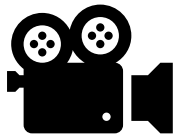
TYNDP 2024

TYNDP 2024

Key findings

Version for public consultation | January 2025

Housekeeping



Presentation will be recorded

Keep microphone muted

Q&A session at the end

Agenda

- Introduction
- Scenarios
- Identification of Needs
- Gaps and Opportunities
- How addressing system needs benefits Europe
- New needs: dynamic and operational challenges
- Project collection and identification
- Cost benefits analysis of projects
- Next Steps
- Q&A

The TYNDP is one of ENTSO-E's system development studies

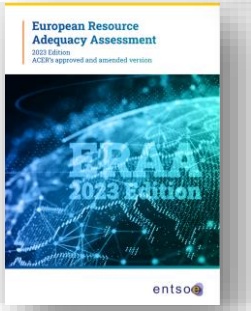
Uncertainty

Purpose: Support long-term investment decisions.

Scenarios/Inputs: Builds on national estimates under various long-term assumptions/scenarios.

Uncertainty: High/Very high.

10 to 30 years



Purpose: Guide policy-makers' decisions on investments and regulatory interventions.

Scenarios/Inputs: National best estimates for demand and energy mix with robustness check.

Uncertainty: Moderate until 5th year & higher beyond 5 years.

2 to 10 years

Purpose: Flag short-term risks for system adequacy so that involved stakeholders at national, regional and pan-European level coordinate to ensure security of supply.

Scenarios/Inputs: TSOs' estimates based on contextual factors.

Uncertainty: Low.

Weeks to months ahead

Time

Introduction

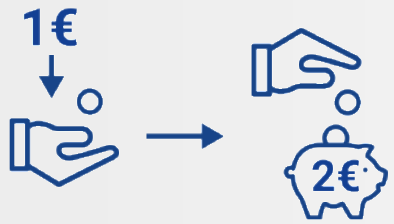
The TYNDP is the European electricity infrastructure development plan.

Following the TEN-E Regulation, the study provides a pan-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.

Three key findings of TYNDP 2024

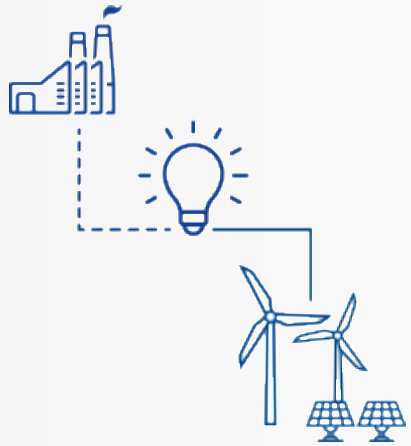
1

By 2040, each euro invested in the electricity grid translates into over 2 euros saved in system costs



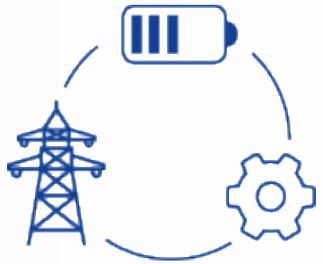
2

Addressing system needs reduces dependence on carbon-intensive power generation and on imports from non-EU countries



3

Existing infrastructure projects address only part of the identified needs. More projects are needed and action must be taken to enable timely implementation of electricity infrastructure projects.



The Process behind the Ten Year Network Development Plan at ENTSO-E

1 | SCENARIOS

Defining up to three most plausible futures, which we call **Scenarios**

2 | NEEDS

Identification of the needs based on our scenarios. Includes Infrastructure Gaps Report and Offshore Network Development Plans

3 | PROJECTS

Project collection and identification

4 | COST BENEFIT

Cost benefits analysis of projects

Union List process led by the European Commission

Projects of Common Interest (PCI) and **Projects of Mutual Interest (PMI) Process**

5 | SELECTION

Key areas for improvement identified in 2022

- Roadmap to climate neutrality / 2050 horizon was not addressed in the analysis of needs
- TYNDP did not address offshore hybrid needs
- Stakeholders acknowledged progress on transparency but improvements requested on size and user-friendliness of TYNDP package

Actions taken by ENTSO-E in 2024

- TYNDP 2024 looks up to 2050 to provide better understanding on the requirements for a carbon neutral energy system
- Implemented an improved methodology to integrate offshore RES into our grids and identify hybrid corridors
- Reduced number of documents, improved interactive data visualisation tool

Key areas for improvement identified in 2022

Only utility scale batteries were considered as investment candidates

Zonal modelling applied in only one time horizon

Actions taken by ENTSO-E in 2024

Both utility scale and residential batteries are considered in 2050

A diverse portfolio of investment candidates provides insights into how different technologies complement each other to provide system benefits.

Zonal modelling in 2040 and 2050

The zonal model allows to provide a more accurate reflection of the power network.

Scenarios

1 | SCENARIOS

2 | NEEDS

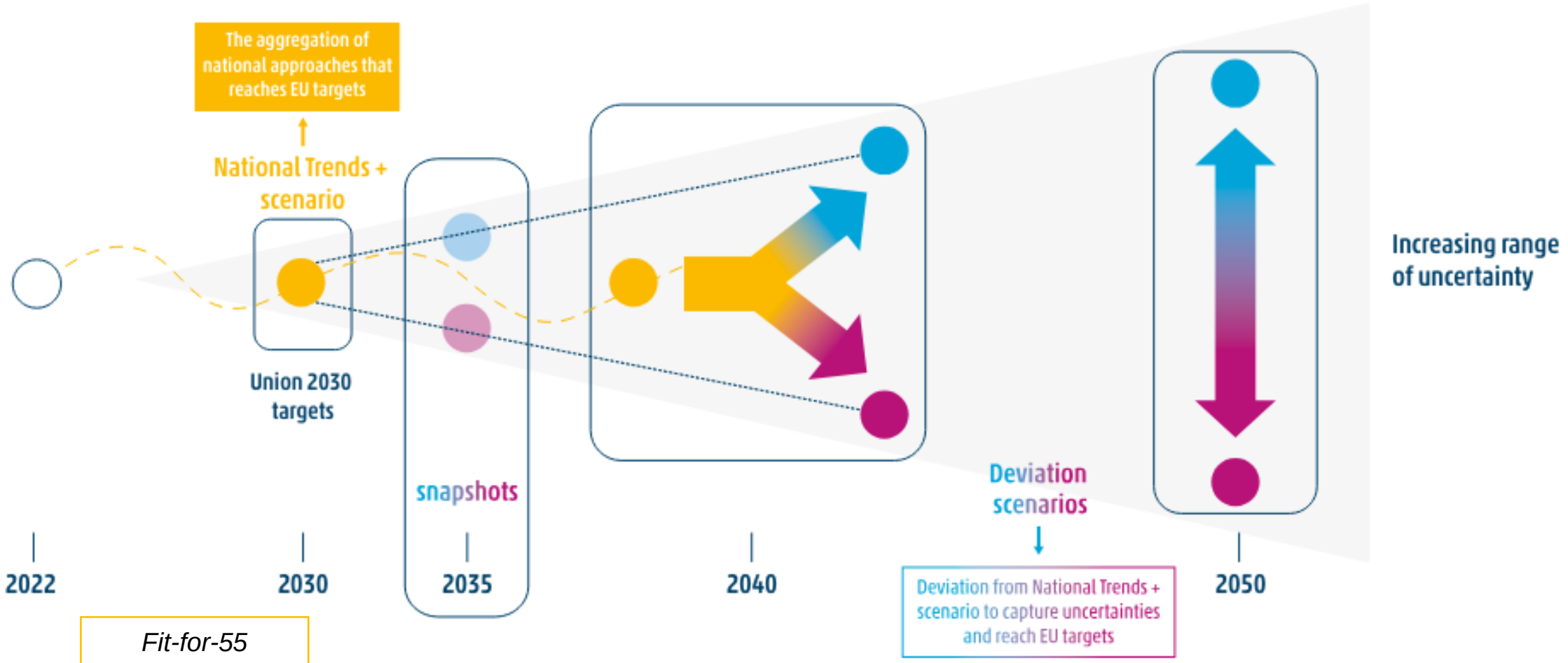
3 | Projects

The 2024 scenarios provide a sound basis to develop an infrastructure that is fit for purpose for a net-zero energy system, with the current available knowledge

Scenarios built in line with policy targets, taking into account the latest available data at the time and aligns with the Guidelines to the extent possible

- ✓ Central scenario NT+ aims to capture NECPs: reflect Member States policies on fuel phase-out, takes the latest available Commission scenarios
- ✓ Deviation scenarios reflect other possible futures if the story unfolds in a different manner

TYNDP 2024 scenario framework



The TYNDP 2024 scenarios align with the energy efficiency first principle, the EU's 2030 energy and climate targets, its 2050 climate neutrality objective

Scenarios captures NECPs and latest national policies *(Q1 2023, for offshore August 2023)*
Take into account the latest Commission Scenarios *(Fit for 55 & REPowerEU)*
Extensive stakeholder engagement on the inputs and methodologies & enhanced transparency

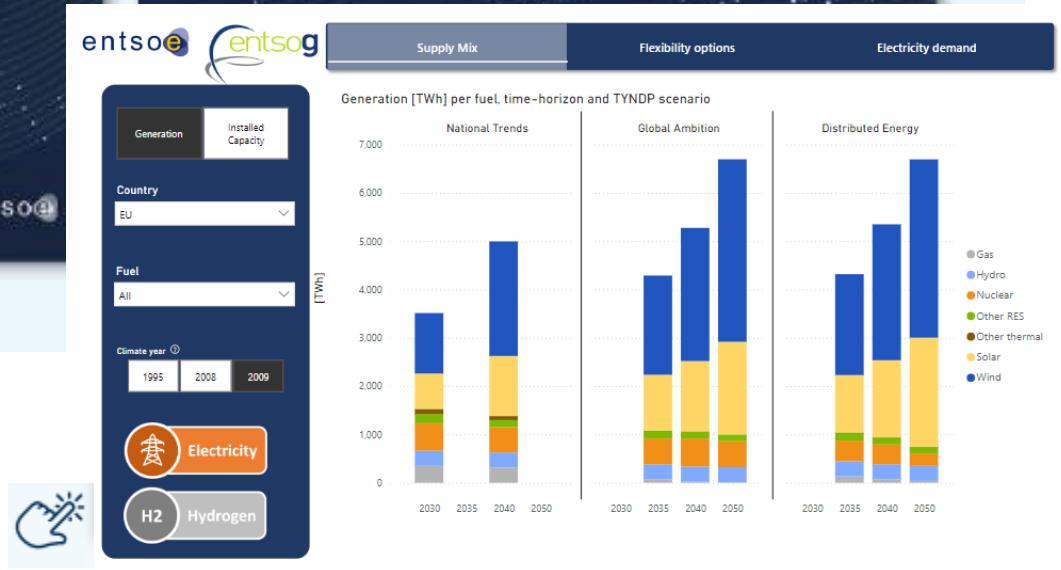
Energy Efficiency First and Union's 2030 targets for energy

- ✓ EE1st 11.7% reduction,
- ✓ Up to 45.4% RES share in GFEC
- ✓ 55% GHG reduction
- ✓ Offshore targets

Climate and its 2050 climate neutrality objective

- ✓ Net-zero emissions in 2050
- ✓ Offshore targets

The TYNDP 2024 Scenarios package was published in May 2024



Download the complete Package

Full datasets & results
Visualisation Platform
Consultation Summary Report

Identification of Needs

Based on our scenarios

1 | SCENARIOS

2 | NEEDS

3 | Projects

System needs study

Study process overview

Input

2030 grid

Investment candidates

- Cross-border capacity increases
- Storage
- Offshore corridors identified by the ONDP

