and workshops will be organised to explain in more detail the various parts of the package and gather further stakeholder feedback.

Stakeholders wishing to engage further with ENTSO-E are welcome to contact us at tyndp@entsoe.eu.

4 What is ENTSO-E's identification of System needs study?

The TYNDP system need study investigates where the opportunities are to make Europe's power system more efficient. It shows where new solutions are needed to reach European decarbonisation targets and keep security of electricity supply and costs under control.

The 2022 study results show that opportunities to make Europe's power system more efficient exist all over Europe. Between 2025 and 2030, the study identifies 64 GW of economically efficient additional capacity on over 50 borders, a 55 % increase over the 2025 grid. In 2040, there is space for 88 GW of cross-border capacity increase after 2025 (a 75 % increase) on over 65 borders, and for 41 GW of storage in 19 countries and 3 GW of CO_2-free peaking units in 4 countries. The 41 GW of storage capacity add up to the 126 GW of battery storage available in 2030. All storage technologies combined, the total storage capacity in 2040 would amounts to 174 GW.

In response to new challenges, the TYNDP also explores 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 which will include high share of inverter-based generation not providing inertia support to the grid and increasingly responsive energy demand.

5 What are the concrete benefits for Europe of investing in its cross-border transmission grid and storage infrastructure?

The TYNDP 2022 system needs study finds that addressing system needs allows a more efficient use of the pan-European generation mix, translating into 9 billion euro/year of savings from 2025 to 2040, with a direct impact on consumers' electricity bills. The curtailment of renewable energy is significantly reduced, by 42 TWh/year in 2040 and replaces more expensive and carbon intensive thermal generation. A more efficient use of the European generation mix translates into significant reduction in CO_2 emissions of 31 Mton/year in 2040, helping Europe to achieve its Green Deal objectives. Additionally, it improves security of electricity supply, reducing energy-not-served by 1,6 TWh to bring it close to 0 TWh in 2040.

The cost-benefit analysis of projects assesses in detail how each proposed transmission and storage projects can contribute to Europe's future power system, with a wider set of indicators including projects' benefits in terms of socio-economic welfare, reduction of CO_2 emissions and curtailment, integration of RES, security of supply and frequency stability. It assesses projects in two scenarios, National Trends and Distributed Energy, representing two very different futures for Europe's energy system, to identify no-regret options.

6 Are the 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/actors and users. The TYNDP 2022 scenarios already assume that some of these solutions will be in place. As an example, the National Trends scenario assumes increases of battery capacity in Europe by 34 GW, of Demand Side Response by 17 GW and of Power-to-Gas by 96 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 interlinkage 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, looks at how cross-border transfer capacities and storage projects can contribute to meeting the system needs of the future. However, all the findings can be extrapolated to identify other technological solutions solving interconnection barriers on either side of a border (including dynamic line rating, demand response, generation, storage, power to gas, etc.). In addition, solutions to address internal bottlenecks in some countries will also be needed.

7 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, progress in energy efficiency and 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 two 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, and developed jointly with ENTSOG. 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.

8 Does TYNDP 2022 consider the EU's goal to reduce dependency on gas imports?

TYNDP 2022 scenarios for the future of Europe's energy system were developed from mid-2020 to early 2022, before the start of the war in Ukraine. The National Trends scenario reflects EU Member States National Energy and Climate Plans and other long-term national strategies as they were in 2020. It foresees 3268 TWh and 2416 TWh of natural gas imports in 2030 and 2040 respectively. The Distributed Energy scenario, while reflecting a willingness of society to achieve energy autonomy and foreseeing less natural gas imports than Natural Trends (2256 TWh in 2030, 1243 TWh in 2040 and 0 TWh in 2050), is also not compatible with complete independence from Russian energy imports in 2030 and 2040.

It is to be investigated how a total energy independence from Russia would impact needs throughout Europe for transmission, storage, power-to-gas assets or any other solution, also in the light of any new target for energy efficiency, renewable energy or electrolysers adopted by the EU. Future TYNDPs will investigate such evolutions. However, a clear finding from our system needs study is that one of the main benefits of addressing system needs is to reduce Europe's dependence on gas-based power generation. By connecting more consumers with more producers, grid development allows a better use of the cheapest generation. As a result, European countries can exchange electricity to replace expensive generation (gas and coal) with cheaper one (mainly renewable). Addressing system needs reduces gas-based generation by 9 TWh in 2030 and by 75 TWh in 2040, equivalent to 14 % of the EU's gas-based electricity generation in 2021.

The TYNDP's findings are therefore still very relevant in the current context of uncertainty on natural gas supply from Russia and of rising gas prices. The higher the price of natural gas, the more beneficial it becomes to invest in Europe's cross-border electricity grid.

Later in 2022 we will perform a sensitivity assessment of transmission and storage projects in a scenario with a revised gas price and publish the results in the fall of 2022.

9 How are infrastructure projects assessed?

The added value of projects in the TYNDP is illustrated through the cost-benefit indicators. Indicators capture the bulk of a project's benefits and costs, by answering questions such as: to what extent does the project contribute to reducing emissions of CO_2 and other gases? Will it help putting more renewable energy on the market? Does it increase security of supply?...

Two main factors impact the results of the assessment of a project's benefits for the pan-European system:

The scenarios investigated: new scenarios are developed for each TYNDP cycle. Projects assessment 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 cost-benefit analysis methodology applied: TYNDP 2022 applies the 3rd CBA Guideline, a methodology developed by ENTSO-E and submitted to the European Commission for approval.

Additionally, the assessment of projects 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 2027 and 2035.

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.

10 Are existing projects 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 needs identified in the 2030 and 2040 horizons with the cost-benefit analysis of specific projects. Only by considering the full framework can conclusions be drawn on the contribution of each individual project to a successful EU energy transition. Identified system needs provide a global view of the optimal needs on the borders analysed with regards to socio-economic welfare, for the National Trends scenario. This global analysis is well complemented by the cost-benefit analysis which finely considers every individual project and investigates how specific projects would benefit all Europeans by increasing socio-economic welfare, reducing CO_2 and other GHG emissions, improving the penetration of RES production in European electricity mix, increasing security of supply in the National Trends and Distributed Energy scenarios.

Comparing the identified opportunities and the proposed projects shows different situations depending on the border. While on some borders the capacity increases of the proposed projects matches the identified 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, non-economic needs (related to grid stability for example). Both future system needs and projects benefits must be monitored over the years.

The future needs identified by the TYNDP and the CBA results provides input to promoters to potentially reconsider the scope or timing of their projects. The TYNDP provides a solid basis to compare European projects through a series of indicators based on a robust methodology. However, it cannot claim to provide a full and exact value of future investments which will eventually depend, for instance, on the future energy mix, local acceptability or on changes to the current market design.

