TYNDP // 2026

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Scenarios Consultations Summary Report

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1 EXECUTIVE SUMMARY //

The TYNDP 2026 Scenarios aim at providing a sound basis to develop an infrastructure that is fit for purpose. As part of the TYNDP 2026 Scenarios cycle, the joint working groups of ENTSO-E and ENTSOG launched their public consultations in summer 2025. These consultations sought stakeholders' views on two consultation packages:

- TYNDP 2026 Scenarios' draft input assumptions, data, parameters and methodologies (publicly consulted upon between 16 June – 14 July 2025);
- TYNDP 2026 Scenarios' draft economic variants methodology (publicly consulted upon between 1 – 29 July 2025).

The consultations aimed to enhance transparency and accountability in the TYNDP Scenarios building process by gathering diverse stakeholder input – including citizens, academia, NGOs, and industry associations. It focused on collecting feedback on the recently published TYNDP Scenarios Innovation Roadmap, gathered data and methodologies used to develop a robust long-term energy forecast for Europe.

Additionally to the required questions and answers to the two consultation packages, this public consultations' summary report includes written answers to questions raised during the complementary public workshop from 4 July on the 2026 TYNDP Scenarios draft input data and methodologies focusing on the public consultation package and economic variants.

Key themes of the consultations' queries comprised the TYNDP Scenarios Innovation Roadmap for strategic planning, energy demand and supply data, infrastructure and capacity, market and commodity assumptions, methodologies for modelling and compliance in relation to the TYNDP 2026 Scenarios framework's central Scenario and economic variants.

One important contributor throughout the TYNDP 2026 Scenarios building process has been the Stakeholder Reference Group (SRG) who gave valuable input on the TYNDP Scenarios Innovation Roadmap, draft gap-filling methodology and draft commodity prices.

Most distinct findings of the two public consultations comprised stakeholder concerns around three key areas: First, the treatment of weather scenarios was widely discussed, with multiple stakeholders calling for the inclusion of more extreme climate events and improved granularity to better reflect future system stress and resilience. Second, demand-side flexibility was emphasised, particularly the need to model industrial, residential, and transport-related flexibility more accurately. Third, hydrogen imports and grid development were recurrent themes, with stakeholders urging more realistic assumptions about import potentials, greater transparency in modelling, and stronger integration with local renewable production and biomethane infrastructure. These topics reflect a shared desire for more robust, transparent, and climate-resilient energy system planning.

The next steps informed by the consultation will include iterative processes in which feedback prompts further engagement, testing, or co-creation activities to ensure continuous alignment with stakeholder needs.

2 INTRODUCTION //

Background

The European Network of Transmission System Operators for Electricity (ENTSO-E) and The European Network of Transmission System Operators for Gas (ENTSOG) typically invite stakeholders and the public to participate in the consultation on the development of joint Ten-Year Network Development Plan (TYNDP) Scenarios. These scenarios, jointly prepared by ENTSO-E and ENTSOG, provide a sound basis to develop a European infrastructure for electricity and gas that is fit for purpose.

Objectives of the consultation within a regulatory context

This consultation phase is grounded in the Framework Guidelines for Joint TYNDP Scenarios, which were developed by the EU Agency for the Cooperation of Energy Regulators (ACER) in accordance with Article 12 (1) of Regulation (EU) 2022/869. These guidelines aim to ensure that the Scenarios are:

- Transparent, with clear methodologies and accessible data;
- Non-discriminatory, treating all stakeholders and technologies fairly;
- Robust, reflecting a range of plausible futures and stress-tested assumptions;
- Aligned with EU policy objectives, including the 2030 climate and energy targets and the 2050 climate neutrality goal.

Therefore, the purpose of the consultation was to enhance transparency and accountability in the TYNDP 2026 Scenarios building process. To achieve this, the consultations gathered diverse perspectives, experiences and expertise from involved stakeholders – including citizens, academia, non-governmental organisations for citizen empowerment and climate action, industry associations – regarding the data and draft application in the process of building a best estimate forecast of European energy long-term planning. The consultation phase additionally aimed for further help in identifying unintended consequences and risks while strengthening of correct estimates that may have otherwise not been considered. The overall goal of building trust by showing that decisions are made through inclusive and transparent processes, rather than in isolation and increase the legitimacy of European climate policies and targets by demonstrating responsiveness of essential organisations for European energy cooperation to European climate policies and targets, the process aims to encourage ownership and acceptance of the outcomes of this TYNDP 2026 Scenarios' cycle. ENTSO-E and ENTSOG additionally anticipate that with the publication of the public consultations' summary report the transparency and robustness of the TYNDP 2026 Scenarios increases.

National and EU climate and energy targets

The Scenarios are built in line with European Union policy targets, using the most up-to-date data available at the time and reflecting the latest updated National Energy and Climate Plans (NECPs) as well as relevant national and EU policies.[1]

According to the European Commission's latest communication on the EU-wide assessment of the final updated NECPs (28 May 2025), the latest available NECPs demonstrate that the EU is closing in on its 2030 targets comparing to the draft updated NECPs. However, some gaps between the latest available aggregated NECPs and the EU-wide targets still remain.[2]

To ensure that the Scenarios remain aligned with EU-wide targets while accommodating NECPs, a methodological approach is developed to bridge the gaps. This EU-wide "gap-filling" methodology applies a transparent and consistent approach across all Member States, ensuring neutrality and equal treatment. It formed an integral part of the consultation process, offering stakeholders the opportunity to give feedback on the approach.

1 The cut-off date for TYNDP 2026 scenarios is communicated as 24 December 2024 after aligning with SRG, the EC and the ACER

2 European Commission's EU-wide assessment of the final updated national energy and climate plans Delivering the Union's 2030 energy and climate objectives.

Legacy framework

In previous cycles, the Scenario framework included a fully bottom-up National Trends + (NT +) Scenario alongside with two deviation Scenarios – Distributed Energy (DE) and Global Ambition (GA) – which illustrated alternative decarbonisation pathways toward 2050. Under the new ACER Scenario Framework Guidelines, this structure has been streamlined: the National Trends + Scenario serves as a Central Scenario with the core reference aligned with EU policy targets, while additional deviation Scenarios have been replaced by high and low economic variants that serve as stress tests to the Central Scenario rather than two additional stand-alone scenarios.

Novel Scenarios framework

ACER Scenario Framework Guidelines establish a structured and inclusive process for Scenario development. This includes the creation of a policy based central Scenario and two contrasting economic variants as a stress-test. The following section summarises the framework upon which the Scenarios are based:

Central Scenario: National Trends +

The Central Scenario, called National Trends + (NT +), reflects the latest updated NECPs. If the datasets are not available in the NECPs, it can be complemented by national planning and strategies, as well as the national strategies of non-EU countries. The National Trends + Scenario aligns with the EU's latest climate and energy targets and will be developed for the 2030, 2035, 2040 and 2050 time horizons. If aggregated TSO data does not align with the EU's latest climate and energy targets, a centralised gap-filling methodology is implemented.

Variant Scenarios: High and low economic variant

The higher and lower economy variants will be developed for the 2035 and 2040 target years only, as required by the ACER Scenarios Framework Guidelines. These economic variants are not stand-alone scenarios, they act as a stress test to the National Trends + Scenario and to be developed based on a centralised methodology, which does not require additional data collections from the TSOs.

Scope and timeline

Stakeholders' feedback is crucial to ensure that the Scenarios are comprehensively aligned with robust methodologies, assumptions, demand and supply figures. From June until late July 2025, the ENTSOs invited all stakeholders to participate in public consultations for the TYNDP 2026 Scenarios. The public consultations provided an overview of all draft input parameters and associated methodologies.

Stakeholders' feedback from the public consultations was integrated through a structured qualitative process. First, responses were analysed thematically to identify recurring concerns, suggestions, and emerging issues via structure of the public consultations. This enabled ENTSO-E and ENTSOG to grasp the breadth and depth of stakeholder perspectives. The insights informed the refinement of objectives, adjustments to draft proposals, and the justification of key decisions – sensuring that stakeholder input meaningfully shapes outcomes.

To maintain transparency, the Draft TYNDP 2026 Scenarios Public Consultations Summary Report summarises the input received via a response matrix (chapter 5), outlining how feedback was considered and why certain suggestions were adopted or were not.

ENTSO-E and ENTSOG extend their sincere appreciation to all stakeholders who contributed to this public consultation. The valuable insights provided by several stakeholder groups have significantly enriched the TYNDP Scenarios development process.

3 METHODOLOGY //

Written online consultations

The public consultations ran for four weeks each, launching on either 16 June or 1 July 2025 and closing correspondingly on either 14 or 29 July 2025. ENTSO-E and ENTSOG received 11 responses to the consultation on draft input assumptions, data, parameters and methodologies from the online survey. Six responses were received for the draft economic variants building methodology consultation. One out of the six responses was submitted belated via email, however, considered in the Public Consultations Summary Report. Stakeholders were encouraged to substantiate the relevance of their input by citing supporting sources in the designated sections.

The data analysis approach of the consultations' responses follows a qualitative analysis as executed in chapter 5 of this report.

Overview of respondents

To inform potential respondents about the then forthcoming two public consultations and the consultation workshop, various communication channels were used.