PEMMDB*

* Scenario National Trends 2030 and 2040, Distributed Energy 2050

Calculation

Optimisation with Plexos and Antares simulators

Minimum of operational costs + investment costs*

* NTC study 2030, zonal study 2040, simplified zonal 2050

Output

Economic opportunities and infrastructure gaps in 2030, 2040 and 2050

System needs study

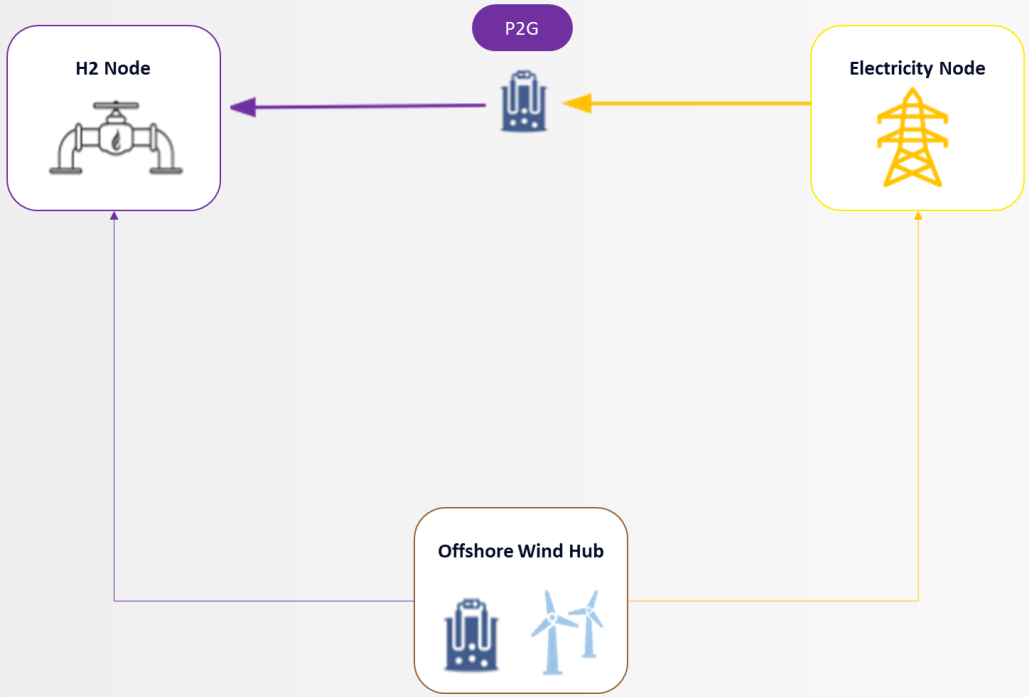
General Market Modelling Approach

Hydrogen Market

SMR Capacity

H2 storage

H2 Demand



Electricity Market

Generation Capacity

Infrastructure

Demand

Target of the modelling approach

The main objective of the modelling approach of the IoSN 2024 is to represent the electricity system with adequate granularity and take in to account the potential impact from the sector integration data coming from the Scenarios.

The model has not explored the co-optimization of electricity and H2 needs.

TYNDP 2024

Gaps and opportunities

for Europe's power system in 2030, 2040 and 2050

Gaps and opportunities for Europe's power system in 2030, 2040 and 2050

Coordinated planning will be needed across sectors.

Non-infrastructure solutions

Addressing tomorrow's challenges will require the parallel development of a diverse range of solutions, including for example storage, the role of prosumers and generation, in addition to reinforcing the transmission grid.

Demand side response

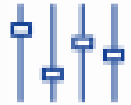
Regulation

Smart Grids

Storage

Smart Sector Integration

Market design



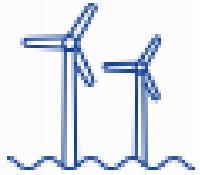
Operational measures

Electricity infrastructure solutions

Our study uses interconnection transmission capacity and storage and peaking flexibility to express the needs because it is based on electricity TSOs' expertise, data and models, but solutions extend beyond electricity infrastructure.

Transmission lines

Energy Storage



Hybrid solutions

Gaps and opportunities for Europe's power system in 2030, 2040 and 2050

Identified needs in 2030 show the immediate economic interest of investing in Europe's grid

By 2030

The study finds that 88 GW additional to the 161 GW of cross-border capacity expected in 2030, and 56 GW of storage power, would be cost-efficient in 2030.

Investment

This capacity increase represents about **5 billion euro of investment per year**.

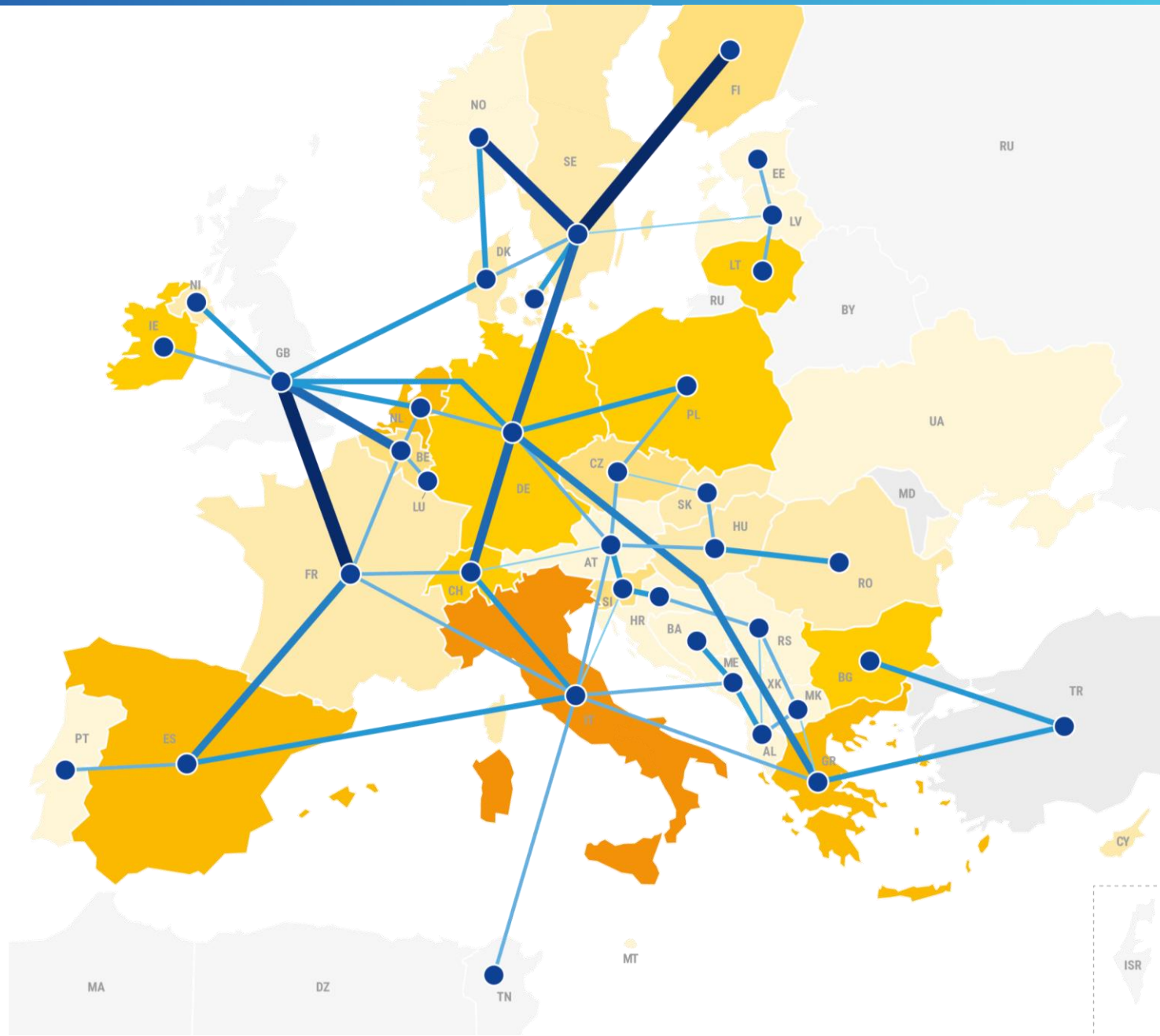
Gains

And would deliver a yearly **gain** in socio-economic welfare of **8 billion euro**.

2030 System Needs

With further investment in its electricity grid and storage infrastructure, Europe could reduce its system costs while going beyond its 2030 targets.

An additional 88 GW of complementary cross-border capacity and 56 GW of storage power would be cost-efficient to reinforce Europe's power system.

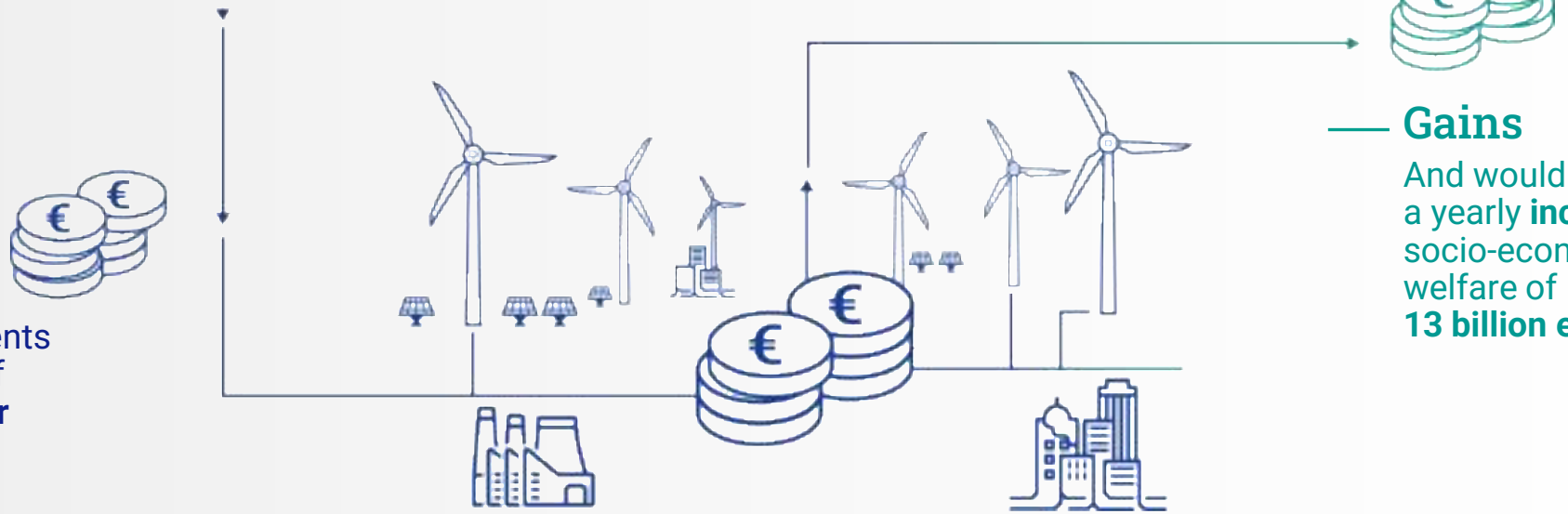


Gaps and opportunities for Europe's power system in 2030, 2040 and 2050

By 2040, each euro invested in the electricity grid translates into over 2 euros saved in system costs

By 2040

The study finds that 108 GW of additional cross-border capacity increases after 2030, including 20 GW of offshore hybrid corridors will be needed to support Europe's move towards a carbon-free power system. 227 GW of batteries will provide flexibility to the system.



Investment

This capacity increase represents an investment of **6 billion euro per year**.