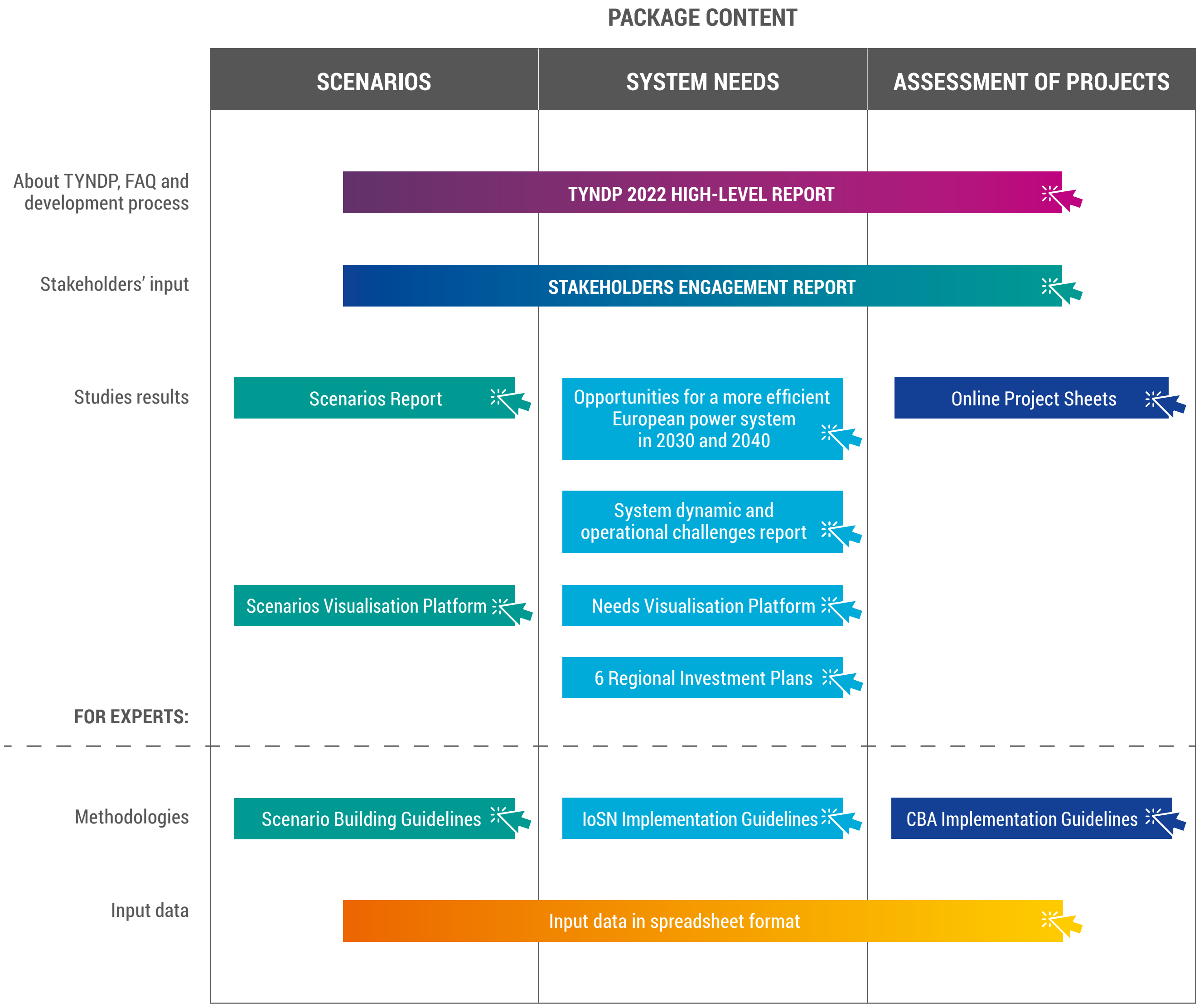
11 What is the role of the TYNDP in the EU energy and climate policy?

Regulation (EC) 2019/943 and Regulation (EU) 2022/869 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 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.

Content of the TYNDP 2022



The TYNDP 2022 scenarios

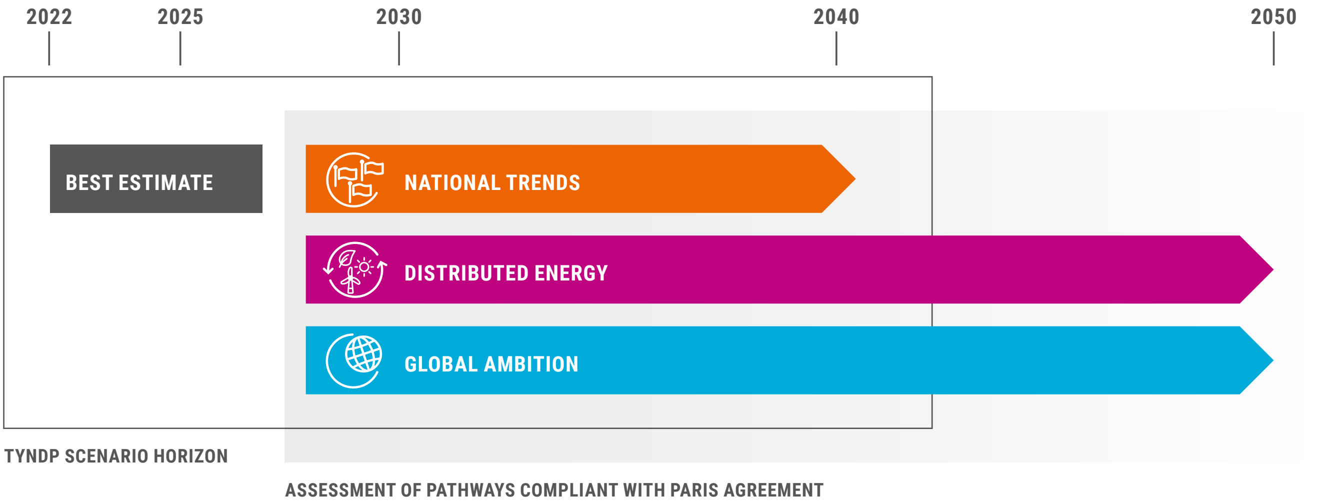


Figure 1 – Scenarios framework in TYNDP 2022

The future of the European energy system is uncertain. To help decide where to invest, ENTSO-E assesses future system needs and the impacts of proposed projects on the electricity system using a scenario-based approach. A scenario is a picture of a possible future under certain defined circumstances. Parameters such as demand for electricity, use of hydrogen, generalisation of solar panels on rooftops, deployment of offshore wind farms all vary according to storylines pre-defined with stakeholders. ENTSO-E aims to identify projects that bring benefits in a variety of futures. Three scenarios have been outlined for the 2030 and 2040 and, for two of them, also for the 2050 horizon.

	Distributed Energy Higher European autonomy with renewable and decentralised focus	**Global Ambition** Global economy with centralised low carbon and RES options
Green Transition	At least a 55 % reduction in 2030, climate neutral in 2050	
Driving force of the energy transition	Transition initiated at a local / national level (prosumers)	Transition initiated at a European / international level
	Aims for EU energy autonomy through maximisation of RES and smart sector integration (P2G/L)	High EU RES development supplemented with low carbon energy and imports
Energy intensity	Reduced energy demand through circularity and better energy consumption behaviour	Energy demand also declines, but priority is given to decarbonisation of energy supply
	Digitalisation driven by prosumer and variable RES management	Digitalisation and automation reinforce competitiveness of EU business
Technologies	Focus of decentralised technologies (PV, batteries, etc.) and smart charging	Focus on large scale technologies (offshore wind, large storage)
	Focus on electric heat pumps and district heating	Focus on hybrid heating technology
	Higher share of EV, with e-liquids and biofuels supplementing for heavy transport	Wide range of technologies across mobility sectors (electricity, hydrogen and biofuels)
	Minimal CCS and nuclear	Integration of nuclear and CCS

Figure 2 – Storylines of the Global Ambition and Distributed Energy scenarios

ENTSO-E and its gas counterpart ENTSOG design these scenarios as the basis for the analysis of system needs and for the cost-benefit analysis of projects that determines their eligibility to EU funding for electricity and gas infrastructure Projects of Common Interest. Where possible, the scenarios are based on official EU and Member State data sources and are intended to provide a quantitative basis for investment planning. They explore uncertainties that are relevant for infrastructure development, and thus primarily focus on aspects that determine infrastructure use. Additionally, the scenarios draw on the current European political and economic consensus and aim to follow a logical path to achieve energy and climate targets. They are designed to provide insights into the possible energy system of the future and the role of electricity and gas carriers, as well as the effects of changes in supply and demand on the system.