Concerning the TYNDP 2026 Scenarios' draft input assumptions, data, parameters and methodologies (publicly consulted upon between 16 June – 14 July 2025), eleven organisations submitted their responses, whose geographic focus of work covered Europe, the EU or as in three cases, additionally individual central-European or south-western EU member states. These organisations were at the time of consultation involved in either energy generation or distribution (5), climate and environmental advocacy (2), renewables (1) or electricity sector policy (1), the natural gas and hydrogen sectors (1) or chemicals (1).

Concerning the TYNDP 2026 Scenarios' draft economic variants methodology (publicly consulted upon between 1 – 29 July 2025), six organisations submitted their responses, whose geographic focus of work covered Europe, the EU or as in two cases, additionally individual central-European EU member states. These organisations were at the time of consultation involved in either electricity generation (2), electricity sector policy (1), climate and environmental advocacy (1), security of supply (1), the natural gas and hydrogen sectors (1).

A total of five organisations participated in both public consultations within this TYNDP Scenarios cycle.

Compared to the 30 respondents from the TYNDP 2024 Scenarios public consultation on the corresponding Input Parameters, published in January 2024, the TYNDP 2026 Scenarios cycle's public consultations' feedback reached a considerably lower turnout. The TYNDP 2024 Scenarios consultation, one third of the respondents consisted of Stakeholder Reference Group (SRG) members, whereas the representation of SRG members in the TYNDP 2026 Scenarios consultations more than halved in the current TYNDP cycle. This reflects the extensive engagement already undertaken with the SRG via dedicated consultations (e.g. economic variants, Scenarios Innovation Roadmap, commodity prices) and pre-consultation workshops on the TYNDP 2026 input parameters and methodologies before their publication.

Independent of the two public consultations as analysed above, the Stakeholder Reference Group provided official feedback in relation to the TYNDP Scenarios Innovation Roadmap, draft gap-filling methodology and draft commodity prices. Their recommendations have also been addressed in the related sections of chapter 5. Summary of Responses by Question and ENTSOs' Comments.

To ensure complete clarity in relation to the data and methodologies consulted upon, a description of each input is listed in chapter 4. Consultation Packages Input.

Public consultation workshop

On 4 July 2025, ENTSO-E and ENTSOG invited all interested stakeholders to take part in the public workshop on the TYNDP 2026 Scenarios draft input data and methodologies, putting particular focus on the first-time application of the economic variants via its draft methodology.

The stakeholder workshop gathered over 200 registered representatives from public and private sectors to discuss the development and later implementation of the upcoming TYNDP 2026 Scenarios. The aim was to foster meaningful exchange of findings and to support the ongoing creation of robust forecasts for Europe's energy and climate ambitions from today through 2030, 2040 up until 2050.

4 CONSULTATION PACKAGES INPUT //

The public consultations represent a significant milestone for the TYNDP 2026 Scenarios, designed to present an overview of all preliminary input data, parameters, assumptions and methodologies prior to finalisation.

In the context of the complex data sets and acknowledged challenges in understanding them, this dedicated chapter offers further explanation on the consulted data by unpacking the draft raw data, methodologies, and assumptions underpinning the TYNDP 2026 Scenarios building process. This chapter is therefore intended to foster additional transparency, allowing stakeholders to trace how draft conclusions were drawn, to provide a solid foundation for informed dialogue.

The consultation packages included:

1 // TSOs' data reflecting NECPs and national and EU policies – provided for informational purposes, including (see 4.1.):

- Energy Transition Model (ETM) Dashboards illustrating energy demand breakdowns by carrier and sector
- ETM links including country and sector specific energy demand inputs
- SMR and pyrolysis capacities
- PEMMDB 2.5. illustrating electricity generation and flexibility capacities
- Additional Data Collection supplementary supply and demand datasets

2 // Draft supply assumptions (see 4.2.):

- Commodity Prices
- H_2 and ammonia import potentials
- Import prices for synthetic fuels
- Technology costs

3 // Draft market modelling methodologies – including relevant assumptions (see 4.3.)

4 // Draft target compliance and gap-filling methodologies (see 4.4.)

5 // Draft carbon budget methodology (see 4.4.)

6 // Draft Scenarios grid methodology (see 4.5.)

7 // Draft Scenario weather year selection methodology (see 4.6.)

8 // Scenarios Innovation Roadmap (see 4.3.)

9 // TYNDP 2026 scenario building – economic variants development methodology (see 4.7.)

4.1 Aggregated TSO input – provided for informational purposes

A joint data collection for TYNDP 2026 and ERAA 2025 Scenarios was established to facilitate the highest possible consistency between studies, while recognising the unique nature of each study and, hence, allowing divergence of data where needed.

The data collection consisted of the following elements:

- Supply & Flexibility Data

The electricity related supply data was collected from TSOs through the PEMMDB application, where the data items are also described in detail. These datasets also cover the electrolyser generation figures. The remaining H_2 generation capacities were provided by gas TSOs via excel; which can be found under "SMR and pyrolysis generation capacities" excel.

- Demand Data

For TYNDP 2026 Scenarios, the demand input was jointly collected by gas and electricity TSOs through the ETM. The ETM is an open-source online tool to build and explore energy system scenarios, covering all relevant sectors and energy carriers[3]. For the Scenario building process, the ENTSOs use a stable standalone version of the ETM on a dedicated server.

3 https://energytransitionmodel.com/

The demand data was collected for the following sectors:

- Households;
- Buildings;
- Industry (energetic);
- Industry (non-energetic);
- Datacenters & ICT (Information and Communication Technology);
- Transport (national);
- Transport (International);
- Agriculture;
- Others.[4]
  - Additional Data Collection

Following a comprehensive analysis of the received data under the Scenario development process, the Working Group reviewed the data workflows and designed a questionnaire to collect the remaining essential datasets required for market modelling.

This additional data collection covered the following:

- District heating (including industrial steam network and agricultural heating) technology split and the respective efficiencies
- Demand and national production capacities for synthetic –and biofuels
- Domestic ammonia production used as shipping fuel
- National CCS capacities (totals, biogenic and those not connected to a powerplant)

The results of this data collection can be found in Additional Data Collection supplementary supply and demand datasets excel.

4.2 Draft supply assumptions – encompassing commodity and CO_2 prices, technology costs, import potential, and costs for hydrogen

The supply assumptions comprise a set of information pieces that are fed into the model to ensure that the most optimal feasible solution is achieved. These information pieces consist of commodity and CO_2 prices, H_2 and ammonia import potentials, import prices for synthetic fuel and technology costs.

The commodity prices recollect prices for different categories of fuels (nuclear, different kinds of coal, natural gas and other relevant gases, different kinds of oil) and CO_2, that are used in the different processes of the TYNDP 2026 Scenario Building. The prices are shown for the relevant target years of this study: 2030, 2035, 2040 and 2050 and are referred to 2024-euro values using the Harmonised Index of Consumer Prices (HICP). Each item has its own source reflected in the table. Some commodities' prices (biomethane, heavy and light oil and blended gas (the gas blend of biomethane, synthetic gasses and natural gas in the system)) are calculated, and those calculations can be consulted in the same file. For CO_2 prices, the values that are shown are the CO_2 prices that were recommended by the European Commission to be used in the NECPs by the different EU countries. The relevant sources can be found within the consultation package. The commodity and CO_2 prices have been already consulted with the SRG, EC and ACER prior to the public consultation.

The technology costs encompass the necessary costs needed to develop new possible sources of electricity generation or hydrogen production. Similarly to the commodity prices, the costs are shown for the relevant target years and are referred to 2024-euro values using HICP index.

Different sources and routes are considered for the imports of hydrogen from outside the EU. These import potentials are based on projects from ENTSOG TYNDP 2024 data collection supplemented with longer-term national strategies. Based on the market modelling methodology put in place, the market simulations will determine how much hydrogen will be imported from these import capacities. For all three hydrogen import sources a low-price band will be made available at a near-zero cost for a certain percentage, reflecting long-term take-or-pay contracts that will be put in place when these import projects would materialise. The remaining import capacities can be used when the market hydrogen price in the simulation model exceeds the marginal production cost of hydrogen for the respective import routes.

4 Includes Not elsewhere specified (Other), Not elsewhere specified (Transport), Natural gas for pipeline transport

4.3 Draft market modelling methodologies – including assumptions

The Draft Market Modelling Methodologies – including relevant assumptions represents the outcome of a collaborative and iterative process involving experts from both gas and electricity TSOs within the Working Group Scenario Building (WGSB). This process was designed to ensure that the methodologies reflect technical expertise, stakeholder expectations, and regulatory alignment.

The development of these methodologies was shaped by extensive stakeholder feedback:

- Stakeholder feedback collected during the TYNDP 2024 public consultation,
- Recommendations from the SRG, which have been systematically reviewed and integrated into planning for the TYNDP 2026 cycle.

Link to the Innovation Roadmap:

The Innovation Roadmap serves as a key reference document for this cycle. It includes:

- A review of innovations not implemented during the TYNDP 2024 cycle,
- A set of essential model fixes introduced to improve the 2024 models,
- Newly proposed innovations to address emerging needs in the 2026 Scenario cycle.

These innovations were prioritised for implementation in 2026 based on their potential impact and feasibility.

From innovation to methodology:

Based on these priorities, the WGSB developed and tested updated modelling methodologies.

- Innovations that successfully passed the testing phase in time were incorporated into the models for this cycle.

As a result, the draft methodology report reflects not only technical improvements but also a direct response to stakeholder feedback and SRG recommendations, ensuring that the TYNDP 2026 Scenarios are built on a transparent and forward-looking foundation.