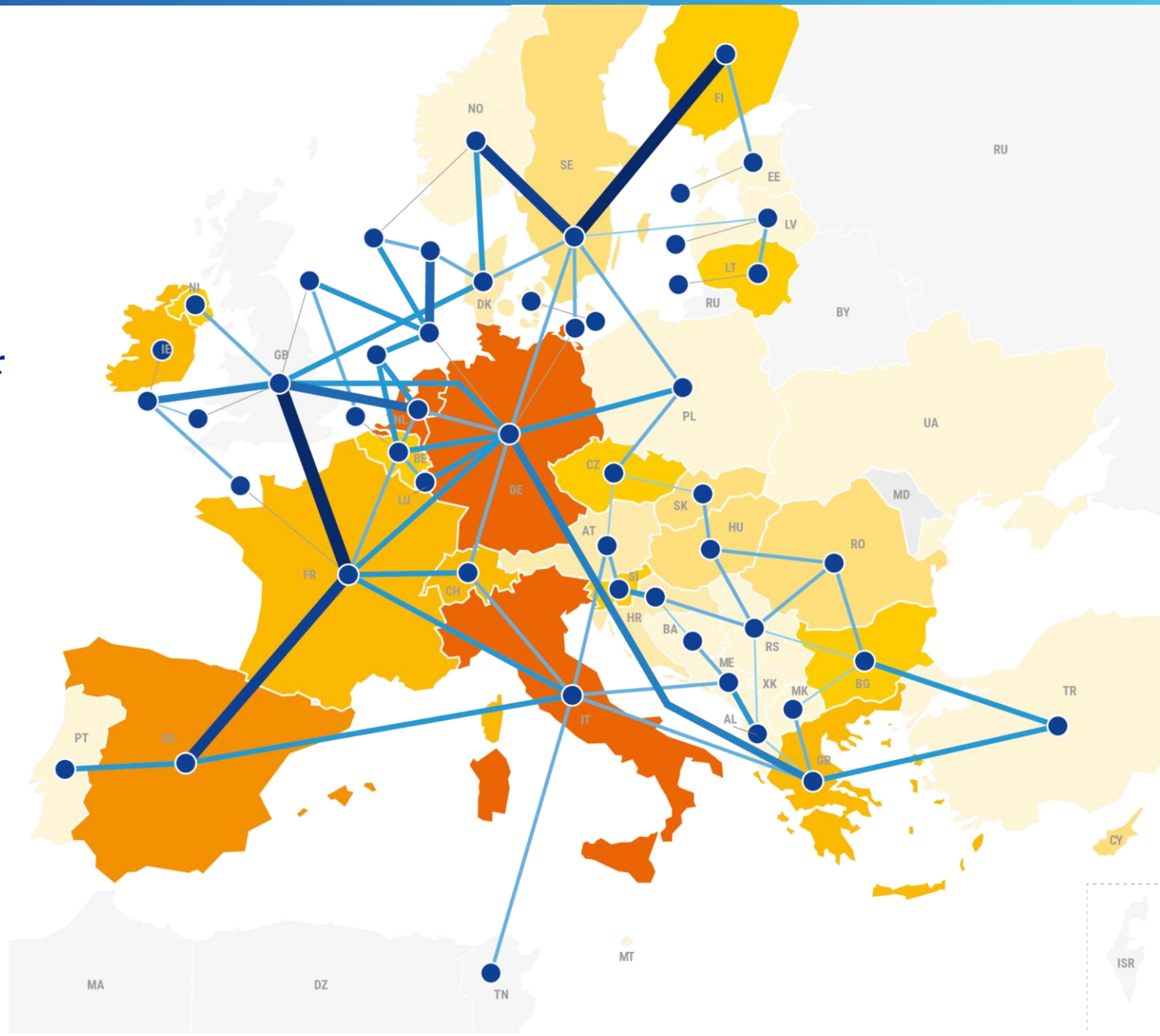
Gains

And would deliver a yearly **increase** in socio-economic welfare of **13 billion euro**.

2040 System Needs

By 2040 108 GW of additional cross-border capacity increases additional to the 2030 grid , including 20 GW of offshore hybrid corridors, would minimise the total costs of Europe's electricity system.

Each euro invested in the electricity grid translates into over 2 euros saved in system costs.



Cross-border capacity increases in 2040 (additional to 2040 starting grid)

- Home Market
- 1 – 500 MW
- 501 – 1,000 MW
- 1,001 – 2,000 MW
- 2,001 – 3,000 MW
- 3,001 – 4,000 MW
- 4,001 – 5,000 MW
- > 5,000 MW

Storage capacities per country in 2040

- 0 – 100 MW
- 101 – 500 MW
- 501 – 1,000 MW
- 1,001 – 5,000 MW
- 5,001 – 10,000 MW
- 10,001 – 20,000 MW
- > 20,000 MW

Gaps and opportunities for Europe's power system in 2030, 2040 and 2050

2050 results show the importanceof investing in grid and storage infrastructure to achieve a CO_2-neutral energy system

By 2050

The study finds that 224 GW of additional cross-border capacity increases after 2030, including 44 GW of offshore hybrid corridors will be needed to support Europe's achieve a carbon-free power system. 540 GW of batteries will provide the flexibility to the system

Investment

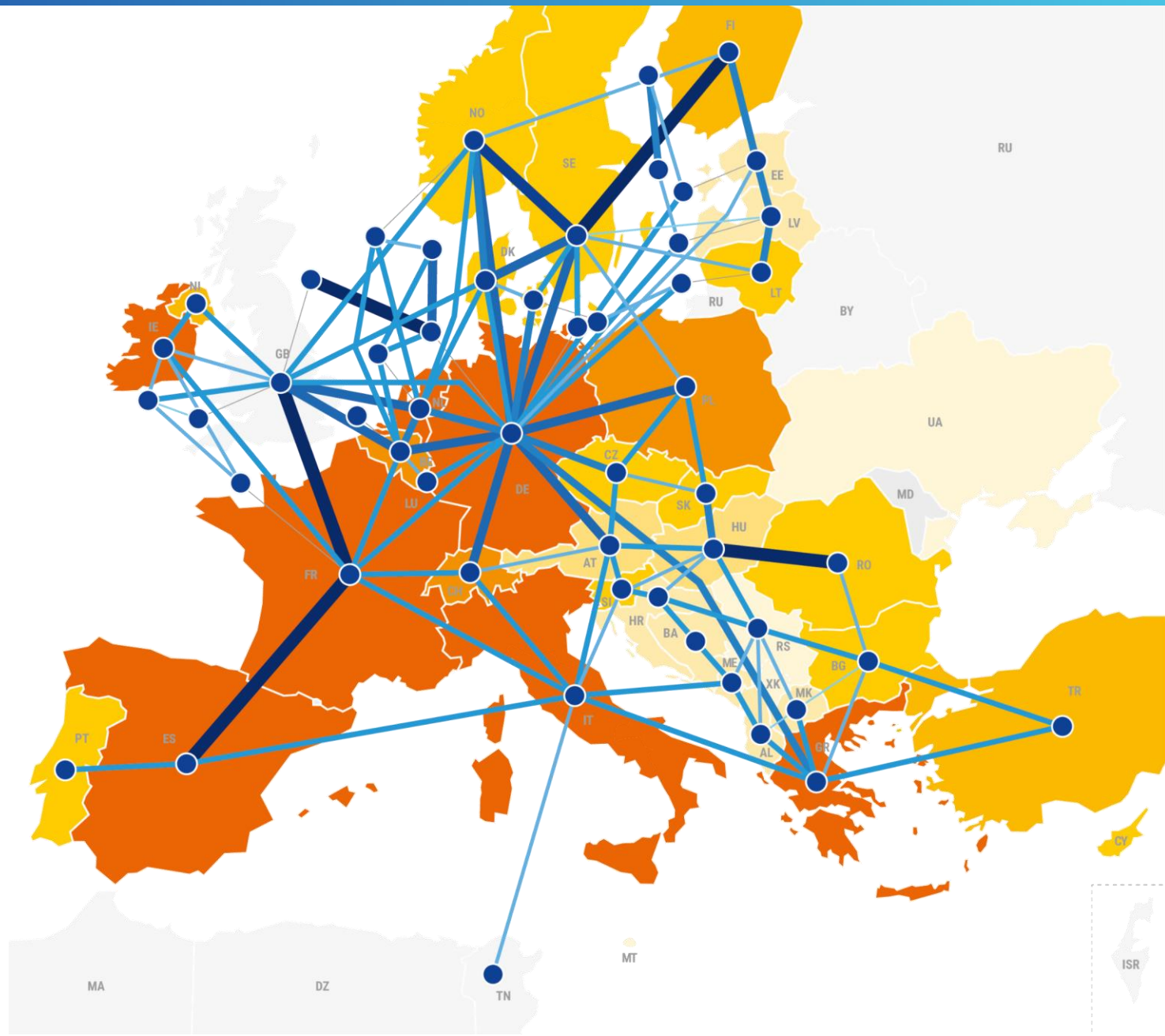
This capacity increase represents an investment of **13 billion euro per year**.

Gains

And would deliver a yearly **increase** in socio-economic welfare of **23 billion euro**.

2050 System Needs

By 2050 investing in an additional 224 GW of cross-border grid capacity, including 44 GW of hybrid offshore capacity, and 540 GW of power capacity from storage units would maximise the cost-efficiency of Europe's carbon-neutral electricity system.



Cross-border capacity increases in 2050 (additional to 2050 starting grid)

- Home Market
- 1 – 500 MW
- 501 – 1,000 MW
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- > 5,000 MW

Storage capacities per country in 2040

- 0 – 100 MW
- 101 – 500 MW
- 501 – 1,000 MW
- 1,001 – 5,000 MW
- 5,001 – 10,000 MW
- 10,001 – 20,000 MW
- > 20,000 MW

Gaps and opportunities for Europe's power system in 2030, 2040 and 2050

Efficiency measures can decrease system needs, but investments will be necessary to support the transition

Our Scenario is based on National Energy and Climate Plans. Already reflecting a world with **significant efficiency improvements of 29.4%**

Needs for capacity increase still exist in addition to these energy efficiency gains.

The future will see higher flows of RES electricity across borders.
Let's get Europe's cross-border transmission grid ready for it!

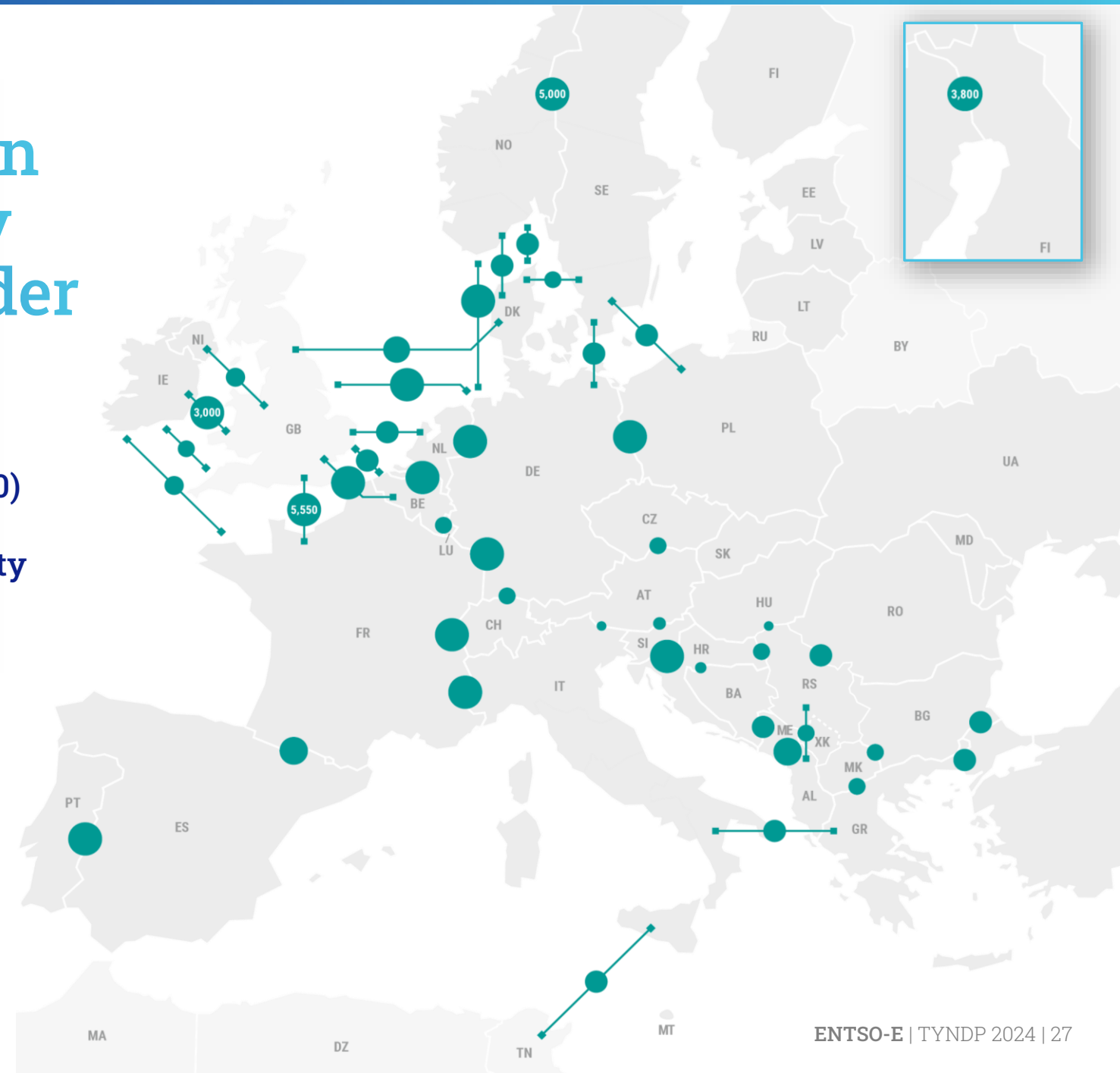
Existing transmission projects address only part of the cross-border needs in 2040

Comparing the TYNDP project portfolio (80 GW of cross-border capacity after 2030) with the optimized grid identified in 2040 (108 GW of additional cross-border capacity needed after 2030) shows a gap of 28 GW.