Stakeholders contribute to shaping the scenarios by providing data and expertise feeding into their development. For example, to estimate the costs of building offshore wind generation infrastructure in 2030 and 2040 we consulted our proposed estimates with WindEurope. Stakeholders also contribute through a series of consultations and webinars, whose core values are transparency, inclusiveness, and efficiency.

For detailed information about how are built, and a breakdown of their outcomes, read the **TYNDP 2022 Scenarios report**.

The identification of system needs

The TYNDP system need study investigates where are opportunities to make Europe's power system more efficient. It shows where new solutions are needed to reach European decarbonisation targets, increase market efficiency and keep security of electricity supply and costs under control.

Needs can be addressed in multiple ways, including with infrastructure (such as new or upgraded transmission infrastructure, storage, hybrid offshore assets, power to X) or non-infrastructure solutions such as dynamic line rating. About two-thirds of the identified needs could be addressed by concrete TYNDP projects, while there is a gap of 15 GW which are not yet covered by any existing projects in the 2030 horizon. The TYNDP 2022 system needs study investigates needs in the 2030 and 2040 horizons. Where could CO_2 emissions be reduced? Where could the curtailed electricity from renewable energy sources be used? Where could the electricity price between neighbouring countries be more aligned? It also assesses the cost of not investing in the required infrastructure.

Detailed system needs results are available on our **System needs data visualisation platform**.

Key findings of the TYNDP 2022 System needs study

In 2030

- 64 GW of capacity increases after 2025 on over 50 borders
- 17 TWh of curtailed energy saved each year
- Dependence on gas for power generation decreases by 9 TWh/year
- 14 Mton of CO_2 emissions avoided each year
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Capacity increases and generation costs are for the whole area covered by the study, which extends beyond ENTSO-E to include Great-Britain, Ukraine, Moldova and Med-TSO countries bordering the Mediterranean Sea. Avoided CO_2 emissions, avoided curtailment, reduction in gas-based power generation and in energy-not-served are for the ENTSO-E area.

In response to new challenges, the TYNDP also explores 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 which will include high share of inverter-based generation not providing inertia support to the grid and increasingly responsive energy demand. Results are presented in a separate report on System dynamic and operational challenges.

The TYNDP 2022 projects portfolio

TYNDP 2022 includes an assessment of 141 pan-European electricity transmission projects and 23 storage projects around Europe. ENTSO-E analyses the benefits that each project could deliver from a socio-economic perspective. Projects were submitted on a voluntary basis by their promoters and were accepted in the TYNDP 2022 after verification by ENTSO-E that they comply with a number of administrative (pan-European relevance) and technical criteria as outlined in the TYNDP guidance for applicants.

Visit our TYNDP 2022 online page to visualise all projects on a map of Europe. You can filter by technology, country, PCI Corridor or current status. Data on projects is downloadable in spreadsheet and PDF format.

Transmission projects

The 141 transmission projects in TYNDP 2022's portfolio represent 285 investments in 38 countries. Onshore transmission line projects represent around 63 % of the total number of investments, while offshore ones represents another 19 %.

TYNDP 2022's portfolio of 141 transmission projects are split between the 4 corridors of projects of common interest (PCI) as determined by the European Commission: 22 are in the North Sea Offshore Grid, 53 in NSI West, 48 in NSI East and 18 in the BEMIP corridors. Most of these projects (85) are cross-border and involve two or more countries, while 56 projects are internal to a country but are considered of European relevance. The TYNDP 2022 portfolio includes 30 transmission projects on the 5th list of European PCIs.

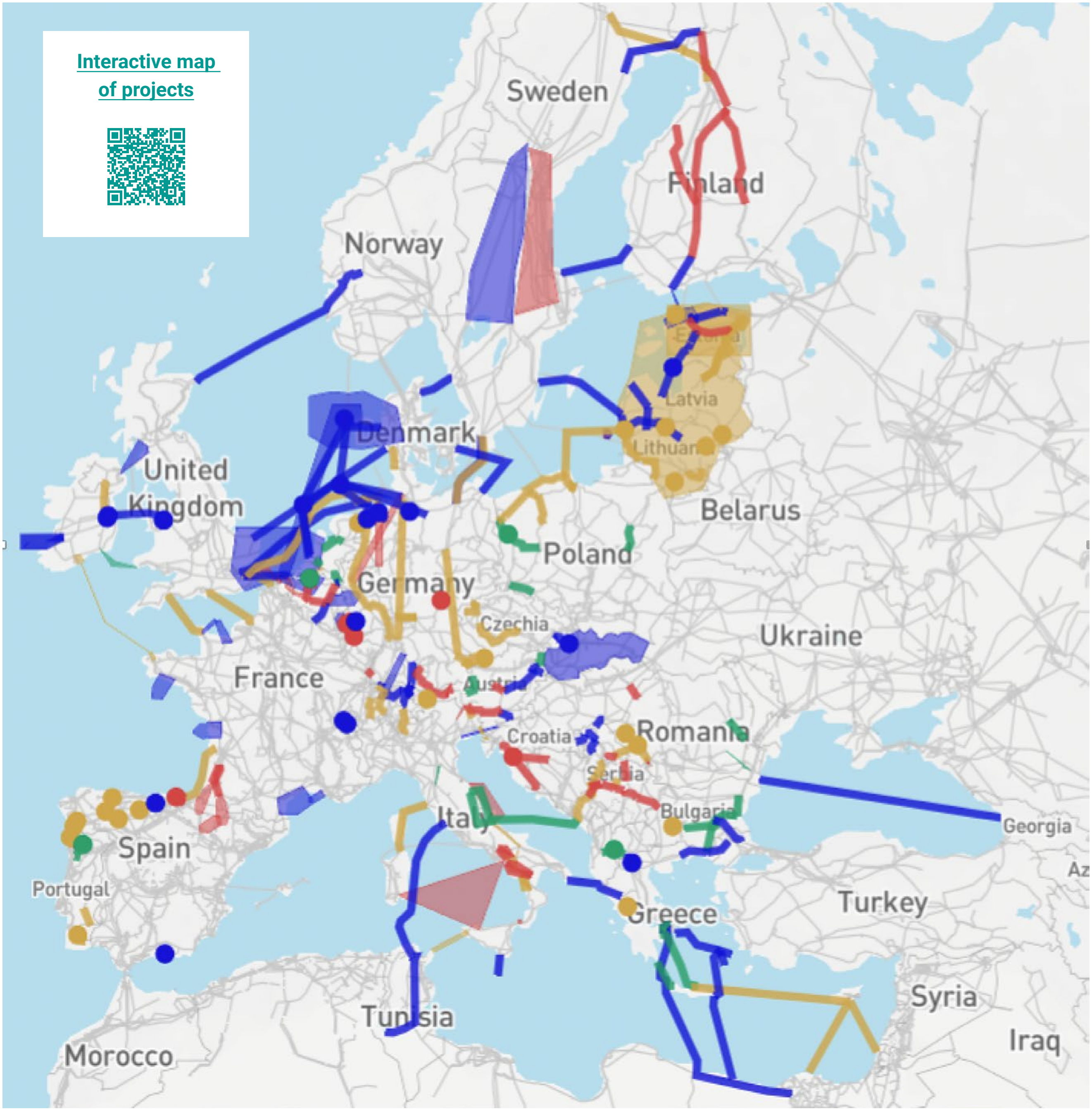


Figure 3 – Map of TYNDP 2022 transmission projects. Areas indicate projects for which the route is not yet known (green: under construction; yellow: in permitting; red: planned but not yet in permitting; blue: under consideration).