4.4 Draft gap-filling methodologies including draft carbon budget methodology

TYNDP 2026 Scenarios focus on target compliance and place strong emphasis on alignment with energy and climate objectives. The target and gap-filling methodology ensures that the Scenarios meet regulatory requirements and climate targets in a consistent and transparent manner.

Scenarios are required to follow the energy efficiency first principle, align with the 2030 energy and climate targets, and EU's 2050 climate neutrality objective. They take into account the latest Commission Scenarios and NECPs. The cut-off date for policy targets and input data for the TYNDP 2026 Scenarios was set at 24 December 2024, following alignment with the SRG, the European Commission, and ACER. As of this cut-off date, there were no binding EU-wide targets for 2035 or 2040. Therefore, target justification is required only for the NT + 2030 horizon and the NT + 2050 horizon, which reflects the climate neutrality objective.

Mandatory targets include at least 55 % GHG emissions reduction by 2030 compared to 1990 levels, carbon neutrality by 2050, at least 42.5 % share of renewable energy by 2030, and maximum EU final and primary energy consumption limits of 763 Mtoe and 992.5 Mtoe respectively by 2030. In addition, non-binding offshore targets provided by the Member States are taken into account.

The gap-filling methodology applied in the TYNDP 2024 Scenarios has been used as the foundation for addressing any discrepancies between national data and EU targets in the TYNDP 2026 Scenarios, ensuring a coherent and comparable approach across countries. For Scenarios not meeting the targets, the process involves reducing final energy demand, applying gap-filling for both energy consumption and renewable energy targets, and adapting a carbon budget approach for GHG reduction targets. All Scenarios must comply with these targets before publication. The gap-filling methodology was developed using country-specific final energy consumption targets.

In the carbon budget the net-carbon emission is calculated for the period from 2030 to 2050. The emissions computed in the Scenarios stem from the use of fossil fuels across the energy, heating and transportation sectors. Besides the carbon emission from these sectors emissions from non-energy related emissions from industry and non-CO_2 emissions (primarily from agriculture) are added. Both are coming from external studies[5] where trajectories are given for different EU policies. Calculated carbon removals are subtracted from total emission in each Scenario. These carbon removals comprise the combined contributions of Carbon Capture and Storage (CCS) and Land-Use, Land-Use Change and Forestry (LULUCF) during the assessed period. CCS estimates are derived from data provided by the TSOs and the values for LULUCF are based on external studies referenced in the impact assessment. The resulting carbon budget is then compared against the indicative carbon budget set up in the impact assessment (16 $GtCO_2$-eq) and the targets of a 55 % reduction by 2030 and climate neutrality by 2050.

4.5 Draft scenarios grid methodology

The TYNDP 2026 Scenarios Grid Methodology provides a structured framework for assessing and categorising electricity and hydrogen infrastructure projects across different time horizons – 2030, 2035, 2040, and 2050. It distinguishes between levels of project maturity and readiness, aligning with CBA Guidelines and EU planning frameworks.

Electricity projects to be included in the Scenarios grid come from ENTSO-E's TYNDP 2026 Project Collection, which took place in Q2 2025. These projects are classified into the following categories:

- Under Construction
- Completed Environmental Impact Assessment (EIA)
- In Permitting/Planned but not yet permitted
- Under Consideration: Projects in the planning study phase, being evaluated for inclusion in national plans or EU-wide TYNDPs.
- Conceptual: Projects not yet submitted to the TYNDP cycle but under investigation by TSOs. These are technically justifiable and economically probable, often supported by preliminary studies.

ENTSOG's TYNDP 2026 Project Collection will end in Q4 2025. Therefore, the hydrogen projects to be used in this Scenarios process are those submitted to TYNDP 2024, with a review applied to ensure relevance and consistency[6]. They are grouped into:

- PCI/PMI: Projects with official status from the latest PCI cycle.
- Advanced: Commissioning date ≤ 2030, included in NDPs or validated via market tests.
- Less Advanced: In concept, design, or planning stages but not meeting advanced criteria.
- Conceptual: Similar to electricity, these are potential projects not yet submitted but under technical and economic evaluation.

5 Impact assessment from European commission, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52024SC0063

6 For offshore infrastructure, additional capacity may be assumed if required to connect offshore energy production.

Each time horizon includes a mix of project maturity levels:

	2030	2035	2040	2050
Electricity	**ELECTRICITY** – Under Construction – Completed EIA	**ELECTRICITY** – Under Construction – Completed EIA – In permitting / Planned, but not yet permitting	**ELECTRICITY** – Under Construction – Completed EIA – In permitting / Planned, but not yet permitting	**ELECTRICITY** – Under Construction – Completed EIA – In permitting / Planned, but not yet permitting – Under Consideration – Conceptual
H_2	**HYDROGEN** – PCI/PMI – Advanced	**HYDROGEN** – PCI/PMI – Advanced	**HYDROGEN** – PCI/PMI – Advanced – Less-Advanced	**HYDROGEN** – PCI/PMI – Advanced – Less-Advanced – Conceptual

4.6 Draft Scenario weather year selection methodology

The TYNDP 2026 Scenarios introduce a significant advancement in energy system modelling: for the first time, future climate projections from the Coupled Model Intercomparison Project Phase 6 (CMIP6) initiative are incorporated alongside historical weather data. This shift reflects the growing need to account for the impacts of climate change on energy infrastructure and system resilience.

Weather variability has a direct influence on energy generation and consumption. Renewable energy sources – such as solar, wind, and hydro – are particularly sensitive to climatic conditions, while temperature fluctuations affect electricity demand. Therefore, selecting representative weather years is essential to ensure robust and future-proof energy system planning.

The methodology developed for the TYNDP 2026 Scenarios identifies a representative subset of climate years from the Pan-European Climate Database (PECD) version 4.2 dataset. It focuses on key climate variables relevant to renewable energy generation and electricity load, ensuring that the selected years reflect realistic and diverse future conditions. All the related information on the PECD, including the definitions, documentations of climate scenarios and models and underlying datasets can be reached from Copernicus's website[7].

Using the Shared Socioeconomic Pathway 2 (SSP2) – 4.5 climate Scenario and three climate models (CMR5, ECE3, MEHR), a pool of 30 years is created for each target year. From this pool, three representative years are selected through a rigorous statistical process. This includes:

- Calculating regional averages and standard deviations of climate variables;
- Normalising and reducing data using Principal Component Analysis (PCA);
- Applying k-means clustering to identify distinct climate patterns;
- Selecting the medoid year from each cluster as the most representative.

These selected weather years form the basis for Scenario development in TYNDP 2026 Scenarios, ensuring that infrastructure planning is aligned with future climate realities. This approach strengthens the EU's ability to build a resilient, sustainable, and climate-adaptive energy system.

7 https://cds.climate.copernicus.eu/datasets/sis-energy-pecd?tab=overview

4.7 Draft Economic variants methodologies

According to Recital 27 of the ACER Scenario Framework Guideline, the set of mid-term (2035) and long-term (2040) scenarios shall include a best-estimate central scenario based on NECPs, complemented by contrasting "low-economy" and "high-economy" variants. These variants are designed to serve as stress tests for the central scenario, examining how different economic conditions could affect the energy system.

The decision-making process for developing the draft economic variants methodology started in Q3 2024 with discussions initiated by the SRG, the European Commission (EC), and ACER. The initial ideas for the economic variants were presented at the public TYNDP Scenarios Workshop in July 2024 to gather early stakeholder feedback.

The draft methodology was first developed by defining the high-level design and main principles for the economic variants. These were presented to the SRG during a joint workshop in September 2024 and reviewed by its members. The next step focused on identifying the key parameters to be differentiated between the variants. This was presented to the SRG during the physical workshop in December 2024 and later shared at the public Scenarios Webinar in March 2025. Following feedback received from the EC and ACER during cooperation platform meetings and from the SRG workshops, the draft economic variants methodology was finalised for public consultation.

The economic variants are not stand-alone scenarios, they act as stress tests on the central Scenario, focusing on changes in consumption behaviours driven by different economic conditions. The main changes between the variants are found on demand side, while the supply generation capacities remain constant, except for limited adjustments that may be necessary to ensure generation adequacy. Supply capacities are often influenced by political and policy-driven factors, such as subsidies and prioritisation, making them difficult to vary consistently across scenarios. Therefore, they are kept unchanged in this cycle unless technically required, for instance, if the model fails to converge.

The demand data reflecting national trends is collected via the ETM and categorised into sectors, focusing on two components: activity level and technology mix. Activity represents overall demand changes within sectors, while the technology mix describes how this demand is met, for example, through different car types like EVs, petrol, or hydrogen vehicles. In the high-economy variant, activity levels increase, and more efficient, carbon-free technologies expected to gain market share under stronger economic conditions are scaled up, with other technologies adjusted to maintain balance. In the low-economy variant, activity levels decrease, and the opposite adjustments are applied. A saturation methodology adds realism to technology adoption and phase-out processes.

An exception applies to the refining industry, where activity levels are decreased in the high-economy variant and increased in the low-economy variant. This reflects lower expected demand for refined petroleum products in the transport sector under higher economic and decarbonisation pathways, and higher demand under lower economic pathways where decarbonisation progresses more slowly.

Commodity prices, including carbon prices, also vary between the economic variants. Prices increase in the high-economy variant reflect the level of activity and demand, while in the low-economy variant, prices decrease.