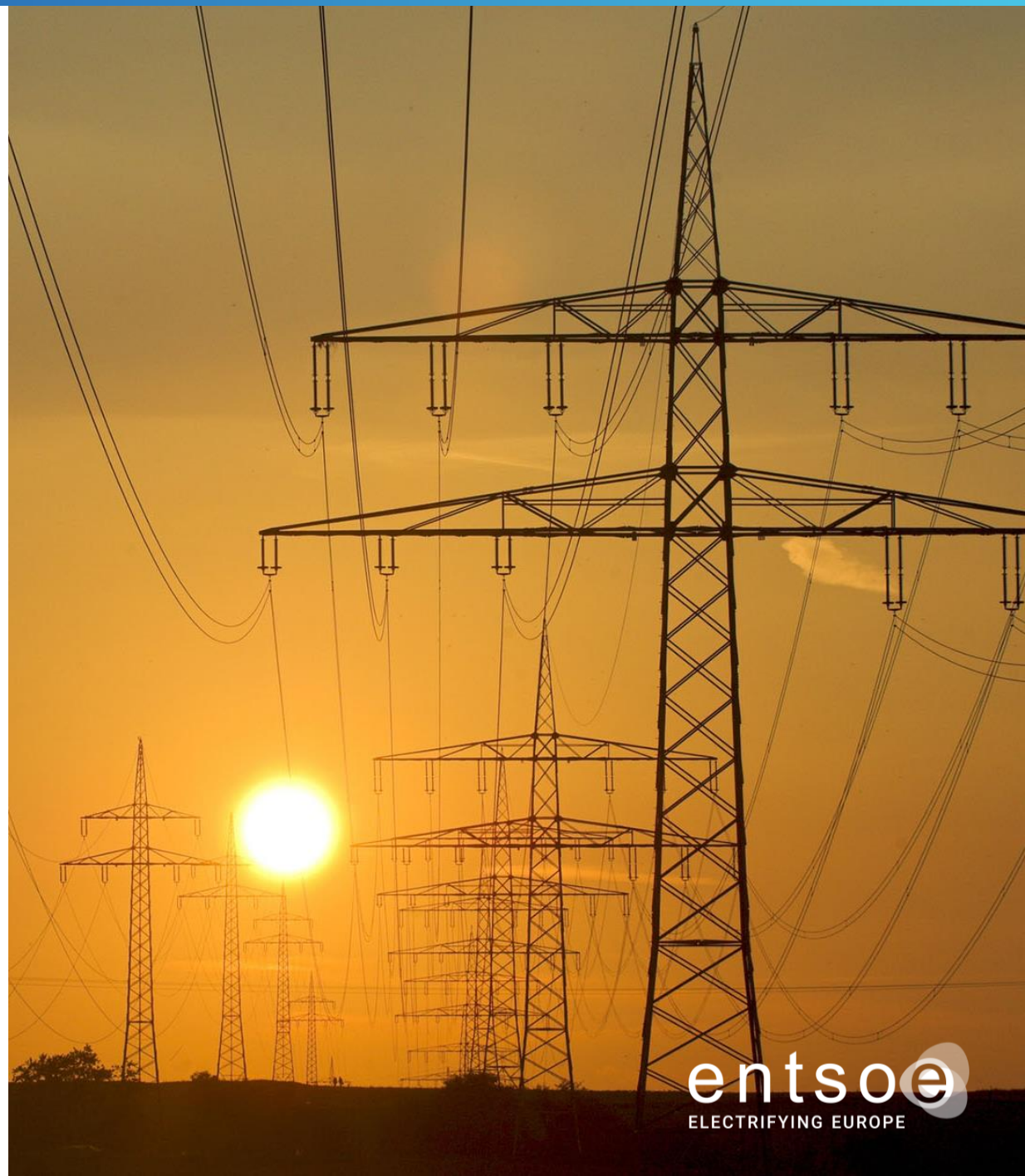
Infrastructure gaps

Difference between the identified needs in 2040 and existing transmission projects by that time horizon (MW). The bigger the circle, the bigger the opportunity for new solutions to increase cross-border capacity.

100 500 1,000 1,500 ≥2,000



How addressing system needs benefits Europe



How addressing system needs benefits Europe

What would happen in 2040 if …

We stopped investing in the power system after 2030?

EU Energy bill rising to 49.5 Billion euro per year

System instability and risk of blackout

473 TWh of renewable energy curtailed each year

Dependence on fossil fuels with 263 TWh of gas-based power generation per year

Grid not sufficient → Leads to no decarbonisation

What would happen in 2040 if …

We addressed system needs?

Investing 6 Billion euro per year cuts generation costs by 13 Billion each year

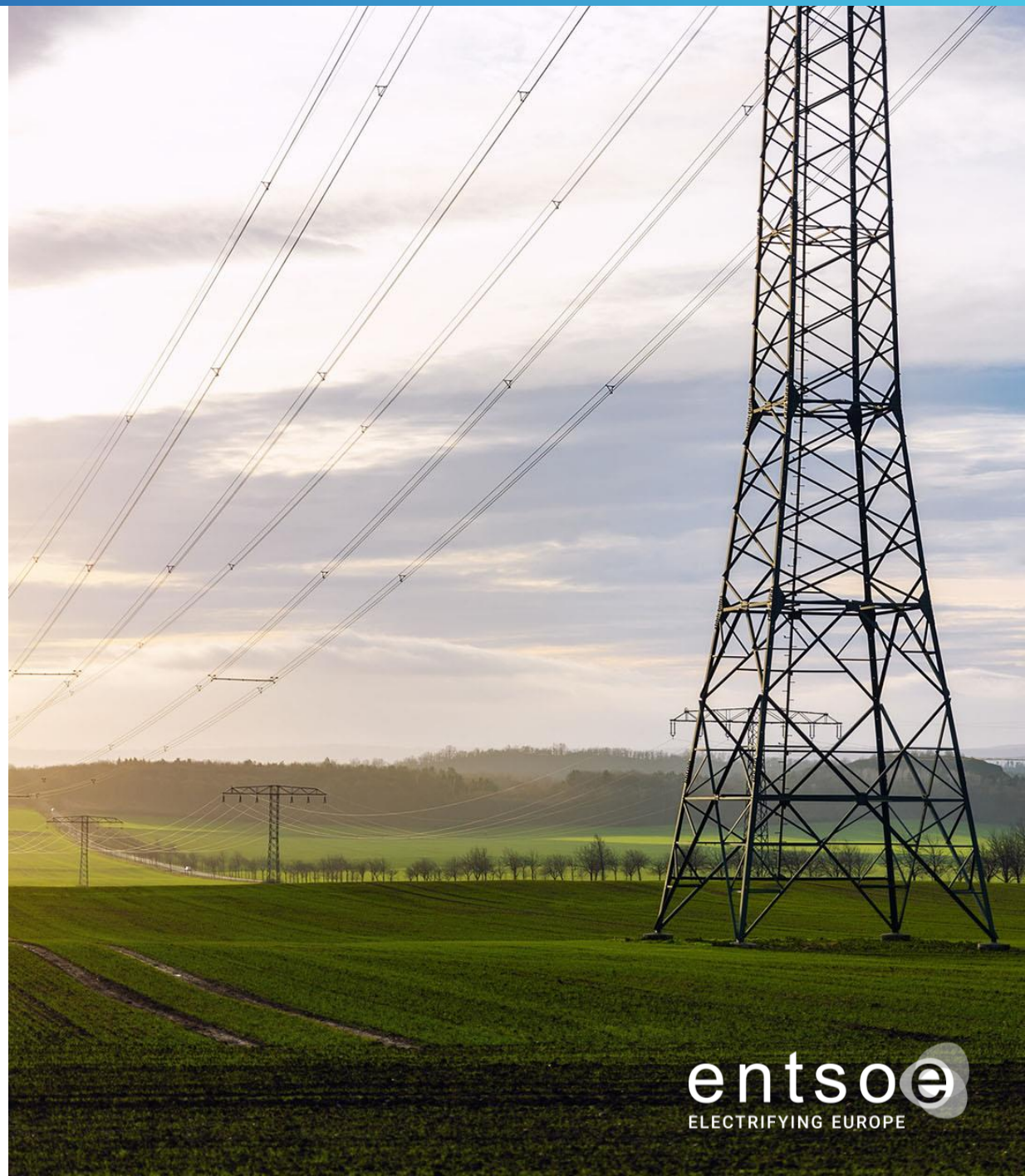
Ensuring stability and security of electricity supply in Europe

Avoiding the curtailment of 130 TWh of renewable energy each year

Fossil fuels' power generation is reduced by 58 TWh per year

Grid welcoming the expected development of renewables → CO_2 emissions cut by 31 Mton per year

High consistency with needs identified in TYNDP 2022



Gaps and opportunities for Europe's power system in 2030, 2040 and 2050

Comparing the results of the 2022 and 2024 system needs studies tends to show the robustness of the identified needs.

ENTSO-E AREA FOR 2040

Results in the
TYNDP 2022

208 GW total cross-border transmission capacity

(needs + capacity in the starting grid)

9 bn euro/year of Economic gains

6 bn euro/year of Investment costs

In cross-border capacity

≃

Results in the
TYNDP 2024

269 GW total cross-border transmission capacity

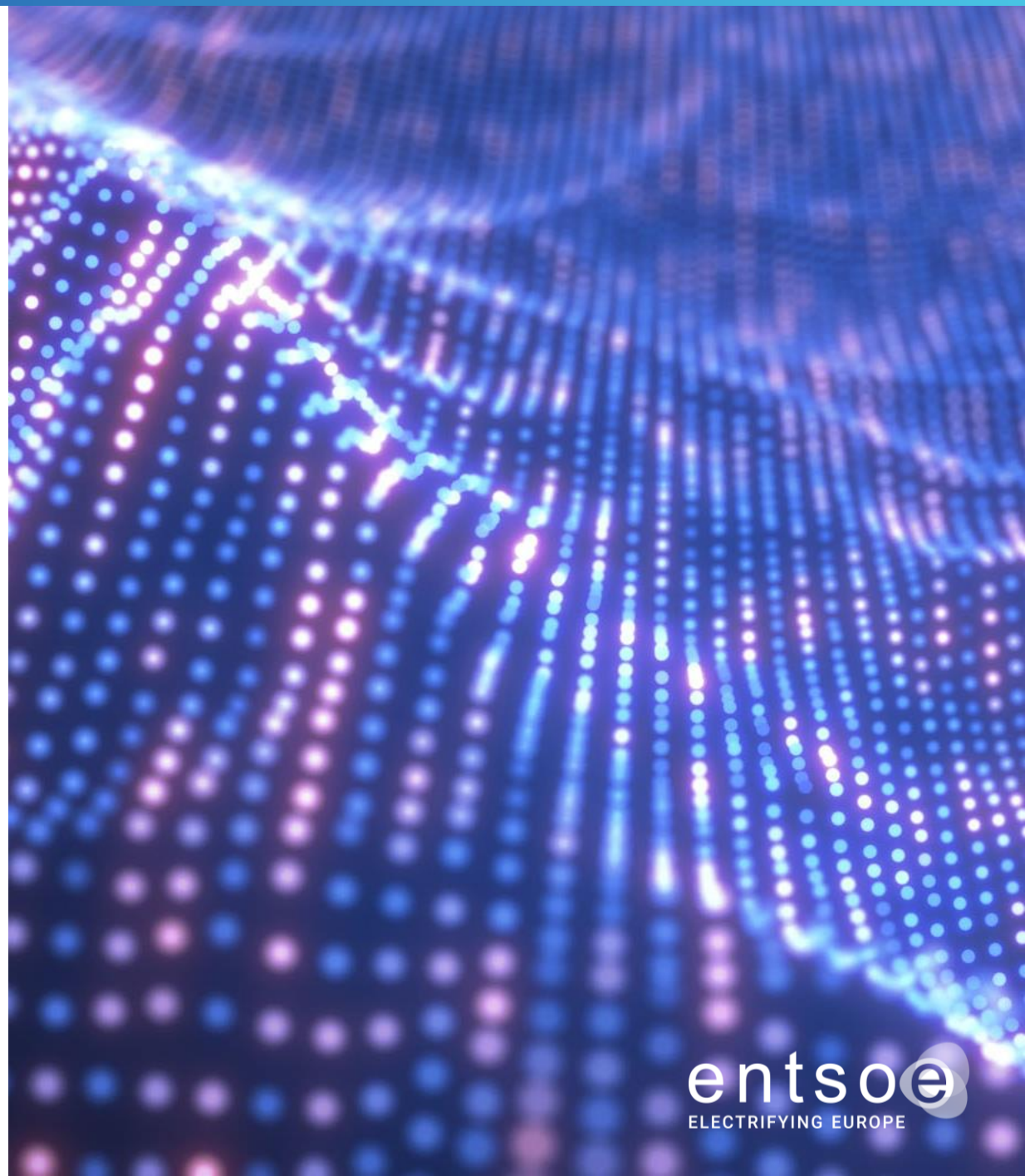
(needs + capacity in the starting grid)