TYNDP 2022's portfolio encompasses projects with over 43,000 km of potential additional cables and lines, of which 18,000 km (42 %) are AC and 25,000 km (58 %) are DC. The rapid advancement of DC technology has led to improved uptake of this technology and seen its portfolio share grow since TYNDP 2018. The ongoing development of offshore infrastructure is expected to require increased investment in subsea DC cables.

High-voltage, direct current (HVDC) technology features in a number of projects. HVDC technology has the advantages of offering greater transport capacity, reducing electromagnetic fields and reducing losses when transmitting electricity over long distances. However, it entails significantly higher project costs that must be compensated by the benefits. Ultranet (project #254), proposed for Germany's North-South transmission corridor from North Rhine-Westphalia to Baden-Württemberg, is one example that will use an innovative concept. It considers the use of existing transmission infrastructure (towers and pylons) and adapt them for the deployment of additional DC overhead lines. Such solution improves significantly overall grid performance by increasing transmission capacity in an efficient and resource-saving manner and limits the impact on the environment.

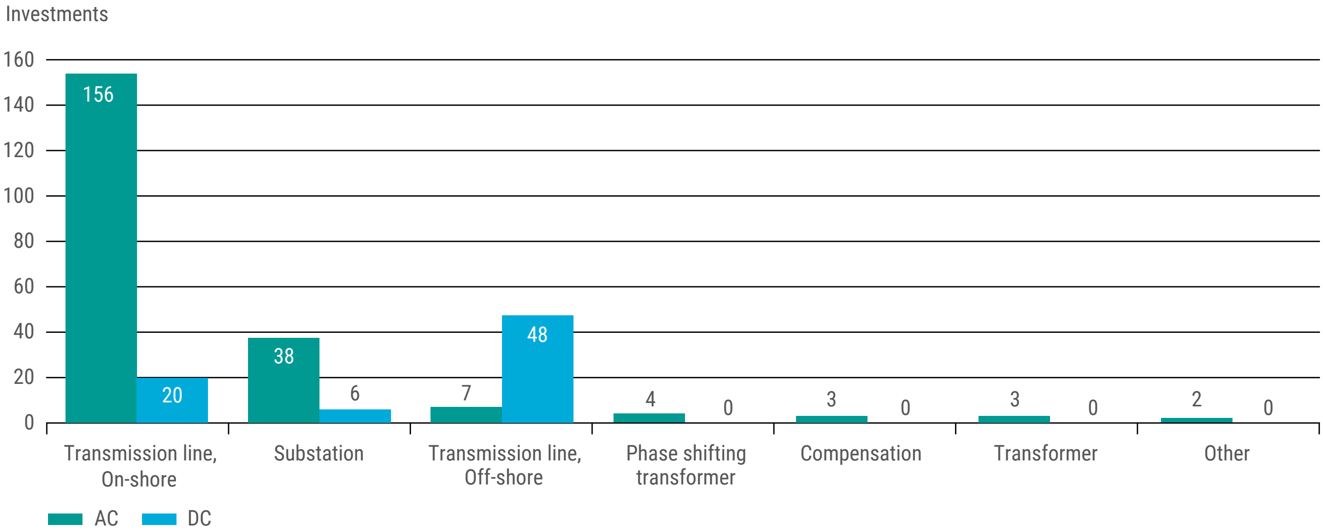


Figure 4 – TYNDP 2022 investments per type of element and technology. Note that converter stations are generally included within DC investments.

Implementation overview

Of the 141 transmission projects, 35 % (44 of the total) are expected by promoters to come into service within the next five years. The rest are expected to be commissioned from 2027 to 2040.

Of TYNDP 2022's transmission projects, 14 are currently under construction (compared to 32 in TYNDP 2020). Of the 43 projects in the permitting phase, 34 were already in the permitting phase in TYNDP 2020.

The TYNDP 2022 portfolio also includes 55 projects under consideration, of which 18 are new projects in this TYNDP. Many of these projects aim at addressing system needs identified in the 2018 and 2020 system-needs studies. Of the 287 transmission investments, 40 (14 %) suffered delays in the past two years (compared with 17 % in 2020), while 37 were rescheduled.

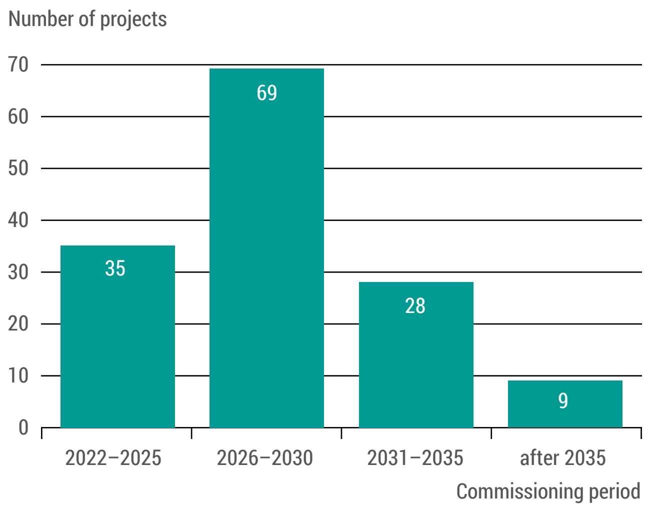


Figure 5 – TYNDP 2022 transmission projects per expected year of commissioning, based on the year of commissioning provided by project promoters.

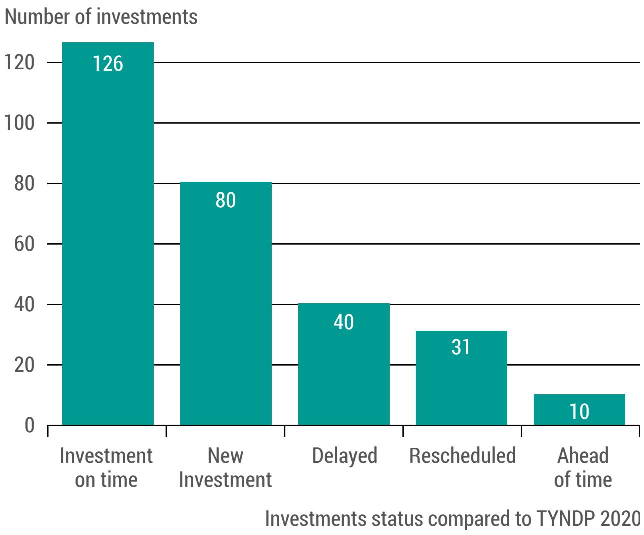


Figure 6 – Evolution of TYNDP 2022 transmission investments since 2020. "New investments" refers to investments that were not included in previous editions of the TYNDP.