This methodology provides a structured approach to testing the robustness of the central scenario against different economic conditions, offering insights into infrastructure needs, policy resilience, and long-term energy system planning.

5 SUMMARY OF RESPONSES BY QUESTION AND ENTSOS' COMMENTS //

Consultation on TYNDP 2026 Scenarios – input data and methodologies on methods and data

SCENARIOS INNOVATION ROADMAP	
RESPONDENTs' VIEWS (11 RESPONDENTS)	**ENTSOs' VIEWS**
QUESTION 4: **HOW WOULD YOU RATE THE INNOVATION ROADMAP (CLARITY, COMPREHENSIVENESS AND FORMAT)? (RANK 1 TO 10 – 10 MOST SATISFACTORY)**	
Rated on a scale from 1 to 10 for clarity, comprehensiveness, and format, the Innovation Roadmap received an average score of 5.7. The distribution of responses was as follows: four respondents rated it 5, four rated it 6, one rated it 4, one rated it 7, and one rated it 9. This reflects a moderate level of satisfaction.	We acknowledge the moderate result and are open to suggestions for improvement.
QUESTION 5: **DO YOU THINK THAT THE PRIORITISATION OF INNOVATIONS FOR THE TYNDP 2026 PLANNING CYCLE COULD BE IMPROVED, AND IF YES, WHY AND HOW?**	
Six respondents acknowledged the value of the current Innovation Roadmap, especially its future orientation and flexibility. However, they also identified several opportunities for improving how innovations are prioritised within the TYNDP '26 planning cycle. Suggestions centred on enhancing **alignment with overarching climate goals, increasing transparency, and ensuring greater involvement of external expertise and societal stakeholders**. Key suggestions included:	The feedback confirms that the Innovation Roadmap largely meets stakeholder expectations, particularly with regard to the emphasis on future climate variability, system integration and transparency, although there is room for improvement. We acknowledge the need to address the following points: • More structured prioritisation criteria that go beyond operational feasibility. Explore how to w climate impact and societal value into prioritisation methodology. • Clearer communication to explain how innovations are selected and what trade-offs are involved. • Institutional openness to external innovation sources and broader stakeholder engagement. • Include status update and an implementation plan for the listed innovations • Expansion its scope aligning with the public consultation and SRG feedback
One stakeholder asked to include more climate years than currently (three) to improve the robustness of the results and supported the **geographic expansion of the ETM**, especially the inclusion of non-EU countries such as Norway and Switzerland and to split the United Kingdom into separate datasets to ensure consistent modelling across interconnected European systems.	Addition of climate year functionality to the ETM and climatic variability is part of the innovation roadmap. We consider that the stakeholder favours for prioritisation of this innovation. The geographic expansion of the ETM is already in the process of being implemented.
One stakeholder recommended to **better include the innovations at DSO level** (such as; ICT solutions, flexible tariffs, community storage) particularly for demand side flexibility, local congestion management and decentralised investment trends by collaborating with the DSOs.	TSO-DSO collaboration is a key strategic priority for the ENTSOs; ENTSO-E and the DSO Entity already have a joint work programme and formal legal mandates on many themes, ensuring that DSO perspectives are integrated into key processes. Work is also ongoing to expand the DSO Entity's mandate to include the gas sector. The DSO Entity is already part of the Scenarios Reference Group (SRG) as well as in numerous bilateral exchanges with ENTSO-E, providing opportunities to ensure that innovations at the DSO level are aligned.

QUESTION 5 (CONTINUATION) : DO YOU THINK THAT THE PRIORITISATION OF INNOVATIONS FOR THE TYNDP 2026 PLANNING CYCLE COULD BE IMPROVED, AND IF YES, WHY AND HOW?	
One stakeholder appreciated the framework but provided suggestions for the **prioritisation**. The current prioritisation criteria (time × impact) were viewed as too narrow and insufficiently climate-goal-oriented. One stakeholder suggested to give more weight for the innovations that are important for climate objectives and for innovations that optimise the entire energy system, especially those that reduce infrastructure needs and improve cost efficiency.	We support the approach that implementation should follow an interactive process, with clear justification for what will be improved in each cycle and why, ensuring alignment with stakeholder needs. We will consider the feedback for better communication of the trade-offs and better involvement of the scientific community.
Two stakeholders emphasised, **involving more independent scientific expertise and broader societal perspective into the discussions and better communication of the trade-offs** (like how prioritising certain innovations affects flexibility needs, emissions or infrastructure) would support informed choices, transparency and inclusive process.	Regarding prioritisation based on climate objectives, Scenario inputs are developed using a "bottom-up" approach in line with the ACER Scenario Framework Guidelines, with data provided primarily by TSOs. This means the models themselves have limited scope to independently select technologies or costs aimed at achieving decarbonisation targets. Nevertheless, we will revisit the prioritisation methodology in the next update of the Innovation Roadmap and explore how climate impact and sociated value can be integrated into prioritisation methodology.
One stakeholder asks for clarification for the Innovation Roadmap's reference to the need for an **economic assessment of new nuclear plants**: whether the context of these "nuclear reactors" for these power plants to produce electricity and deliver this electricity to public grid where it finds its way to customers. They also commented on the evolved business case for SMRs over past years – based on deployment on industrial sites co-located with heavy industry users.	It is true than an assessment was requested for nuclear and steam methane reforming plants. The origin of this request is the deviation (DE & GA) Scenarios, where these two technologies were not expansion candidates, but set ex-ante. Currently, the generation mix is established by TSOs according to their national plans, therefore, we cannot decide what technologies to implement in our Scenarios.
SRG Innovation Roadmap RECOMMENDATION 1: SRG recommends the format of the Innovation Roadmap document to remain a living document that continuously captures and integrates inputs from various SRG Working Groups (and other stakeholders) including recommendations for future innovations.	We support SRG's recommendation to keep the Innovation Roadmap as a living document, as outlined in the ACER Scenario Guidelines, continuously enriched by input from SRG Working Groups and other stakeholders.
SRG Innovation Roadmap RECOMMENDATION 5: SRG expects the status of each innovation in the Innovation Roadmap to be provided along with its implementation plan compliant with ACER Scenario Guidelines Article.	We acknowledge SRG's expectation and confirm that each innovation listed in the Innovation Roadmap will be accompanied by a status update and an implementation plan aligned with the ACER Scenario Guidelines.

QUESTION 6: ARE ANY INNOVATIONS MISSING IN THE SCENARIOS INNOVATION ROADMAP THAT SHOULD BE MENTIONED IN FUTURE EDITIONS?	
Five stakeholders provided a range of suggestions for innovations that are not yet fully addressed in the current Innovation Roadmap. Their feedback reflects a shared ambition to expand the scope of the Innovation Roadmap to better **align it with the scale and urgency of the energy transition**.	The feedback confirms that the Innovation Roadmap is broadly aligned with stakeholder expectations. However, the input highlights the necessity to expand its scope. We acknowledge the need to consider the inclusion of the proposals in future versions of the Innovation Roadmap.
Possible Need for Broader Demand-Side Modelling Two stakeholders called for better integration of demand-side dynamics, including industrial shifts, building renovations, and local consumption patterns. They stressed that these factors could significantly reduce infrastructure needs and therefore should be systematically assessed.	Demand-side assessment and flexibility modelling will be considered for deeper integration, building on existing innovations such as Section 8.10 (Flexibility of Heat Pumps) and Section 9.13 (Prosumer Demand).
Flexibility and Local Participation Two stakeholders highlighted the importance of innovations that enable flexible operation of local loads (e.g. electric heat pumps) and simplify participation for households and small businesses in energy markets.	We take note of the respondents' highlight; specifically in relation to heat pumps, we hope to receive valuable insight from SRG members and other stakeholders working in the industry.
Electric Vehicle Modelling beyond Passenger Cars Two stakeholders proposed wider modelling of EVs by including heavy-duty EVs, busses and trucks considering HDVs contribute over 50 % of road transport CO_2 emissions. They recommended modelling up-to-date driving patterns and charging behaviours to better assess grid impacts.	We take note and include modelling of the EVs beyond passenger cars in the future innovation roadmap. In the current cycle, heavy duty EVs are not explicitly modelled. They have non-flexible charging patterns; therefore, these are included in the overall electricity demand profiles.