13 bn euro/year of economic gains

5.9 bn/year of investment costs

In cross-border capacity

New needs – dynamic and operational challenges



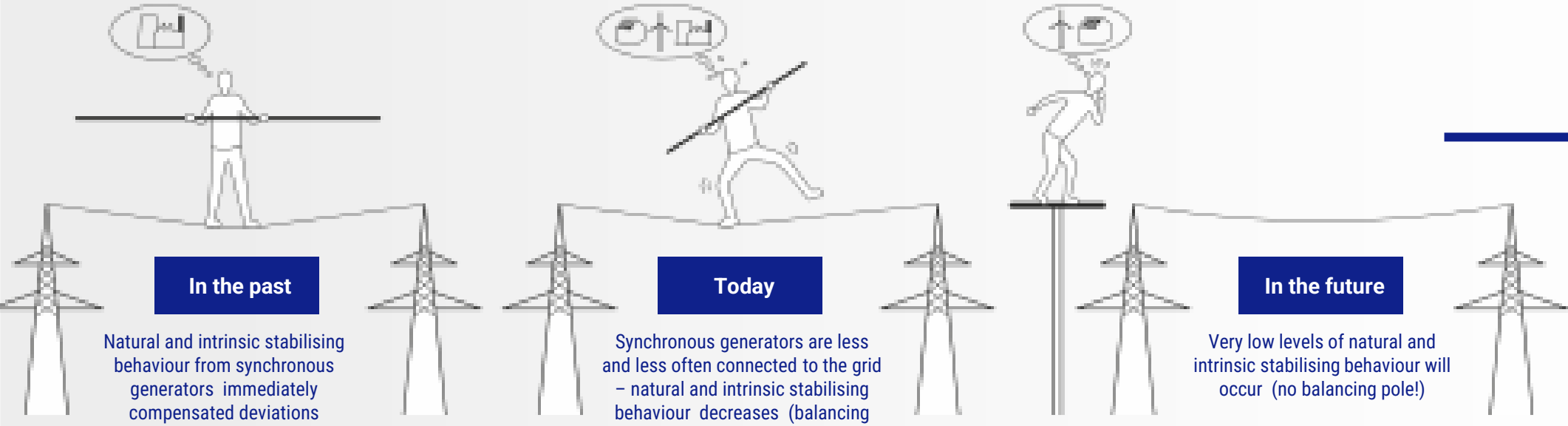
New needs – dynamic and operational challenges

Many challenges to consider in relation to the stability of the system

Flexibility aspects
New flexibility sources will be needed to accommodate for higher generation variation.

Transient and voltage stability related aspect
- Short-circuit power
- Reactive power fluctuations

Frequency management
- System inertia
- Frequency variations



In the past

Natural and intrinsic stabilising behaviour from synchronous generators immediately compensated deviations (long balancing pole)

Today

Synchronous generators are less and less often connected to the grid – natural and intrinsic stabilising behaviour decreases (balancing pole gets shorter and shorter)

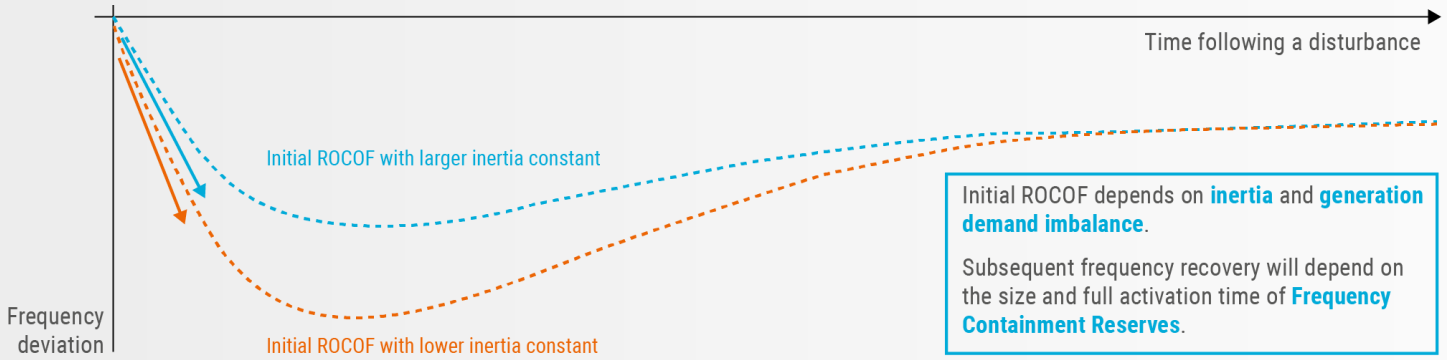
In the future

Very low levels of natural and intrinsic stabilising behaviour will occur (no balancing pole!)

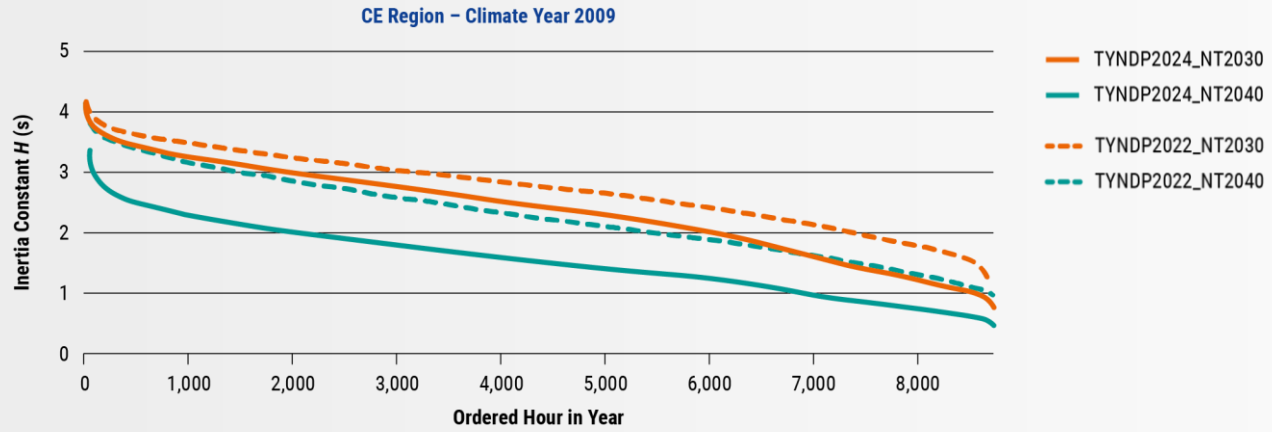
Need to restore this stabilising behaviour of the power system

New needs – dynamic and operational challenges

The more synchronous generators are disconnected, the more inertia decreases, the higher a frequency deviation can be



Inertia is the natural capability of the machines to stabilise the system thanks to the energy stored in the rotating masses



The most recent studies confirmed the trend in the decrease of inertia in all regions, but the challenges change from one region to another

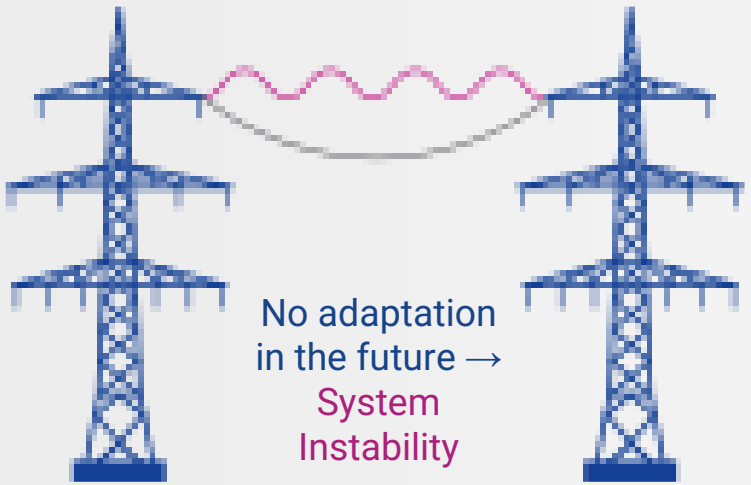
New needs – dynamic and operational challenges

How to adapt to the new system stability challenges?

Connection codes

New technical capabilities for system users

Network investments



No adaptation in the future → System Instability

Coordinated solutions in the future → System Stability

New needs – dynamic and operational challenges

Project Inertia studies the challenges related to inertia in Continental Europe and the impact of system splits

ENTSO-E, through Project Inertia and the TYNDP, proposes decision-making information and a roadmap to the foundational measures as part of a step-by-step, non-regret approach to deliver secure and efficient operation for a future-ready decarbonised system

A feasible and agreed roadmap with policy and regulatory decision-makers and further stakeholders is necessary and urgent. Resilience targets should be defined for the short/ medium and long-term. ENTSO-E proposes:

- Future devices (such as PPMs, STATCOMs, and SCs connected for system strength/voltage needs) to be connected to the grid shall in practice be equipped to provide inertia.
- Regarding future connection requirements to be enforced by the revision of the connection network codes, dedicated implementation guidance documents should support TSOs in defining adequate specifications for non-exhaustive requirements for the identified needs
- Optimisation and development of enhanced response measures and preventive measures should always be pursued
- By 2035, a minimum inertia constant of 2 sMW/MVA for 50 % of the year should be reached in CE SA
- A subsequent long-term target, subject to reassessment based on the return of experience, efficiency of grid forming, progress on foundational measures, and evolution of assets' RoCoF withstand capability, all countries shall ensure a minimum inertia constant of 2 sMW/MVA for 90 % of the year

Long-term needs and global resilience levels should be reassessed every two years in the regular TYNDP identification of system needs (IoSN) to ensure a focused assessment of the inertia needs leading to feasible mitigation plans implemented at the national level.