Offshore projects represent an increasing share of the TYNDP transmission portfolio

TYNDP 2022 will assess 52 offshore transmission projects (including interconnectors, offshore generation connection and hybrid projects), which represent over a third of the total transmission project portfolio. There is an increase compared to previous TYNDPs, with 43 offshore projects in TYNDP 2020 and 45 offshore projects in TYNDP 2018. Of the 29 new projects in TYNDP 2022 17 are offshore, including 7 generation connection projects and 3 hybrid projects.

Offshore transmission infrastructure and related onshore connections and reinforcements need to be built much faster than the current onshore grids, which were developed step by step for more than a century. Several challenges for this expansion will have to be addressed in the coming years, including a holistic and multi-sectoral planning and coordinated on-and-offshore grid developments, combining the fields of grid and spatial planning, engineering, construction and financing.

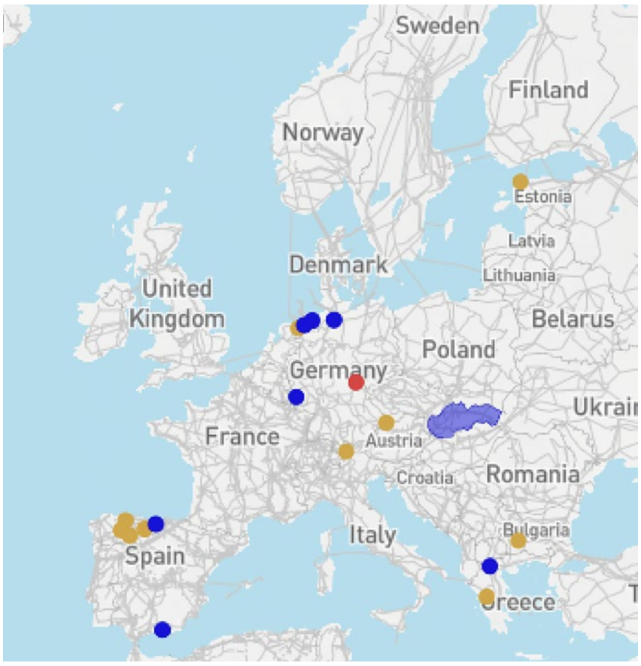


Figure 7 – TYNDP 2022 storage projects (yellow: in permitting; red: planned but not yet in permitting; blue: under consideration)

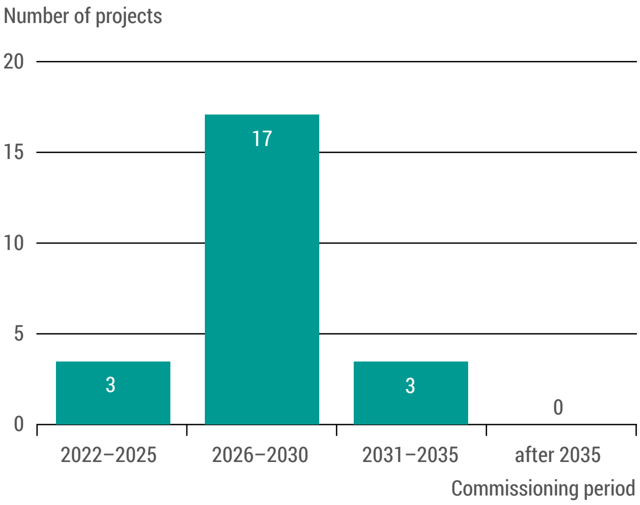


Figure 8 – TYNDP 2022 storage projects per expected year of commissioning, based on the year of commissioning provided by project promoters

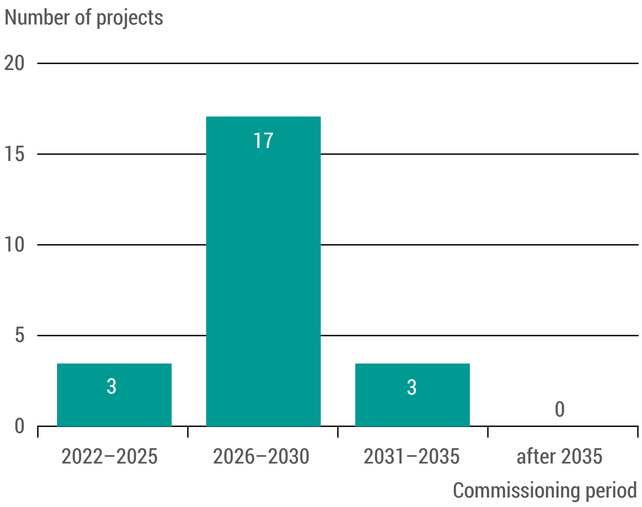


Figure 9 – Evolution of TYNDP 2022 storage projects since TYNDP 2020. 'New projects' refers to projects that were not included in previous editions of the TYNDP.

Storage projects

The TYNDP 2022 portfolio includes 23 storage projects, of which 12 use pump-hydro technology. Six compressed-air energy storage projects and two electrochemical storage projects complete the portfolio. None of the projects has started the construction phase, while 12 are under consideration. One is in planning but has not completed the permitting phase, and 10 are in permitting. TYNDP 2022 includes three fewer storage projects than in 2020.

Electricity infrastructure creates jobs and contributes to Europe's economy

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. ENTSO-E has computed the impact of the project portfolio in the European Union economy, during the whole cycle of each project[2]. 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 2022 project portfolio:

- 1,6 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 close to 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.

Twelve years of TYNDP – Europe is more and more interconnected

Over the last twelve years, the European cross-border transmission grid has developed significantly. 12 borders saw the commissioning of their first electric interconnection, joining the 80 European borders terrestrial or maritime that have at least one cross-border line in 2022. New interconnections include for example Denmark and the Netherlands, the UK and Belgium, Italy and Montenegro, and Norway and Germany. Increased cross-border interconnection goes hand in hand with increased electricity exchanges. 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, the 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 assessed in the pilot TYNDP 2010 represented over 42,000 km of lines, of which close to 11,500 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.