QUESTION 6 (CONTINUATION): ARE ANY INNOVATIONS MISSING IN THE SCENARIOS INNOVATION ROADMAP THAT SHOULD BE MENTIONED IN FUTURE EDITIONS?	
Grid-Aware Planning and Innovative Grid Technologies Two stakeholders proposed tools that proactively steer new demand to strong grid areas and called for a more prominent role for innovative grid technologies in the Innovation Roadmap.	Grid-aware planning tools and topology enhancements will be reviewed in light of suggestions to incorporate distribution-level data and steer demand proactively (see Section 8.13 and 9.17).
System Resilience and Climate Stress Two stakeholders emphasised the need to model the resilience of energy infrastructure against extreme weather events and climate-induced stress, especially for long-term planning.	The climatic variability is already part of innovation roadmap (Section 9.2.) Please note that extreme weather data will be available and be used in the subsequent process of the TYNDP 2026.
Storage and Topology Enhancements One stakeholder advocated for the inclusion of seasonal and long-term storage technologies, as well as more granular grid topology based on national distribution plans.	Higher granularity topology is part of the innovation roadmap (see Section 8.12). Storage enhancement for H_2, heat, e-liquids are part of innovation roadmaps. We will review the provided JRC source to see additional relevant storage technologies and data integration into the innovation roadmap.
Open Source and Transparency One stakeholder encouraged the adoption of open-source modelling approaches to increase transparency and stakeholder engagement.	Open-source modelling and transparency will be promoted through the SRG and future Innovation Roadmap updates (see Section 9.16).
Evolving Regulatory Frameworks One stakeholder suggested that the Innovation Roadmap should explicitly account for evolving regulatory frameworks – such as dynamic grid fees and flexible connection agreements – as these can significantly influence market attractiveness and grid planning.	Whilst we keep track of evolving market-driven regulatory frameworks and try to anticipate any significant impact on infrastructure planning, there is little chance that such market-oriented activities will have a clear impact on future Scenarios. We continue to monitor these evolvements.
Backcasting Two stakeholders questioned the incremental nature of the Innovation Roadmap and suggested a more ambitious, backcasting approach from a 2050 – 100 % renewable system – optimal state.	The TYNDP Scenarios are based on a bottom-up approach which is furthermore based on the data provided by the TSOs, in line with the regulatory framework. The representation of specific technologies, such as biomethane and small modular reactors (SMRs), therefore depends on the datasets provided by TSOs.
Technological Opportunities While one stakeholder considered the role of AI and biomethane to be underexplored, another expressed similar concerns regarding small modular reactors (SMRs).	

QUESTION 7: IS THERE ANYTHING THAT YOU WOULD LIKE TO ADD?	
Seven stakeholders used this open-ended question to raise broader concerns about the **accessibility and transparency** of the Innovation Roadmap and its implementation. Their feedback reflects a desire for a more **inclusive, comprehensible, and more transparent process** that supports both expert users and the wider energy community.	The feedback suggests that the Roadmap process should: • Improve transparency and accessibility, including visual form in platform with an open feedback mechanism. • Adopt a balanced, technology-neutral approach that reflects the diversity of national energy strategies. • Enhance clarity and usability for both expert and non-expert audiences. • Expand the modelling scope to better represent flexibility, demand-side measures, and infrastructure resilience.
Transparency and Communication One stakeholder expressed concerns about declining access to TYNDP information and called for a more transparent implementation process. Two stakeholders called for clearer justification of how feedback is handled and proposed more interactive formats – such as visual platforms with comment functions – to improve transparency and engagement. One stakeholder emphasised that showcasing innovation in this way could also reflect the EU27's energy sector competitiveness in a global context.	The ENTSOs will explore options for publishing the Innovation Roadmap in a more interactive format. The published datasets are reduced comparing to last cycle because with the updated Scenarios framework, the ENTSOs are not using an expansion system anymore.

QUESTION 7 (CONTINUATION): IS THERE ANYTHING THAT YOU WOULD LIKE TO ADD?	
Terminology and Accessibility Two stakeholders noted that the Innovation Roadmap is highly technical and may be difficult to follow without prior knowledge. They recommended more visual summaries and clearer explanations of terms like NT+, TSO, and SRG.	We will aim to clarify technical terms where they occur and provide more visual explanations to support broader understanding.
Data accuracy One stakeholder highlighted discrepancies in Germany's ETM assumptions – such as the number of installed heat pumps and biomethane pricing, which lacks sectoral differentiation. In general, it was emphasised that inconsistencies between the NECPs and the assumptions used in the Innovation Roadmap should be avoided.	The 2019 data is the base case stored in the ETM and was not modified for the TYNDP 2026. While there is a potential for improvement here, this data does not drastically influence the TYNDP, so it cannot be seen as not too relevant. In the TYNDP target years (2030, 2035, 2040, 2050) the ETM parameters were chosen to meet the final energy demand as stated in the NECP. Since the model used for the NECP and the ETM have different underlying calculations it is impossible to perfectly align all input with all output data. The granularity or ambition to align, the output values are seen as more credible and therefore chosen to align. In the current modelling, a simplification is necessary in complex market models which might be refined in future TYNDPs. The price of biomethane is not sourced from the ETM. Instead, we have based it on the Danish Catalogue and apply this single commodity price across Europe.
Technology Neutrality Two stakeholders emphasised the need for a technology-neutral approach, referencing both heating systems (e.g. existing gas boilers) and grid optimisation in countries open to nuclear solutions. One stakeholder called for a more granular representation of flexibility options and non-wire alternatives to better reflect future energy systems. In line with this, innovative technologies – such as thermal energy storage and energy efficiency measures were seen as essential. Furthermore, one stakeholder stressed that grid technologies must adapt to climate change, which already affected energy generation. These innovations should be integrated into TYNDP planning to support a resilient and decarbonised energy future.	The TYNDP Scenarios are based on a bottom-up approach which is based on data provided by TSOs, in line with the regulatory framework. The representation of specific technologies therefore depends on the data sets provided by TSOs.
Modelling Gaps and System Representation Two stakeholders pointed to gaps in the modelling of innovative grid technologies as well as grid flexibility, transmission/distribution splits, and demand-side measures. They also called for better integration of innovative grid technologies and seasonal storage. One stakeholder questioned the limited openness of the ETM modelling interface and the lack of open-source access across all vectors.	Suggestions regarding demand-side measures will be considered for better evaluation in future Innovation Roadmap editions. We would like to clarify that the focus of the scenarios is not on grid analysis – this is addressed within the scope of the TYNDP. The models used are single-node economic dispatch models operating under the assumption of a perfectly competitive market. The generation and demand data included in the scenarios are based on the NECPs, which should inherently reflect both transmission and distribution aspects. However, since this is not a zonal/network model, all elements are aggregated. We acknowledge the importance of innovative grid technologies and flexibility measures. Although these are not the primary focus of the current modelling framework, this feedback can be included in the Innovation Roadmap's long-term development strategy Some stakeholder suggestions – such as full open-source access to the ETM or immediate integration of all national data – may not be feasible in the short term due to technical, security, legal, and resource constraints. However, these concerns are acknowledged and will inform the TYNDP Scenarios Innovation Roadmap's long-term development strategy.
SRG Innovation Roadmap RECOMMENDATION 2: SRG expects clarity to be provided on how its first set of recommendations from February 2024 will be acted upon by ENTSOs.	We appreciate the SRG's contributions and confirm that the recommendations provided in February 2024 have been taken into account. These are reflected in the Innovation Roadmap, with details outlined in Section 9. We encourage SRG members to review this section and remain open to further discussion to ensure shared understanding of how these recommendations are being implemented.

QUESTION 7 (CONTINUATION): IS THERE ANYTHING THAT YOU WOULD LIKE TO ADD?	
SRG Innovation Roadmap RECOMMENDATION 3: SRG calls for sufficient time to be provided when the group is involved in decision-making processes related to innovations to allow for a deepened discussion among its members.	We understand the importance of allowing sufficient time for meaningful discussion and review. For this cycle, the timelines provided to the SRG were aligned with those given to TSOs to ensure consistency and fairness in the process. Looking ahead, we are committed to working with the SRG to jointly agree on review periods and timelines at the start of the next cycle. This will help ensure that members have adequate time to engage in deeper discussions and provide well-considered feedback on innovation-related decisions.
SRG Innovation Roadmap RECOMMENDATION 4: SRG expects transparency to be provided on the process and clear explanation regarding the consideration or non-consideration of SRG feedback to the Innovation Roadmap.	We acknowledge the SRG's expectation and are committed to ensuring full transparency in how feedback is handled throughout the Innovation Roadmap's life cycle. Going forward, we will provide clearer communication on how SRG input has been considered – or, where applicable, the reasons why certain suggestions could not be incorporated. Our aim is to ensure that all relevant innovation requirements from the SRG are captured within the roadmap and that the decision-making process remains open and traceable for all members.

DRAFT SUPPLY ASSUMPTIONS – ENCOMPASSING H_2 IMPORT POTENTIAL AND PRICES, TECHNOLOGY COST, AND COMMODITIES PRICES, CO_2 COST AND SYNFUEL IMPORT COST

QUESTION 8: DO YOU THINK THAT THE DRAFT IMPORT POTENTIALS FOR H2 AND AMMONIA COULD BE IMPROVED, AND IF YES, WHY AND HOW?	
Four stakeholders expressed a range of concerns regarding the figures and/or transparency of the assumptions for hydrogen and ammonia imports in the draft Scenarios. While there is recognition of the strategic role imports may play in diversifying the EU's energy supply, the feedback reveals a shared view that the **current import potentials may be overly optimistic, insufficiently transparent, and not fully aligned with market realities.**	H_2 and ammonia imports are based on project information submitted by project promoters and TSOs for the TYNDP 2024, which are also applied in the TYNDP 2026 Scenarios cycle. In the long-term (for 2040 and 2050) national strategies and visions are included. In the final Scenario report this will be explained explicitly.
Two stakeholders questioned the realism of the projected import volumes, one is citing delayed infrastructure readiness (e. g., Germany and the Netherlands not importing before 2035–2040), limited demand in key sectors (e. g., ammonia for power generation), and the absence of clear transit roles for countries like France.	For Ammonia imports, it is important to highlight that the imports mentioned here represent a source of hydrogen as the ammonia will be cracked to hydrogen before entering the EU hydrogen grid. Hydrogen can be exported to neighbouring countries if required by the supply and demand balance. Ammonia will not be considered as a fuel in power plants in the scenarios.
Need for Greater Transparency in Assumptions One stakeholder called for more openness in how assumptions for hydrogen and ammonia imports are developed.	
Exploring Low-Import Pathways One stakeholder advocated for Scenarios to explore pathways that minimise reliance on imports, and instead prioritise local renewable hydrogen production and direct electrification of end-use sectors as this approach would better reflect potential global supply constraints and sustainability risks.	While the import potentials may seem great, it is important to note that this potential should only be seen as the absolute maximum the model can import, rather than reflecting actual l import figures
Alignment with National Strategies and Market Signals One stakeholder emphasised the need to align import assumptions with national hydrogen strategies, such as France's focus on domestic production. The role of ammonia as an energy carrier was debated, noting that its use in power generation was not currently pursued in France and was only marginally considered in global markets, raising questions about the rationale for high import figures.	ENTSOG's TYNDP 2026 project collection is scheduled for Q3 2025 therefore in this Scenarios process are those submitted to TYNDP 2024, with a review applied to ensure relevance and consistency.
Local H_2 Manufacturing One stakeholder emphasised the competitiveness of nuclear-based hydrogen using PEM, alcaline, or high temperature SOEC technologies.	Regarding domestic hydrogen production, each country sets its own P2G capacity levels. Electrolysers connected to the electricity market use clean electricity, which may include both renewables and nuclear power – unlike dedicated or hybrid ones that rely solely on renewable sources like solar and wind.