Project collection and identification

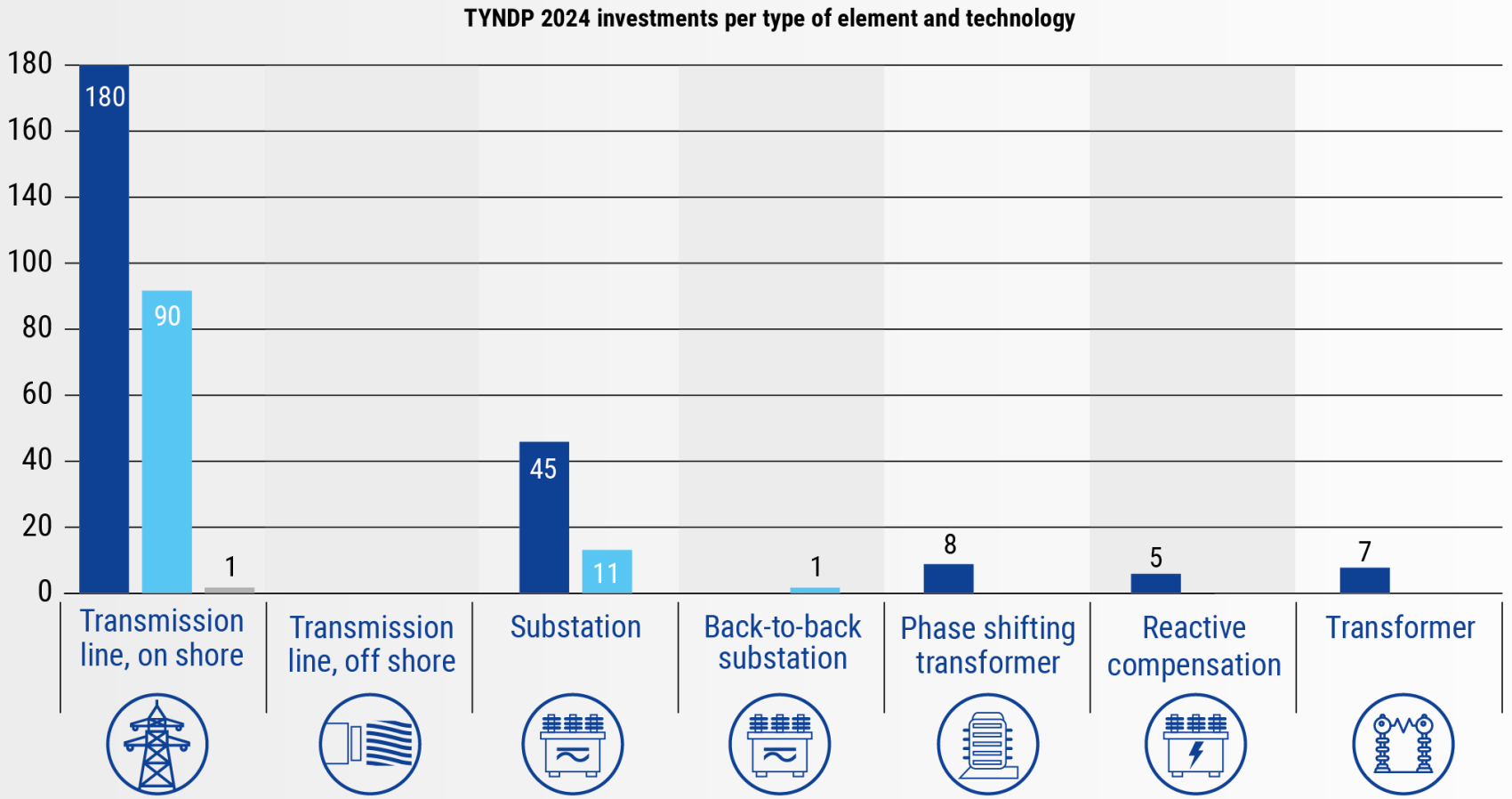
2 | NEEDS

3 | Projects

4 | COST BENEFIT

Project collection

Project portfolio: 348 Transmission investments

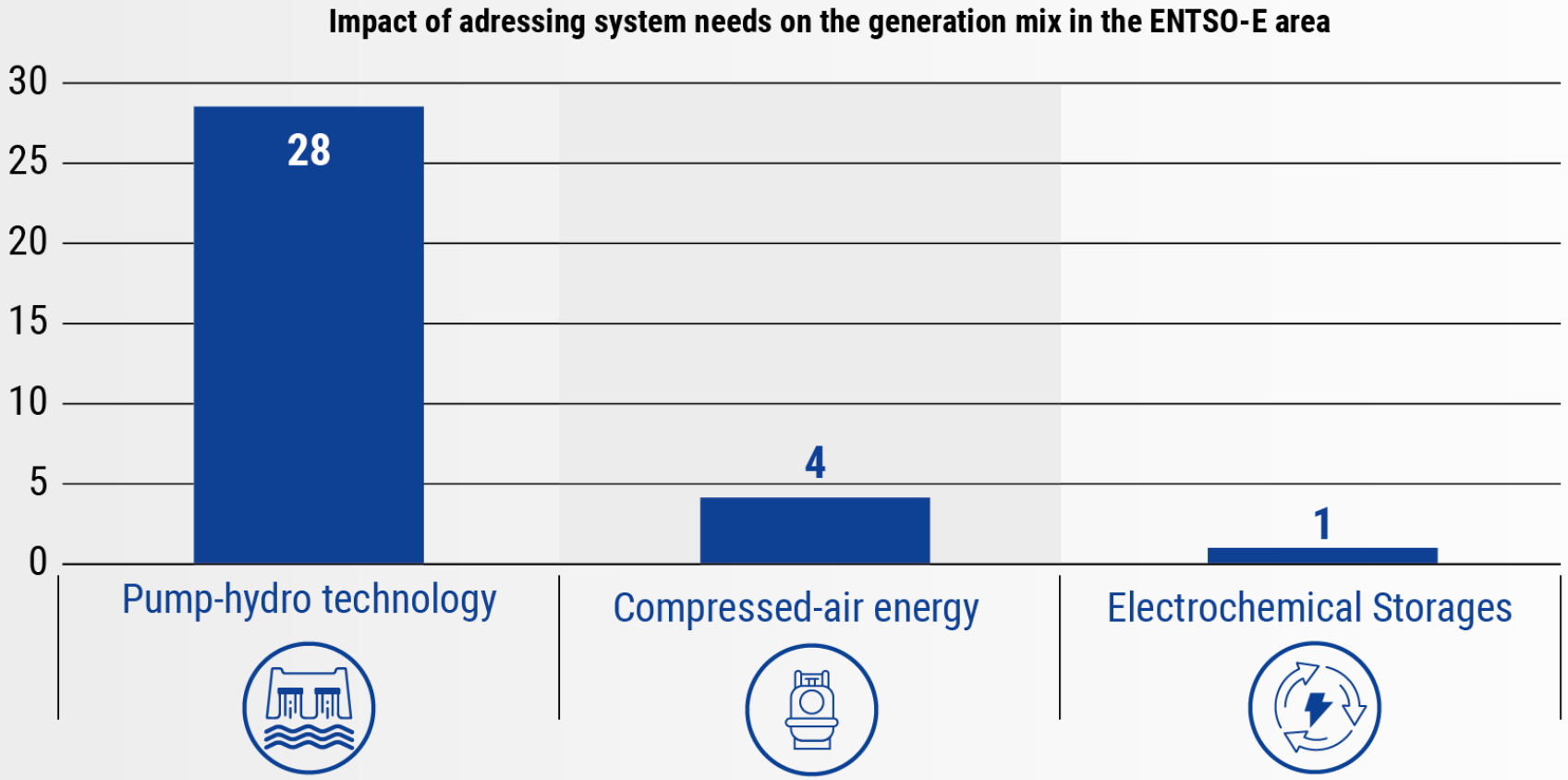


Context

TYNDP 2024's portfolio includes over 61,000 km of potential additional cables and lines. Of these, 19,000 km (42%) are AC, while 42,000 km (58%) are DC. The rapid advancement of DC technology has increased its doption, representing in this edition a 68% increase since TYNDP 2022.
A significant part of this growth comes from offshore infrastructure, which ist expected to drive higher investment in subsea DC cables.

Project collection

Project portfolio – 23 Storage Projects



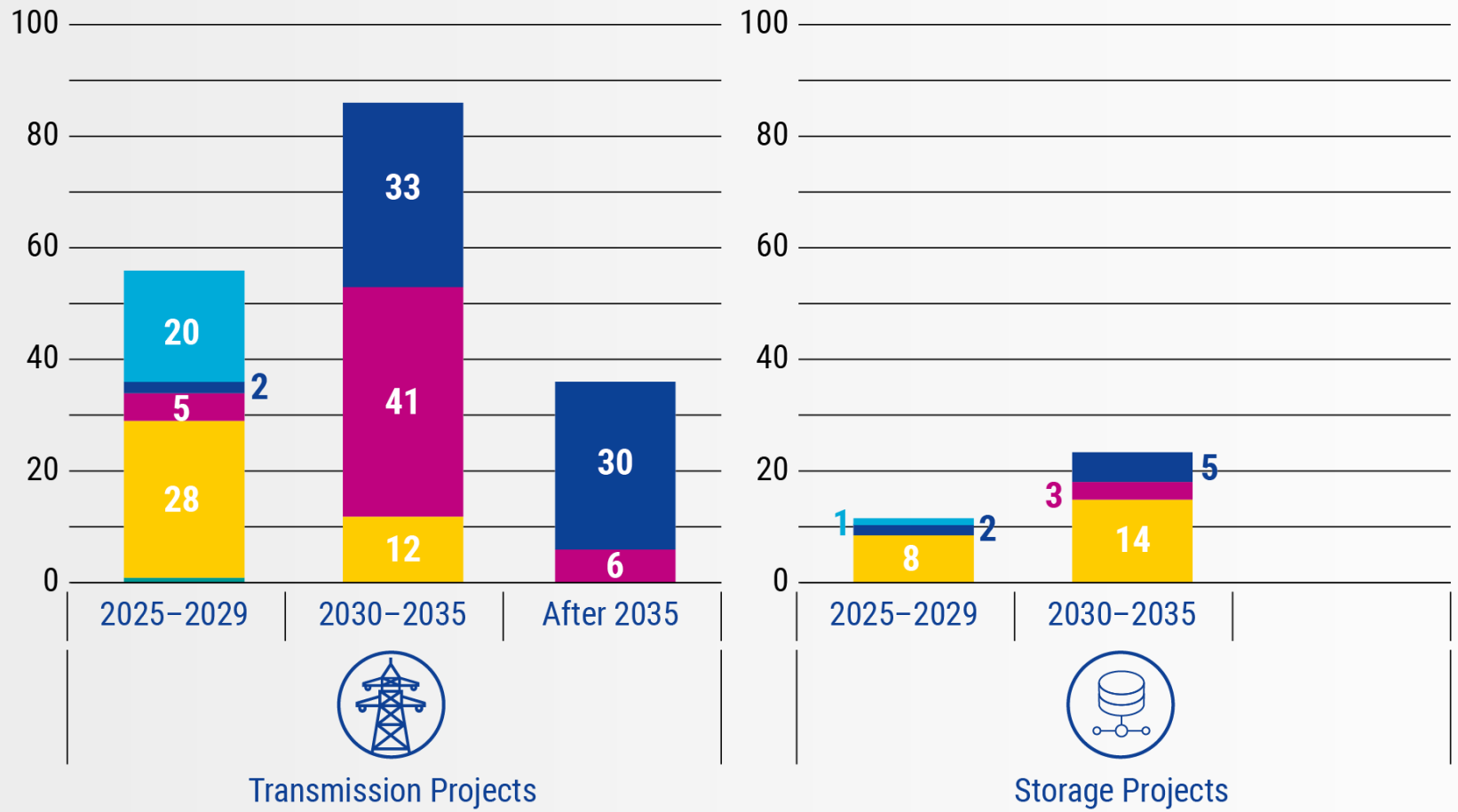
Context

The TYNDP 2024 portfolio includes 43 storage projects, of which 28 use pump-hydro technology, 4 compressed-air energy storage projects and 1 electrochemical storage projects complete the portfolio.

Only one of the projects has started the construction phase, while 7 are under consideration. 3 are in planning but has not completed the permitting phase, and 22 are in permitting. TYNDP 2024 includes 10 more storage projects than in 2022.

Project collection

Projects' expected commissioning year



Context

> 31 % of transmission projects are expected by promoters to come into service before 2030.

> Of the 40 transmission projects in the permitting phase, 29 were already in the permitting phase in TYNDP 2022.

> 65 transmission projects under consideration, of which 42 are new projects in this TYNDP.

> Of the 348 transmission investments, 46 (13 %) suffered delays in the past two years.

Cost benefits analysis of projects

3 | COLLECTION

4 | COST BENEFIT

Cost Benefit analysis

Cost Benefit Analysis: General Principle

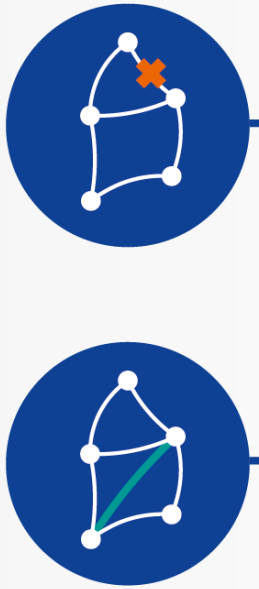
2030 grid (for the 2030 CBA) or 2035 grid (for the 2040 CBA)

Basis against which analysis are conducted.