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

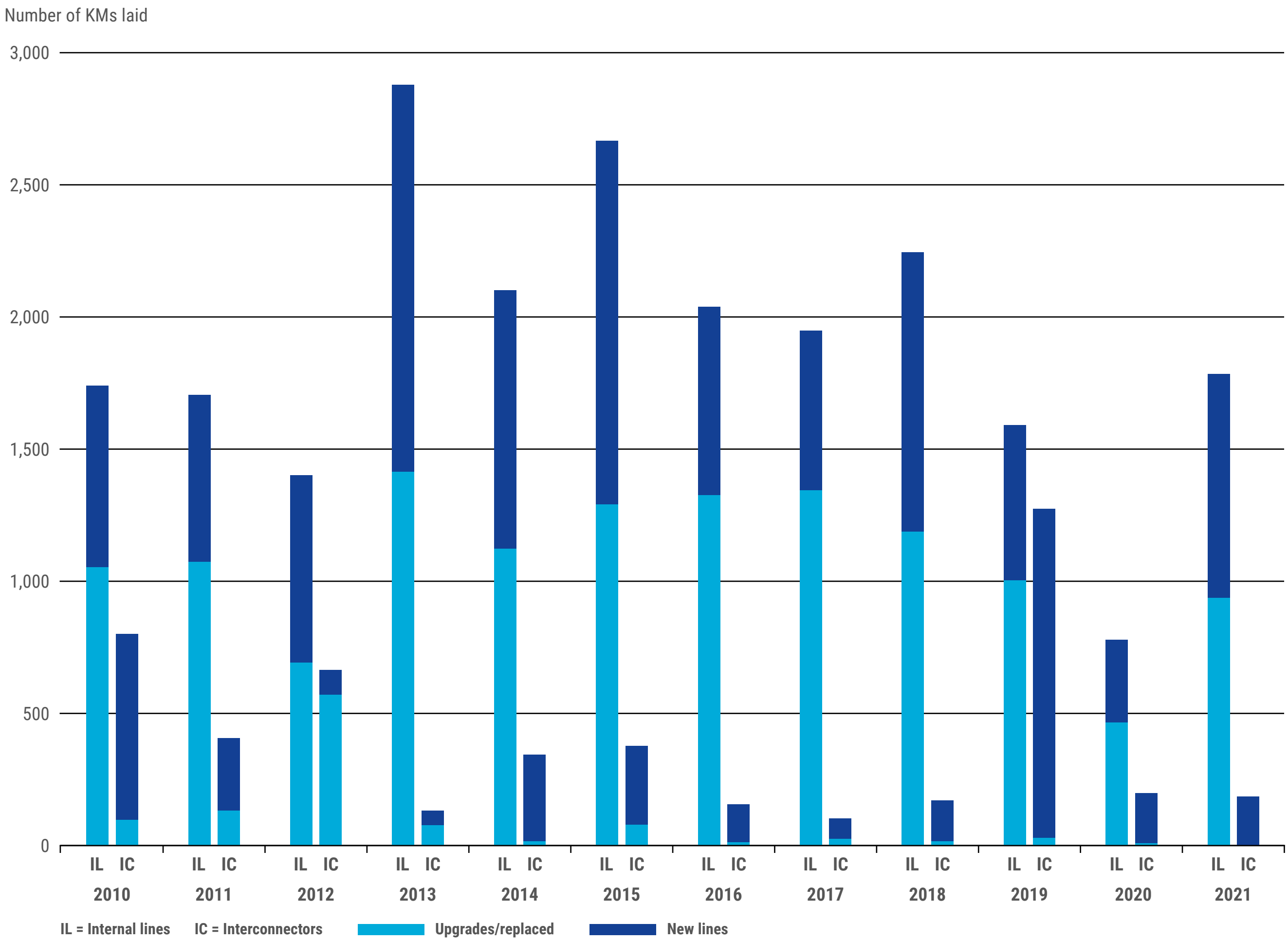


Figure 10 – Projects commissioned each year from 2010 to 2021 in km of line

The CBA framework

A project can have various impacts on the electric system. ENTSO-E has developed Costs-Benefits Analysis Guidelines for the European Commission that describe how best to assess these impacts for each project, taking into account social, economic and environmental considerations. This framework assesses issues such as the potential for reducing emissions, stability, flexibility, capital and operating costs, mitigation of loss of power over long-distance transmission and integration of renewable energy into existing systems, for example by connecting offshore power to a grid. The 3rd CBA Guidelines are in the process of validation by the European Commission. In the TYNDP 2022, ENTSO-E has assessed the impact of each project according to the following indicators:

- **B1.** The socioeconomic benefits, calculating 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 or redispatch. This evolution is monetised thanks to a societal cost of carbon that takes into account climate change.
- **B3.** The change in the RES integrated or curtailed energy volume induced by the project. This indicator is not monetised because its effect is already fully accounted for within socioeconomic welfare.
- **B4.** The evolution of emissions of several polluting gases induced by the generation mix: nitrogen oxide (NOx), ammonia (NH_3), sulphur dioxide (SO_2), particulate matter (PM_5 and PM_{10}) and non-methane volatile organic compounds (NMVOC).
- **B5.** The evolution of the volume and 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 expectation and decreasing the need for generation capacity.

The CBA guidelines also defines three additional indicators that are not assessed by ENTSO-E. Project promoters were invited to propose an assessment.

- **B7.** The support to the capability of the power system to face system balancing energy needs in the context of high penetration levels of non-dispatchable electricity generation.
- **B8.** Provides an indication of the change in system stability as a result of the addition of the project to the power system.
- **B9.** The change in needed reserve power plants for redispatch.

For more information about the assessment of infrastructure projects, please refer to the 3rd CBA Guideline (submitted to the European Commission for approval in March 2021) and the TYNDP 2022 Implementation Guidelines.

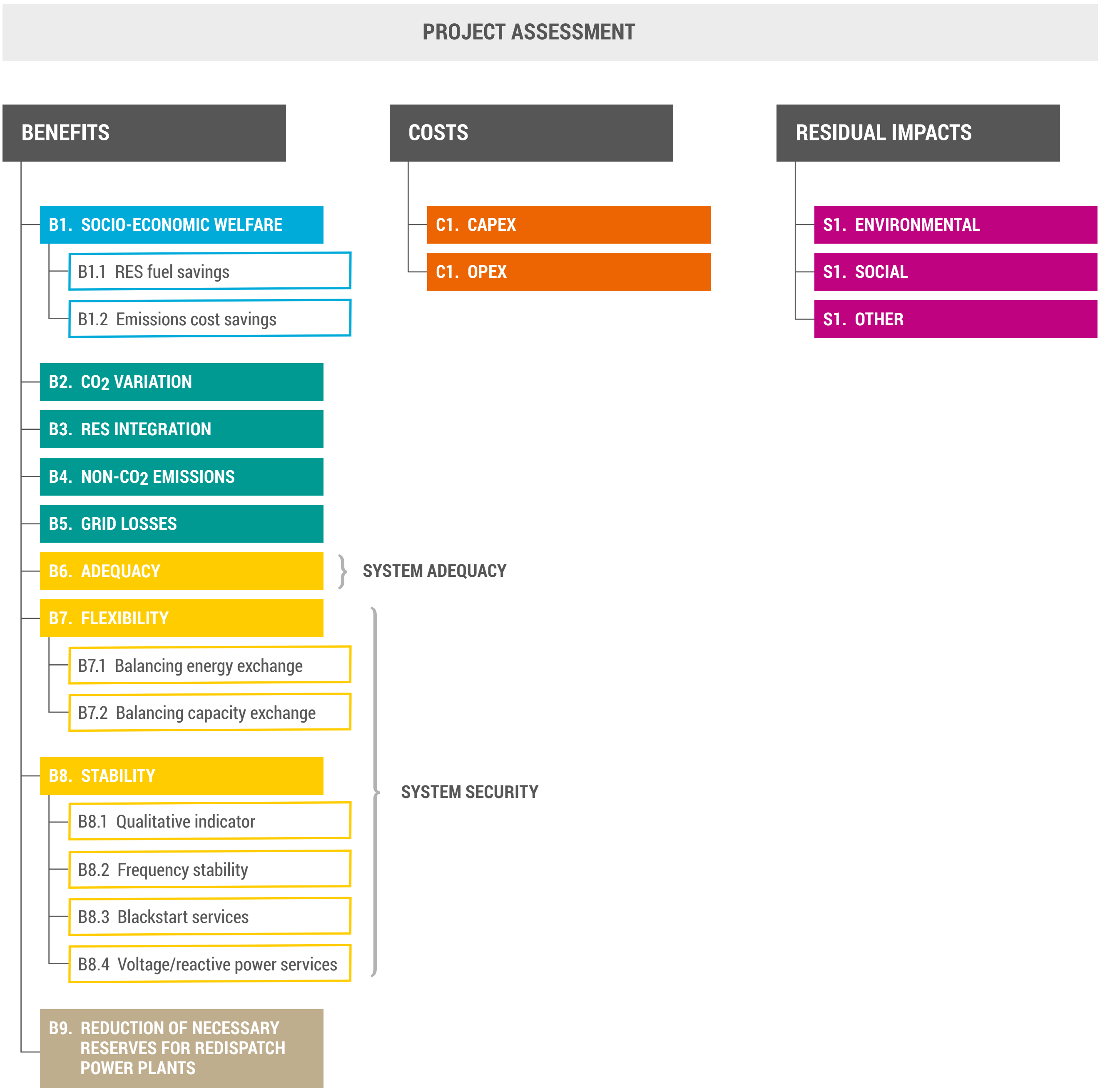


Figure 11 – Assessment framework categories of TYNDP projects

Benefits delivered by infrastructure projects in TYNDP 2022

B1 – Socio-Economic Welfare

Additional exchange capacity between European countries favour and amplify the overall mutualisation of cheap generation capacity (mainly RES generation through avoided spillage and nuclear), thus increasing their use in place of expensive thermal generation. This leads to an overall decrease of generation cost across Europe.