QUESTION 9: IF YOU ANSWERED TO THE PREVIOUS QUESTION, PLEASE REFERENCE A SOURCE TO SUPPORT YOUR CLAIM.	
The following sources were provided as references. https://www.ulc-energy.com/news/study-reveals-low-cost-of-nuclear-h2 (Provided by one respondent.) https://bellona.org/news/climate-change/hydrogen/2023-03-7-reasons-why-hydrogen-ready-is-a-myth https://eu.bellona.org/2023/09/26/risks-and-challenges-of-importing-hydrogen-to-europe/ (Provided by one respondent.)	We thank all respondents who provided supporting sources to substantiate their feedback.

QUESTION 10: DO YOU THINK THAT THE DRAFT TECHNOLOGY COSTS COULD BE IMPROVED, AND IF YES, WHY AND HOW?	
Four stakeholders provided feedback on the draft technology cost assumptions. While perspectives varied in focus, there was broad agreement that the current assumptions require refinement to reflect recent market developments, national strategies, and more realistic cost trajectories.	We agree that accurate and forward-looking technology cost assumptions are essential for credible Scenario development. For this Scenario building cycle, a variety of possible sources have been considered for each technology. The final technology costs reflect the figures shown by well-grounded and sound sources such as IEA and EC.
Possible Underestimation of Cost Declines for Key Technologies Three stakeholders expressed concern that the draft assumptions for solar PV, wind, battery storage, and electrolyser systems were overly conservative. One stakeholder pointed to recent global auction results and industrial learning rates that suggest faster cost declines than currently reflected. Furthermore, this stakeholder warned that this could lead to underestimating the affordability and scalability of a renewables- and flexibility-led transition, while an additional stakeholder highlighted the rapid drop in lithium-ion battery pack prices – down to $ 115/kWh in 2024, an 84 % reduction over the past decade.	The role of technology costs for this Scenario building cycle isn't as central. **They will not be used in TYNDP 2026 Scenarios as there is no expansion loop.** Keeping this in mind, the update on the technology costs aims to reflect sound values that are aligned with the spirit of the Member States' NECPs. For this reason, some stakeholders might judge that the figures don't entirely reflect the rapid drops in prices that can be seen in some sources.
Possible Need for Updated Learning Curves and Market Data Two stakeholders recommended revising cost pathways using more realistic learning curves and up-to-date market data. They argued that this would better capture the pace of cost reductions and support more accurate modelling of local renewable generation, storage, and grid digitalisation.	
Granularity and Transparency in Wind Cost Assumptions One stakeholder provided a comprehensive breakdown of wind technology costs, noting that several CAPEX and OPEX assumptions—particularly for offshore and floating wind – appeared optimistic. They also raised concerns about the lack of clarity regarding whether transmission and substation costs are included in the published figures. The stakeholder acknowledged that adjusting assumptions upward may not be strategically favourable in the ENTSO-E model but stressed the importance of realism and transparency.	It is worth highlighting that the technology costs are highly dependent on the economical context of the supply chains and global trade. In a business-as-usual economic scenario technology costs have been declining steadily for years but with the most recent developments in tariffs and global trade price distortions this cost decline could be easily affected. With the help of stakeholders, particularly members of the SRG, the necessary further technology costs reviews and implementation of the strongest and most up-to-date ones will be possible.
Inclusion of Nuclear as Source of Electricity and Heat One stakeholder commented to include nuclear as source of electricity and heat.	While Scenarios include nuclear as a source of electricity and not of heat as heat – since the heat sector is not explicitly modelled (except for Hybrid Heat Pumps) – we can consider including the modelling of this sector and the suggested sources in the Innovation Roadmap's long-term strategy.

QUESTION 11: IF YOU ANSWERED TO THE PREVIOUS QUESTION, PLEASE REFERENCE A SOURCE TO SUPPORT YOUR CLAIM.	
The following sources were provided as references: https://www.ulc-energy.com/news/study-reveals-low-cost-of-nuclear-h2 AND https://www.ulc-energy.com/_files/ugd/890cef_5a0a15dc94f042f59b2b5e1e91dc3e4f.pdf (Provided by one respondent.) https://ourworldindata.org/cheap-renewables-growth (Provided by one respondent.) Lifecycle overview | Guide to an offshore wind farm: https://guidetoanoffshorewindfarm.com/offshore-wind-lifecycle-overview/ Lifecycle overview | Guide to a floating offshore wind farm: https://guidetofloatingoffshorewind.com/floating-wind-lifecycle-overview/ (Provided by one respondent.) BloombergNEF Press release (December 10, 2024) https://about.bnef.com/insights/commodities/lithium-ion-battery-pack-prices-see-largest-drop-since-2017-falling-to-115-per-kilowatt-hour-bloombergnef/ Preliminary ERAA 2025 Economic and technical investment parameters: https://eepublicdownloads.blob.core.windows.net/public-cdn-container/clean-documents/sdc-documents/ERAA/ERAA_2025/Economic%20and%20technical%20investment%20parameters.zip (Provided by one respondent.)	We thank all respondents who provided supporting sources to substantiate their feedback.

QUESTION 12: DO YOU THINK THAT THE DRAFT COMMODITIES PRICES, CO2 COST AND SYNFUEL IMPORT COST COULD BE IMPROVED AND IF YES, WHY AND HOW?	
Three stakeholders suggested that the draft assumptions for commodity prices, CO_2 costs, and synfuel import costs should be revised, citing the need for greater realism and transparency in how these figures are derived. Stakeholders identified four areas where the draft price assumptions could be improved:	Due to the high uncertainty of future commodity prices, it is impossible to make perfect predictions. To improve the consistency of assumptions and to follow EC and ACER guidance and SRG recommendations, we opted for the European Commission's "Recommended harmonised values for key supra-nationally determined parameters" as per their "Recommended parameters for GHG projections" for both CO_2 and natural gas prices that can be found here: (https://epanet.eea.europa.eu/Eionet/reportnet/docs/govreg/projections/govregart18_ec_parameters_projections_2021.zip/view).
Natural Gas and Oil Prices: One stakeholder recommended aligning assumptions with the European Commission's 2040 Climate Target Impact Assessment, which projects higher natural gas prices than those used in the draft.	
Consistency of Data Sources: One stakeholder emphasised that using price Scenarios from different years and sources – especially from the 2022–2023 energy crisis – may lead to inconsistencies. They called for a harmonised and coherent approach to price modelling.	
CO_2 Price Trajectory: One stakeholder questioned the political feasibility of CO_2 prices reaching € 502.7/tCO_2 by 2050. They suggested including variants with lower prices, noting that hard-to-abate sectors may be regulated through norms rather than market mechanisms.	
Biomethane Pricing: One stakeholder noted that the draft assumptions diverged from current industrial benchmarks. According to the Biomethane Industrial Partnership, production costs range between € 54 and € 84/MWh, with no indication of significant increases.	The biomethane cost are based on assumption from the Danish Technology Catalogue: (https://ens.dk/en/analyses-and-statistics/technology-data-renewable-fuels) and are with these calculated to around 50 €/MWhso that the lie in the lower end of the span given by BIP.
SRG – recomondation on commodity price projections. **The SRG strongly suggests that the commodity prices for the TYNDP 2026 are based on the European Commission (EC WAM) prices, as opposed to those from the IEA (IEA APS). The reasoning is by doing so the scenarios will follow the Acer guidelines, align with the proposed prices for the NECPs and be consistent with price trajectories developed by member states**	