Includes the capacity available in 2025 and all projects currently under construction or in advanced stages and that are expected to be commissioned until 2030.

Project already included in 2030 grid? ▶ Remove project from 2030 grid

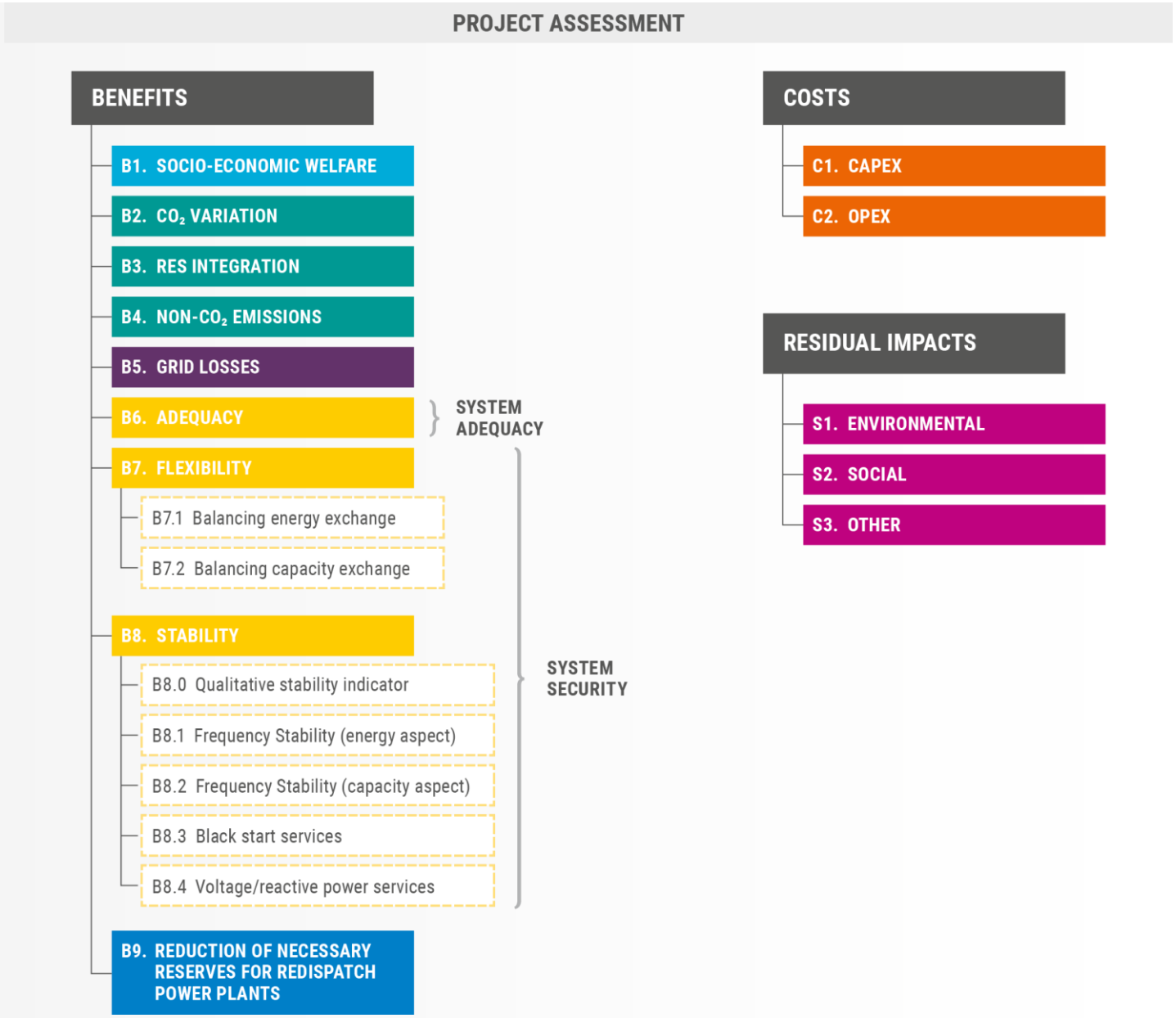
Project not included in 2030 grid? ▶ Add project to 2030 grid



Compare cases with and without the analysed project to evaluate costs and benefits

Cost Benefit analysis

What are the indicators we use?



Cost Benefit analysis

TYNDP 2024 Cost-benefit analysis of projects – Simulation details

MARKET STUDIES

- 211 projects
- 4 assessment teams
- 3 scenarios
- 3 comparisons
- 22,788 simulations
- 108 reference cases

NETWORK STUDIES

- 187 projects
- 3 scenarios
- 3 CO_2 variations
- 2 losses cases
- 3,366 simulations (tbc)

SECURITY OF SUPPLY STUDIES

- 3 scenarios
- 35 climate years
- 500 iterations
- 35,500 simulations

B6 CBA Indicator

- 3 scenarios
- 205 projects
- 2 cases (with and without projects)
- 1,230 simulations

Each simulation is conducted for the entire continent over a year, ie. 8 760 hours.

> 500 million instant renderings of the European electricity system

Cost Benefit analysis

What is in the project sheets?

Information distributed in 3 pages

TR 1 - RES in north of Portugal

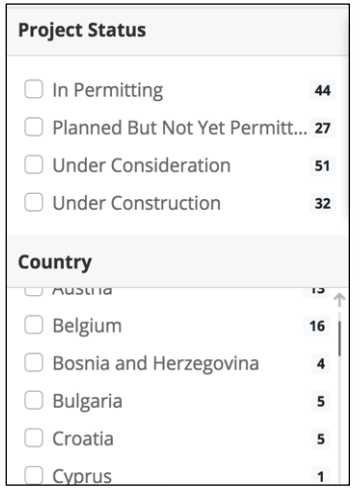
Export to spreadsheet | Download as PDF

Key Information | Project Description & Context | Project Assessment

Internal Project | Onshore substation | New | PCI number 2.16.3 (5th list) | Under Construction

Commissioning year estimated by the promoter(s): 2023

User friendly search/filter/export options



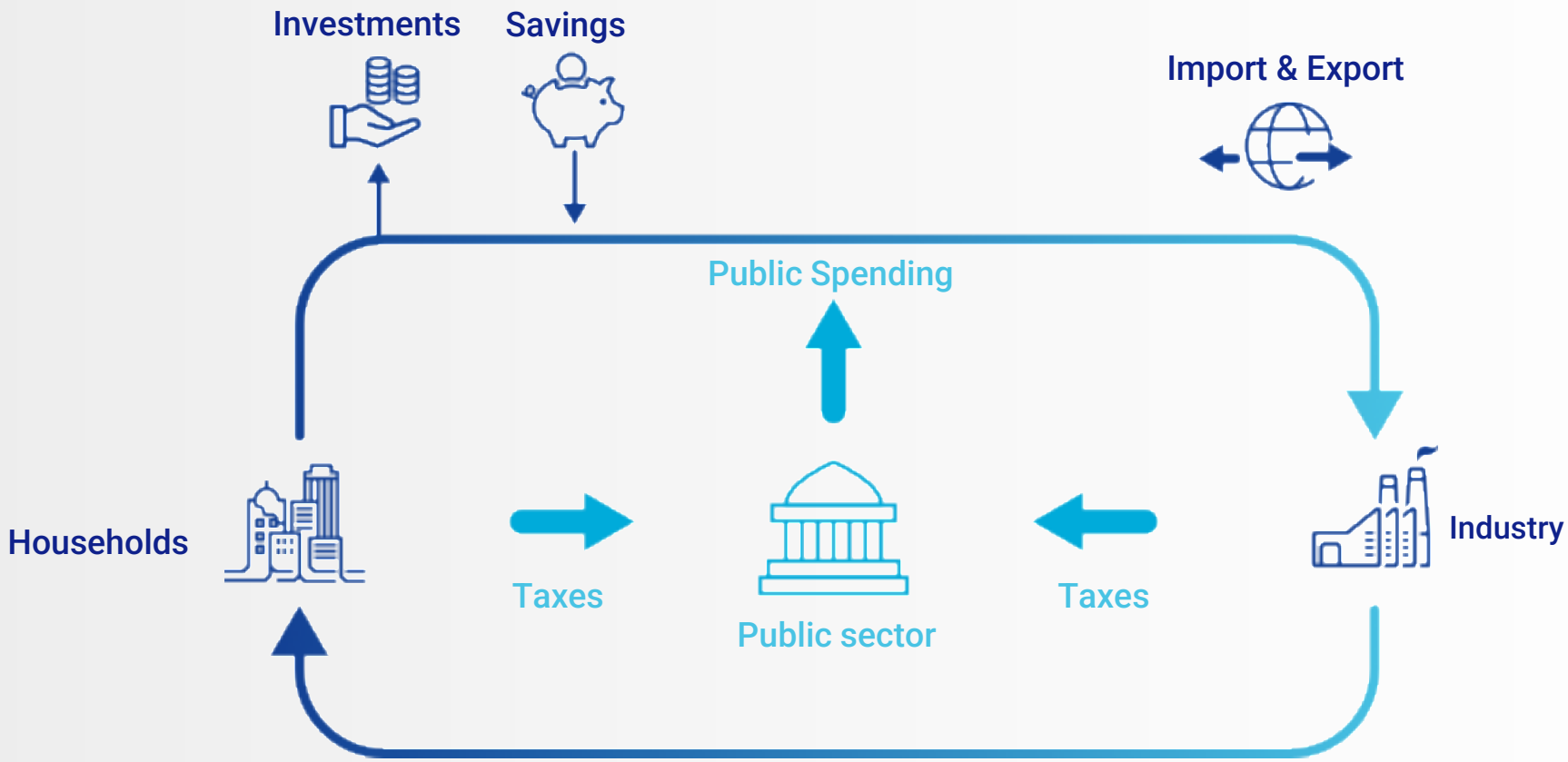
Pop-up with explanation on technical elements

Cost-benefit analysis results

How electricity infrastructure development will help Europe's economic recovery?

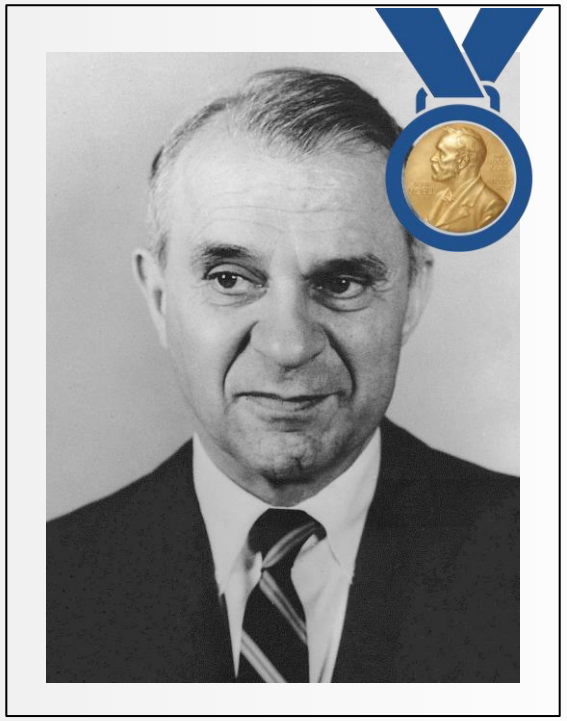
How electricity infrastructure development will help Europe's economic recovery

Any investment stimulates the economy



How electricity infrastructure development will help Europe's economic recovery

Methodology – Theoretical fundations

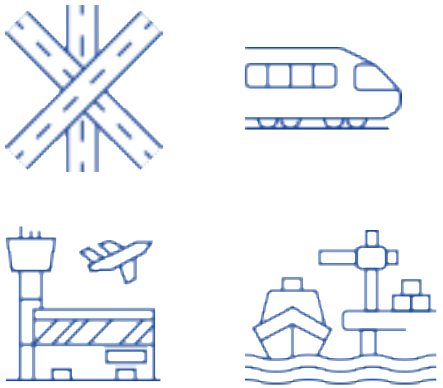


Wassily Leontief

was awarded the Nobel Memorial Prize in Economic Sciences in 1973 for the development of the input-output method and for its application to important economic problems.