Access CBA results of all TYNDP 2022 projects.

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. This is exemplified by the results in the sensitivity of the Distributed Energy 2030 scenario with a higher gas price, more on this below.
- 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 2030 horizon compared to the 2040 horizon. The progress of the energy transition across Europe from 2030 to 2040 explains the main part of this increase of projects' impact on socio-economic welfare, with the share of electricity demand covered by wind, solar and other RES increasing from 71 % in DE 3030 to 89 % in DE 2040.

In the 2030 horizon, projects' impact on socio-economic welfare seems to be higher in Distributed Energy than in National Trends, for various reasons including differences in RES penetration of the scenarios (2104 TWh of combined wind and solar energy in DE 2030 versus 1431 TWh in NT 2030), and a slight difference in the ETS CO_2 price (78 €/ton in DE 2030 versus 70 €/ton in NT 2030) impacting the marginal cost of power plants, and therefore also socio-economic welfare. Of course, other hypothesis can explain locally other trends and differences that could be observed.

B2 – Reduction in 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.

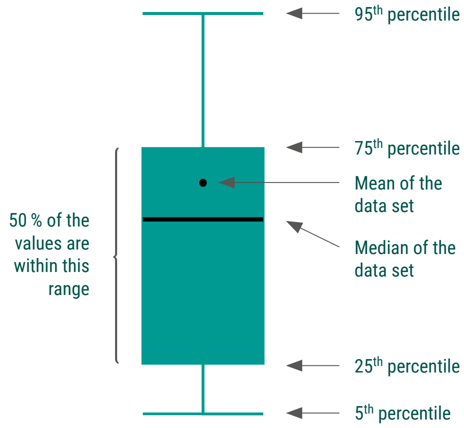
Because of the energy transition overall CO_2 emissions are lower in 2040 than in 2030 in all scenarios, mechanically reducing the room for infrastructure projects to reduce CO_2 emissions. This explains why the impact of TYNDP projects on CO_2 emissions is markedly lower in DE 2040 in Figure 13.

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.



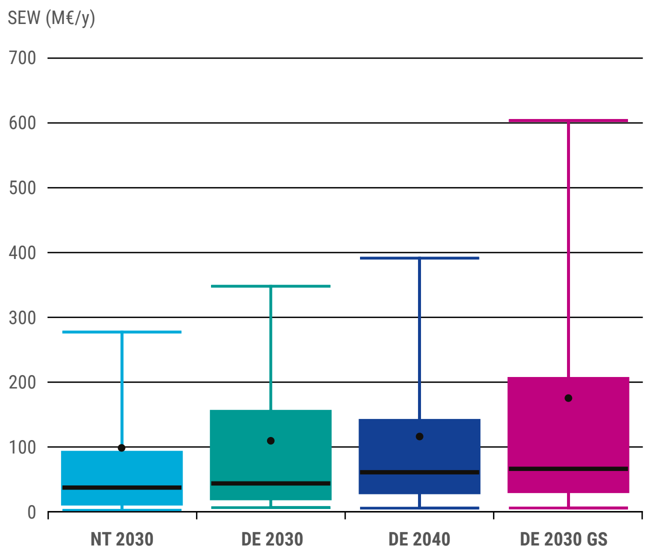


Figure 12 – Increase in socio-economic welfare enabled by TYNDP 2022 transmission and storage projects

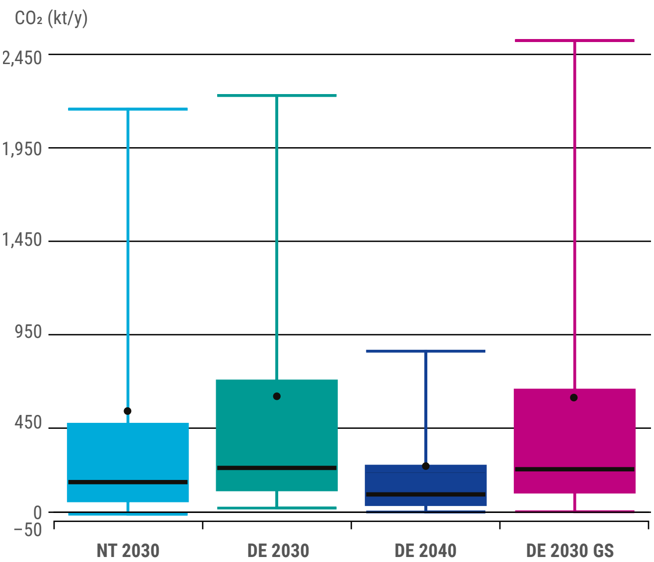


Figure 13 – Reduction in CO_2 emissions enabled by TYNDP 2022 transmission and storage projects

B3 – Integration of Renewable Energy Sources

Transmission and storage infrastructure projects make more RES available to the market in two ways:

- by directly connecting additional RES generation to Europe's power system, and
- by avoiding the curtailment of RES generation (Figure 14). In particular, transmission infrastructure increasing the exchange capacity between one area with excess RES generation and other areas tend to facilitate an overall higher level of RES penetration.

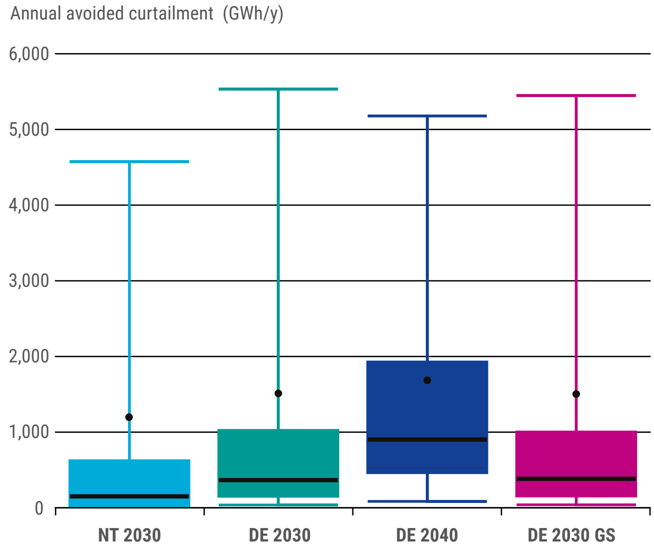


Figure 14 – Annual avoided curtailment (GWh/year) caused by TYNDP 2022 transmission and storage projects

Sensitivity study on the price of gas

Recently, gas price in EU has increased rapidly because of decreasing gas supply. Gas represents a significant part of the EU's primary energy consumption and have comprehensively affected the energy markets, including electricity sector. In order to provide some insights in what would be the effect of a sustainably high gas price, a sensitivity analyses was performed on the DE 2030 scenario.