QUESTION 13: IF YOU ANSWERED TO THE PREVIOUS QUESTION, PLEASE REFERENCE A SOURCE TO SUPPORT YOUR CLAIM.	
The following sources were provided as references: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52024SC0063 (Provided by one respondent.) If only one source would be kept, the World Energy Outlook (2024) of the IEA assesses CO_2 prices to reach up to 250 €/tCO_2 in the highest case in Advanced economies (corresponding to all net zero emissions targets being reached). This is half the value given in the TYNDP. (Provided by one respondent.) BIP Task force 4.2 report https://bip-europe.eu/2023/11/02/executive-summary-and-slidedeck-available-for-download-task-force-4-2-reveals-current-biomethane-production-costs-from-real-industry-data/ (Provided by one respondent.)	For CO_2 prices, two sources were considered by WGSB: Both IEA's World Energy Outlook 2024 and the European Commission's recommended parameters for GHG projections 2025.After comparing one against the other, the WGSB decided that the CO_2 prices of the EC recommended parameters for GHG projections 2025's were to be used .These prices provide a better alignment with Member States' NECPs. ACER and European Commission also recommended the ENTSOs to use these sources. The source for the commodity and CO_2 prices used: https://epanet.eea.europa.eu/Eionet/reportnet/docs/govreg/projections/govregart18_ec_parameters_projections_2021.zip/view

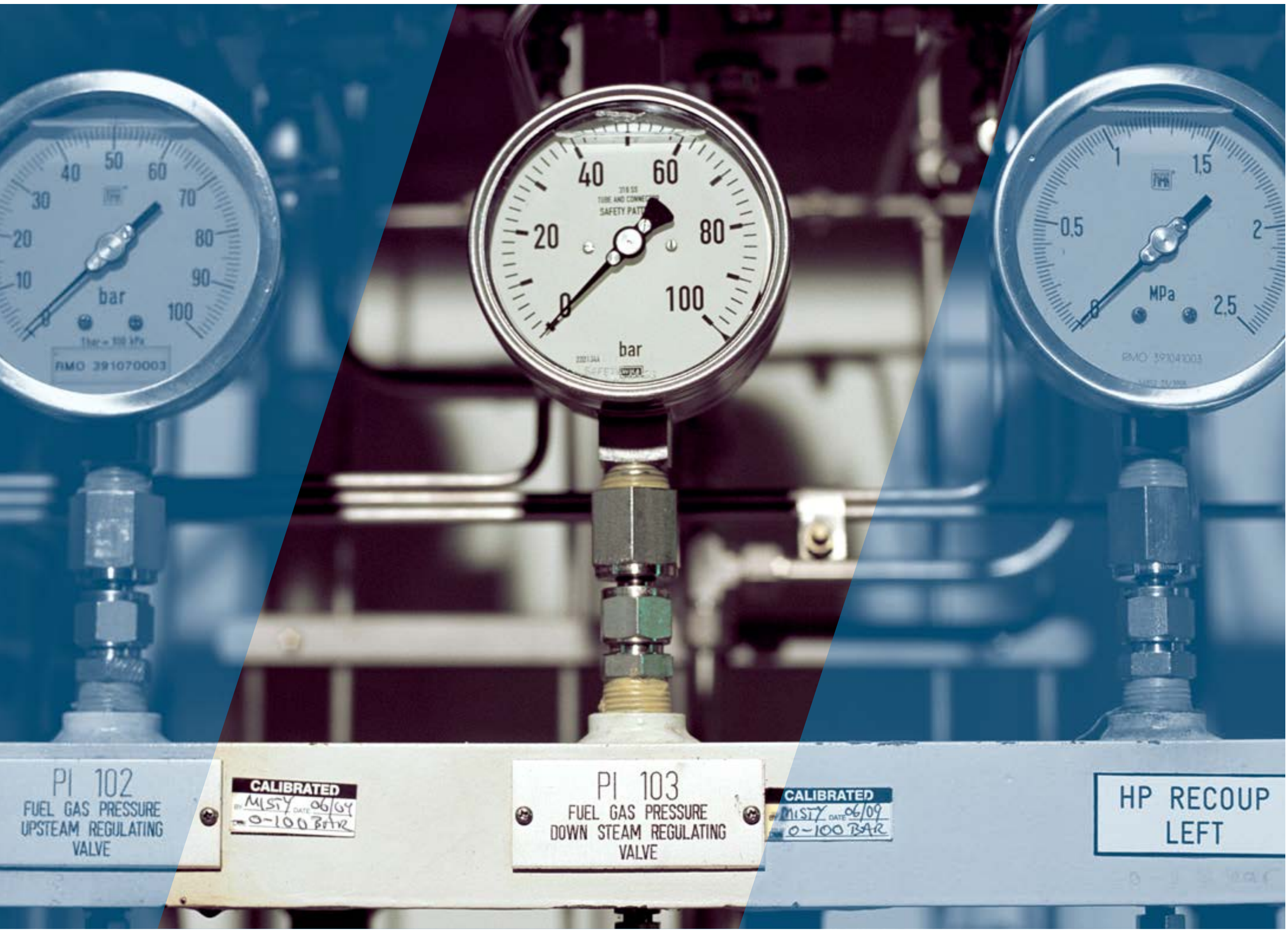
QUESTION 14: IS THERE ANYTHING THAT YOU WOULD LIKE TO ADD?	
Three stakeholders have expressed additional considerations regarding the current approach to the TYNDP 2026 Scenario framework.	The development of the TYNDP 2026 Scenarios has been carried out in compliance with the ACER Scenarios Framework Guidelines, including one central Scenario (National Trends +) complemented by two economic variants (high and low) featuring as stress tests to the central Scenario.
One stakeholder raised a fundamental concern about the **limitation of modelling only a single central Scenario**. While acknowledging that two economic variants are foreseen, they emphasised that relying on a single Scenario presents an overly narrow perspective on the potential evolution of Europe's economy and society. Although the economic variants are derived from the ACER Framework Guidelines, it was noted that these guidelines do not preclude the inclusion of multiple Scenarios within the TYNDP framework.	The development of the TYNDP 2026 Scenarios has been carried out in compliance with the ACER Scenarios Framework Guidelines, including one central Scenario (National Trends +) complemented by two economic variants (high and low) featuring as stress tests to the central Scenario.
Building on this, one stakeholder questioned whether the **current Scenario development process adequately enables both TSOs and DSOs to fulfil their responsibilities in ensuring supply reliability** – particularly for natural gas, hydrogen, and biogas – throughout the transition period. They highlighted the ongoing transformation of the energy system, driven by innovation, and stressed the need for grid operators to meet demand reliably, including during peak periods. It was recommended that the draft Scenario and its parameters be reviewed with a stronger emphasis on supply security.	Given the tight timeline, the focus has been to follow this approach Scenario and not to develop additional Scenarios at this stage. We truly appreciate the interest and understand the value of exploring further options, but current resource and time constraints make it materially impossible within this cycle.
A stakeholder highlighted the critical importance of including biomethane potential in the scenario development. This is essential for informing national grid expansion plans and strategic energy infrastructure decisions. Moreover, biomethane represents a significant renewable energy source and a key provider of biogenic CO_2 for Carbon Capture and Utilisation (CCU) and Carbon Capture and Storage (CCS) applications.	Biomethane is included in the scenarios and is collected through a dedicated data process coordinated with the gas Transmission System Operators (TSOs). It represents a significant energy source within the scenarios and is also considered a key contributor of biogenic CO_2 in combined with CCU and CCS applications.
In addition to these strategic considerations, one stakeholder provided detailed technical feedback on the supporting documentation, particularly the Excel files. In Excel 2.1, they noted that the "Gasblend" sheet referenced outdated Scenarios (NT +, DE, and GA), suggesting that this should be updated for **clarity and accuracy**. In Excel 2.4, they observed that no **technology costs have been assigned to storage technologies**[8]. While recognising the methodological challenges in projecting costs for emerging technologies, they recommended that this issue be explicitly acknowledged. Furthermore, it was suggested that JRC's "European Energy Storage Inventory: Real-time Energy Storage Dashboard" should feed and be integrated into TYNDP Scenarios and modelling reference data[9].	The calculation of the gas blend requires data on the volumes of gas used for electricity generation as well as in blue Hydrogen (SMR) generation. Since this information is generated as an output of the modelling process, figures from the previous cycle (TYNDP 2024) were used for the gas blend calculations in this cycle.

8 Source: US DoE (2022) 2022 Grid Energy Storage Technology Cost and Performance Assessment. US Department of Energy. https://www.energy.gov/eere/analysis/2022-grid-energy-storage-technology-cost-and-performance-assessment.