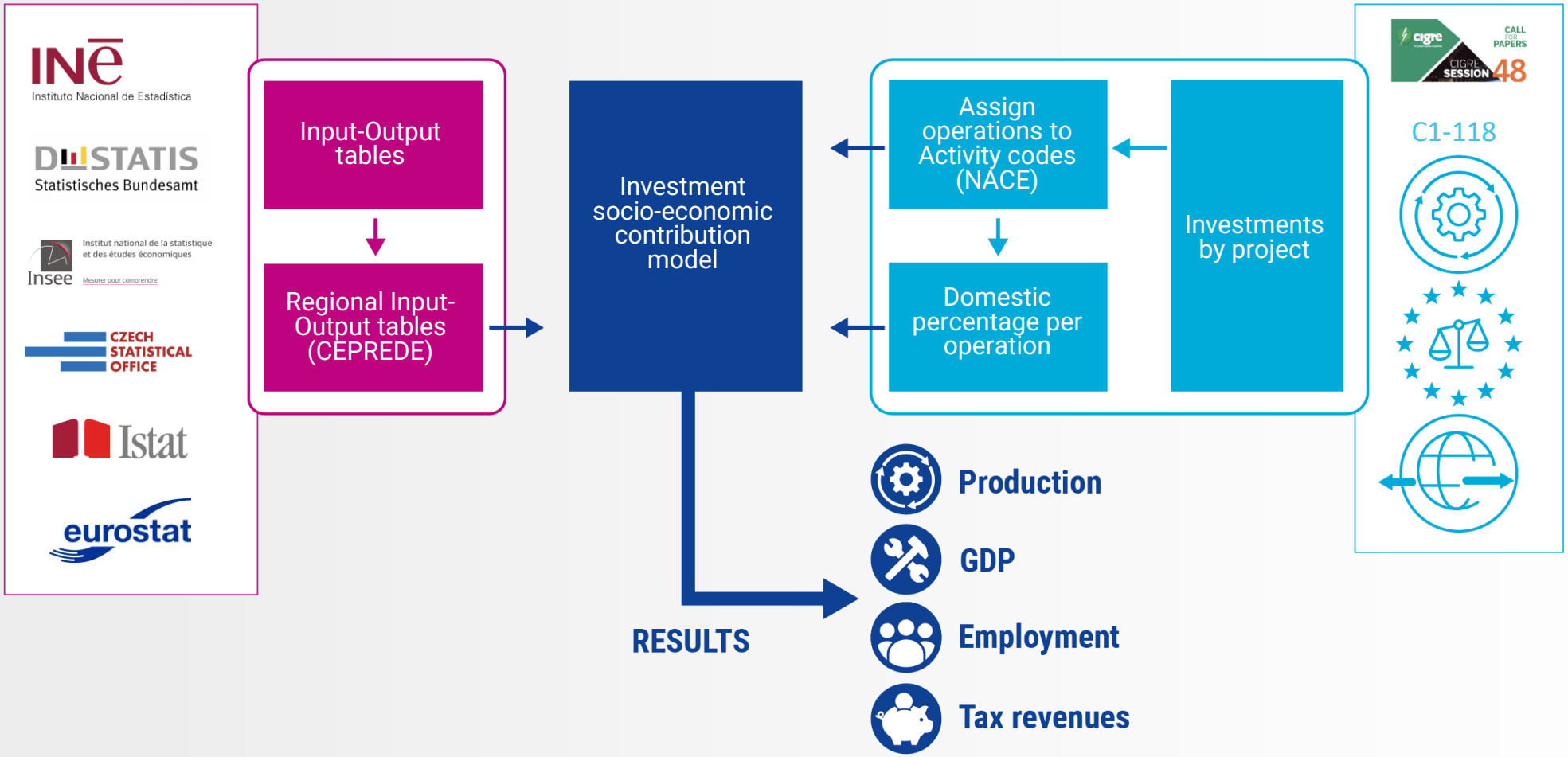
WIOD

Used in other infrastructure sectors



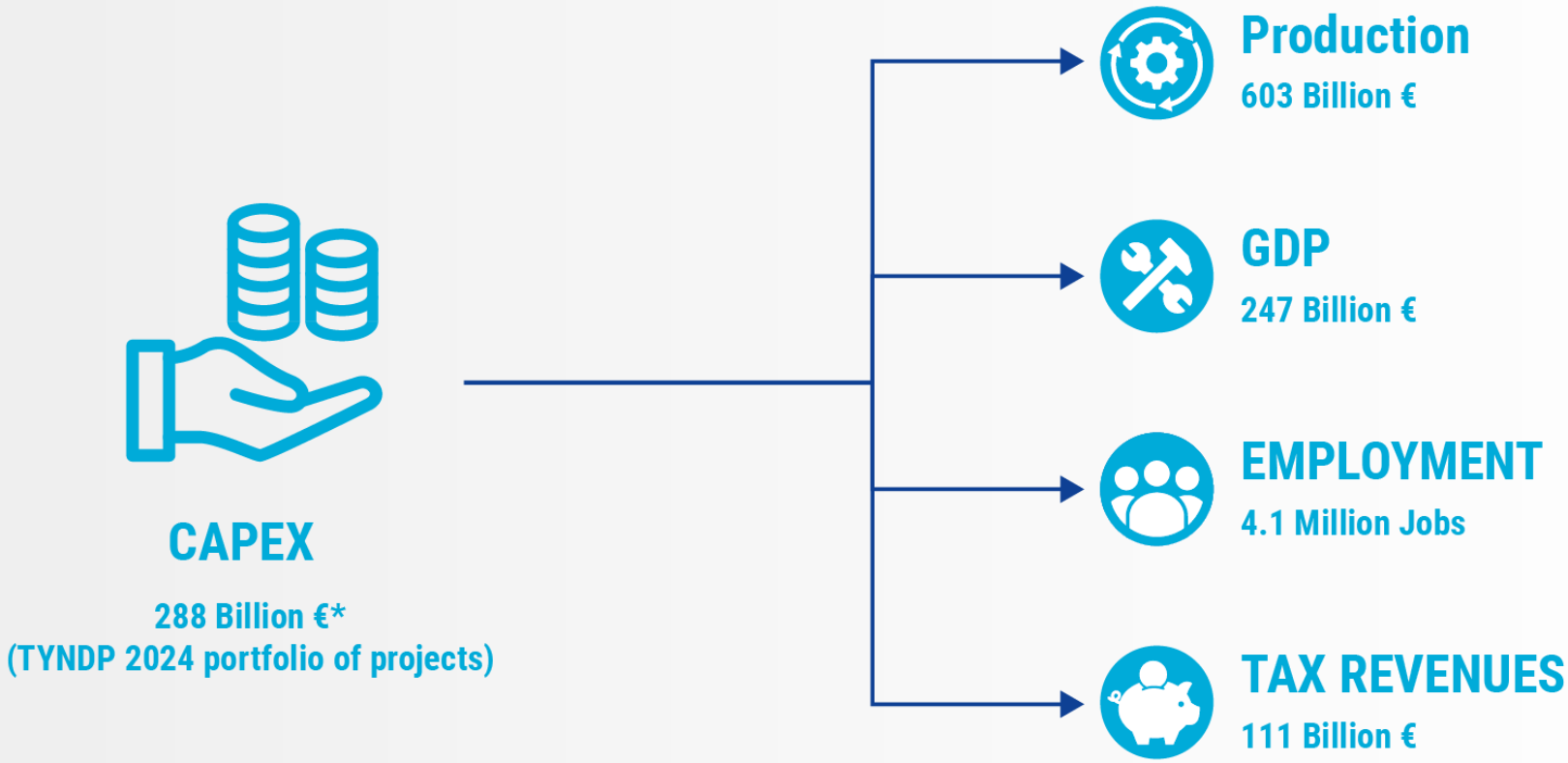
How electricity infrastructure development will help Europe's economic recovery

Methodology. Inputs and Outputs



How electricity infrastructure development will help Europe's economic recovery

Investing in electricity infrastruture will contribute to the European economic recovery



* CAPEX value correspondends exclusively to investments in the EU

What's next?

What's Next?

Polling survey

The TYNDP lays out our perspective, but now we want to hear from you

Give us your contribution now!

Share your views on
tyndp.entsoe.eu

The consultations runs until 14 March 2025

Stakeholders workshop on TYNDP: Past, present, future

Brussels (In Person) - March 27th

(Link)

Collaboration and questions at

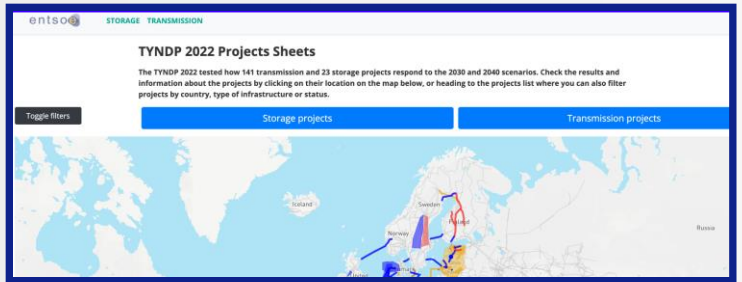
tyndp@entsoe.eu

Find the key messages and data you need to make a change on

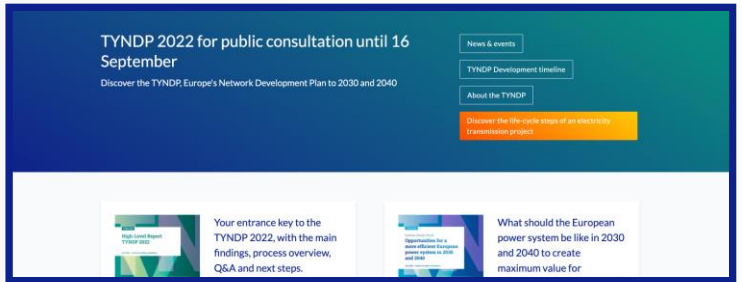
tyndp.entsoe.eu

Quick access

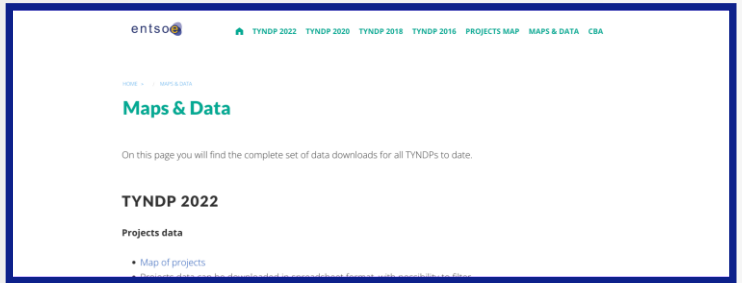
Reach what you need in one click!



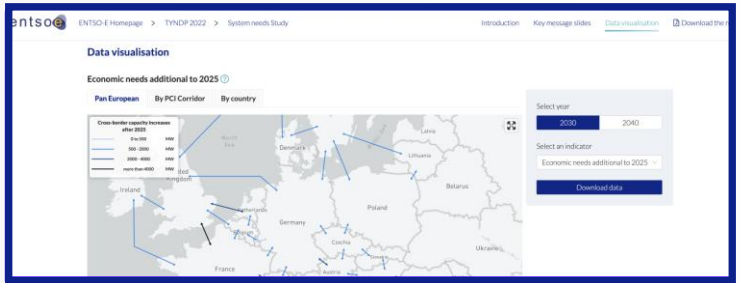
[Projects sheets]



[The TYNDP website]



Downloadable data



System needs interactive data visualisation

Q&A

Thank you

We hope today's presentation will allow you to make confident and impactful decisions for the future of energy in Europe!

ENTSO-E Mission Statement

Our values

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 40 member TSOs, representing 36 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.

ENTSO-E Mission Statement

Who we are

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 contibutions

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.

Our values define who we are, what we stand for and how we behave.
We all play a part in bringing them to life.

EXCELLENCE

We deliver to the highest standardss. We provide an environment in which people can develop to their full potential.

TRUST

We trust each other, we are transparent and we empower people. We respect diversity.

INTEGRITY

We act in the interest of ENTSO-E

TEAM

We care about people. We work transversal and we support each other.
We celebrate success.

FUTURE THINKING

We are a learning organisation.
We explore new paths and solutions.

We are ENTSO-E