Basically, the sole difference between this sensitivity study and DE 2030 scenario is that the sensitivity model considers a gas price twice as high as it is in the base case of DE 2030 (5,91 €/GJ in DE 2030, 12,16 €/GJ in the sensitivity). This consequently leads to an increase of the price of electricity production from gas. It therefore modifies the overall merit order and the resulting generation mix by penalizing gas-sourced electricity production compared with any other sources.

Figure 15 shows the impact on the generation mix of increasing only the price of gas. Gas is replaced primarily by hard coal and lignite and by hydro generation to a lesser extent. Curtailed energy increases slightly.

As visible in Figure A, the impacts of infrastructure projects on socio-economic welfare increases with a higher price of gas. Indeed, with higher costs the benefit of replacing expensive generation by cheaper (renewable) one also increases.

Regarding reductions in CO_2 emissions, the price of gas alone has no significant impact on how new infrastructure projects will benefit society. This can be explained by the fact that a new interconnector will contribute to replacing the technology that is last in the merit order. When gas is more expensive than other more CO_2-emitting fossil fuels, a new project's impact on cutting CO_2 emissions is lower than if e. g. coal was the last technology in the merit order. The situation would probably have been very different if the prices of all CO_2-emitting technologies had been increased.

Higher gas price also have no significant impact on infrastructure projects' benefits in terms of avoided curtailment (Figure 15). Overall, the sensitivity analysis confirms that infrastructure projects become more valuable for society when gas prices increase.

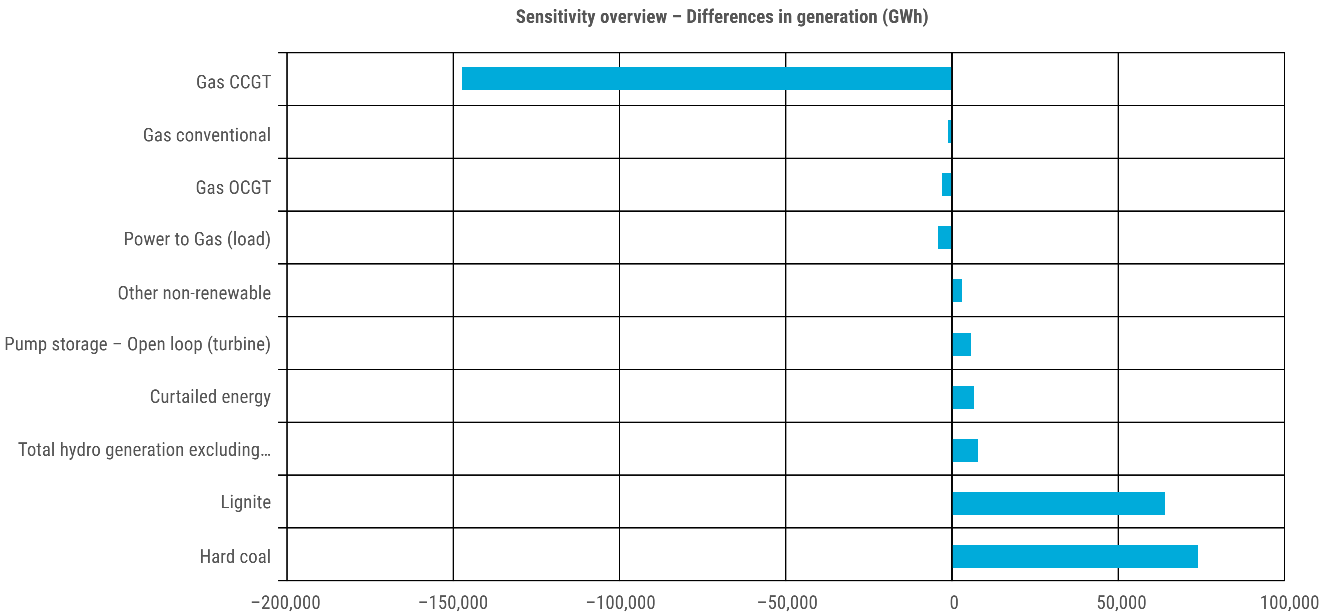


Figure 15 – Differences in the generation mix between DE 2030 scenario with a gas price at 5,91 €/GJ and the sensitivity at 12,16 €/GJ

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 introduced in TYNDP 2022 include:

Two new stakeholder involvement phases have been introduced in the TYNDP roadmap: a webinar before the start of the system needs study on the draft methodology to identify system needs, and a public consultation on key improvements proposed to be introduced in the TYNDP 2022 Implementation Guidelines. Feedback received at an early stage on both deliverables allows for an improved alignment of the TYNDP with stakeholders expectations. These two new engagement steps come in addition to those already held in previous editions, which include the consultations on the guidance for project promoters and on the draft TYNDP 2022 package and the several events and consultations on scenarios.

Implementation guidelines: The draft TYNDP 2022 Implementation Guidelines has been released much earlier than in previous TYNDPs, in March 2022, before the start of the cost-benefit analysis of projects. This early release creates more transparency for project promoters, who know in advance the details of the methodology used to assess their project.

System needs study methodology: The methodology to identify system needs has been improved, with in particular the use of multiple climatic years to account for improvements in security of supply, and the introduction of storage and peaking flexibility assets in 2040. Another improvement concerns the zonal model used in the 2030 horizon, where the zonal clustering has been entirely reviewed to account for grid contingencies.

Tools / platform: in order to improve further the readability and user-friendliness of our findings, we have in particular developed a data visualisation platform on system needs. The platform allows stakeholders to visualise needs at pan-European, PCI corridor and country level and features brief analytical texts to contextualise our results. Project sheets, presenting projects and how they benefit Europeans in a series of indicators, have also been further improved.

Scenarios: Like in previous TYNDPs, scenarios have been developed jointly with ENTSOG. Improvements in scenarios include in particular extensive stakeholder engagement at an early stage, including with bilateral discussions to factor in stakeholders' expert knowledge of their specific field. The differentiation between scenarios has been increased. On the methodological side, the modelling of sector coupling has greatly improved thanks to the support of EuroHeat and Power, DSO associations CEDEC, E.DSO, Eurelectric, Eurogas and GEODE and Hydrogen Europe. The modelling of hydrogen, electrolysis, prosumers, vehicle-to-grid and district heating is much more detailed and complex than in previous editions.

Towards TYNDP 2024

Preparation of the TYNDP 2024 is already ongoing. Stakeholders comments during the public consultation phase from July to September 2022 will feed into discussion on the definition of the scope of the TYNDP 2024 and potential areas for improvements in comparison to the 2022 exercise.

Next steps

Public consultation

ENTSO-E is collecting feedback on TYNDP 2022 until 16 September. All interested stakeholders are invited to reply to our public consultation via **ENTSO-E's Consultation Hub**. Stakeholders comments will serve to improve TYNDP 2022 reports and online platforms. In addition, stakeholder webinars and workshops will be organised to explain in more detail the various parts of the package and gather further stakeholder feedback.

Cost-benefit analysis of transmission and storage projects

Assessment results for National Trends 2030 are already partially available. Results for Distributed Energy and for the 2040 horizon will become available in the fall of 2022.

ACER opinion

In the fall of 2022 the entire TYNDP 2022 package will be submitted to ACER for Opinion.

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