9 https://ses.jrc.ec.europa.eu/storage-inventory

METHODOLOGIES AND ASSUMPTIONS	
QUESTION 15: **DO YOU THINK THAT THE DRAFT MARKET MODELLING METHODOLOGIES AND THEIR RELEVANT ASSUMPTIONS COULD BE IMPROVED AND IF YES, WHY AND HOW?**	
Eight stakeholders provided detailed and constructive feedback on the draft market modelling methodologies. Their responses collectively highlight the need for:	We acknowledge that the feedback highlights the importance of ensuring that model assumptions are aligned with actual operational and economic conditions. Inaccurate or overly simplified assumptions could lead to misinformed infrastructure investments, underestimation of flexibility potential, and missed opportunities for demand-side optimisation.
Transparency and Documentation: Six stakeholders stressed the need for clearer documentation of assumptions, especially regarding demand profiles and hydrogen origin.	We acknowledge many of the concerns raised and outline several relevant developments:
Demand Flexibility: Four stakeholders voiced that the current modelling lacks sufficient detail on intra-year demand flexibility, particularly for industry, households, and gas-based transport. One stakeholder noted that flexibility was still simplified through basic price-responsiveness assumptions, overlooking the potential of smart charging, load shifting, flexible heat pumps, and local coordination to ease grid stress and reduce system costs. A more holistic approach to modelling demand-side behaviour and local congestion could highlight how smarter demand can defer costly infrastructure investments. One stakeholder noted that there is still room to strengthen how the models handle flexibility, demand-side measures, and integrated operation across electricity, heat, hydrogen, and other sectors.	Regarding e-demand flexibility, models currently include Demand Side Response (DSR) which leads to demand shedding (DSR capacities are included in PEMMDB). However, we acknowledge heat pumps' flexibility – demand shifting – is not modelled (heat pumps electricity demand is treated as inelastic and included in the total electricity demand timeseries). This topic is included in Section 8.10 of the Innovation Roadmap and will be tackled in future TYNDP Scenario cycles. However, we do model the flexibility from hybrid heat pumps (fuel switch between electricity and gas).
EV Modelling: Three stakeholders called for a more nuanced modelling of EV flexibility and a more accurate representation – particularly with regard to heavy-duty vehicles and evolving charging patterns. The at the time of the consultation assumed split between home charging (30 %) and street charging (70 %) should be reconsidered. Moreover, the availability of charging infrastructure varied significantly across countries, which was why it should be explicitly accounted for rather than uniformly assumed.	The gas market is not modelled; therefore, we cannot model its flexibility.
V2G Ambition: One stakeholder considered the projected volumes of vehicle-to-grid (V2G) integration overly ambitious, while others focussed more on the need for broader EV flexibility modelling.	EV modelling has improved this cycle, but we recognise there is still significant room for improvement. We look forward to further discussing EV modelling with the SRG in future cycles. Currently, we assume that heavy-duty EVs are not market-driven, and therefore, we include their charging profiles in the total electricity demand timeseries. About V2G ambition and passenger EVs' flexibility, a survey was distributed to TSOs where they could provide their estimation capturing different country specific behaviour.
Hydrogen Infrastructure and Electrolyser Operation: Three stakeholders requested better integration of hydrogen storage (including distribution-level tanks) and clearer assumptions on hydrogen sourcing and prioritisation. Furthermore, one stakeholder suggested the inclusion of decentralised and off-grid generation. One stakeholder also suggested the inclusion of different electrolyser operation types.	Hydrogen storages have been submitted by TSOs, including information about the storage technology.[
Dedicated RES for Hydrogen: One stakeholder challenged the physical and economic realism of the "dedicated RES" concept, suggesting it may distort dispatch modelling if not properly defined. One stakeholder also called for greater clarity on the prioritisation of green hydrogen – beyond what was covered in the materials package – highlighting the possible need for a more explicit and transparent approach.	Off-grid hydrogen generation is accounted for via dedicated RES. We model different operational types of electrolysers, including dedicated RES, shares of RES and E-market optimised. We acknowledge that the way H_2 pricing is represented in our models doesn't fully capture market realities, given the marginal framework (especially when linked to dedicated renewables under PPAs both in EU and non-EU countries). The ENTSOs are well aware of the relevance of this issue and are actively working on pragmatic adjustments for this cycle, with more robust solutions planned as a priority for future cycles.

QUESTION 15 (CONTINUATION): DO YOU THINK THAT THE DRAFT MARKET MODELLING METHODOLOGIES AND THEIR RELEVANT ASSUMPTIONS COULD BE IMPROVED AND IF YES, WHY AND HOW?	
SRG Innovation Roadmap RECOMMENDATION 6: SRG expects reasoning provided on why some innovations were considered out of scope for the TYNDP 2026 cycle and others were not. These include at least addressing the flexibility of electric heat pumps (noting that electric vehicle (EV) charging was considered). Another case concerns the value chain of carbon capture and utilisation (CCU) under 9.17 of the innovation Roadmap.	The inclusion of innovations in the TYNDP 2026 cycle was guided by data availability, modelling feasibility, and relevance to system needs. While EV charging met these criteria, the flexibility of electric heat pumps lacked sufficient harmonised data. However, we do model the flexibility from hybrid heat pumps (fuel switch between electricity and gas). CCU was excluded due to current limitations in assessing its system-wide impact. These areas remain under observation for future inclusion.
SRG Innovation Roadmap RECOMMENDATION 7: SRG suggests increasing the granularity of nodes already for the 2026 TYNDP cycle and if not incorporated, justification should be provided.	We acknowledge SRG's suggestion. Given the current structure of the data collection, we are not able to develop more granular models in the short term. We do not have the means or resources to support zonal modelling at this stage. Moreover, we would like to reiterate that the focus of the Scenario building exercise is not to analyse the grid or internal congestions within countries as this type of analysis is performed in a later stage of the TYNDP process.
SRG Innovation Roadmap RECOMMENDATION 8: SRG suggests deepening the modelling of electrified mobility, incorporating different transport modes, to assess their contribution to the system.	EV modelling has improved this cycle, but we recognise there is still significant room for improvement. We look forward to further discussing EV modelling with the SRG in future cycles.



QUESTION 16: **DO YOU THINK THAT THE DRAFT TARGET COMPLIANCE AND GAP- FILLING METHODOLOGIES CAN BE IMPROVED AND IF YES, WHY AND HOW?**	
Eight stakeholders provided feedback on the draft methodologies for target compliance and gap- filling. Their responses collectively highlight a need for greater transparency, methodological rigour, and alignment with EU targets and regulatory frameworks.	We acknowledge the importance of transparency, methodological rigour, and alignment with EU policy objectives in the target compliance and gap-filling methodologies. Ensuring a robust and transparent approach is essential for maintaining trust in the TYNDP process and supporting informed decision-making by all stakeholders.
Transparent and Robust Gap-filling Methodology · Six stakeholders emphasised that the **gap-filling methodology must be more transparent and robust**. They called for the publication of both raw and adjusted data, as well as clearer documentation of assumptions and decision-making processes. There is also agreement that the methodology should include a consistency check of demand forecasts and that NECPs should not be used uncritically as a basis for projections. · In addition, one stakeholder expressed uncertainty about how the **gap-filling methodology for energy consumption targets would also ensure compliance with renewable energy targets**. They recommended that the methodology be clarified and aligned with the provisions of Articles 31 to 33 of the Governance Regulation (2018/1999), which outline how gaps in renewable energy contributions should be addressed. One stakeholder called for the publication of rankings of sectors and energy carriers based on their greenhouse gas emission and decarbonisation potential.	To this end, we work closely with our members to increase visibility on how NECPs are reflected in the datasets. With the publication of the public consultation, both the raw Member State datasets and the EU-level gap-filling methodology is made publicly available. This allows stakeholders to see the raw data and gap to comment on how adjustments are planned to be applied. Following the public consultation, and once the methodology is finalised, the EU-level gap-filled datasets will also be published as part of the Draft Scenarios Report to ensure full transparency.
EU-policy Target Compliance · Three stakeholders raised concerns about the **discrepancy between NECPs and the EU target**. They highlighted a significant discrepancy between projected total energy consumption for 2030 and the EU target, and warned that any adjustments made without revisiting the underlying demand development methodology could result in arbitrary outcomes. One stakeholder recommended that the gap-filling methodology include a thorough consistency check of final demand figures against the forecasting methodologies used for individual demand segments. They also highlighted that the NECPs are currently misaligned with EU targets, making them an unreliable basis for projections. · Two stakeholders noted that the **current methodology does not account for the 2040 climate targets**. One stakeholder pointed out that the European Commission had already initiated the process to establish the 2040 targets as early as February 2024, and urged ENTSOs to anticipate these developments in the TYNDP 2028 cycle. One stakeholder referenced a draft working paper from SRG WG1, which raised concerns about the current gap-filling methodology. Specifically, the paper warned that reducing final energy consumption from liquid fuels without a corresponding increase in other energy carriers could lead to demand destruction and an underestimation of infrastructure needs required for modal shifts such as transport electrification.	We understand that there is some confusion about how the gap-filling methodology ensures compliance with renewable energy targets. To clarify, the methodology is designed to be iterative: · If the initial application of the methodology does not achieve compliance with the relevant renewable energy targets, it will be re-applied until compliance is reached. · This process ensures that scenarios remain consistent with both energy consumption targets and renewable energy objectives, as required under the Governance Regulation. Regarding the concern about discrepancies between NECPs and EU targets, we acknowledge that differences currently exist. The gap-filling methodology is explicitly designed to bridge these gaps, while ensuring methodological consistency and avoiding arbitrary adjustments.
Wind Capacity Figures · One stakeholder identified discrepancies between the wind capacity figures used in the TYNDP and those published by WindEurope. They provided detailed estimates for both onshore and offshore wind capacities across EU member states and recommended that the TYNDP figures be updated to reflect more accurate and recent assessments.	Scenarios are required to follow the energy efficiency first principle, align with the 2030 energy and climate targets, and EU's 2050 climate neutrality objective. They take into account the latest Commission Scenarios and NECPs. The cut-off date for policy targets and input data for the TYNDP 2026 Scenarios was set at 24 December 2024, following alignment with the Scenarios Reference Group (SRG), the European Commission, and ACER. As of this cut-off date, there were no binding EU-wide targets for 2035 or 2040. Therefore, for this cycle, target justification applies only to the NT + 2030 horizon and the NT + 2050 horizon, which represents the climate neutrality objective. We appreciate the feedback received regarding the 2040 targets and algin with the feedback that preparatory work should already begin to anticipate their inclusion in the TYNDP 2028 Scenarios.

QUESTION 16 (CONTINUATION): DO YOU THINK THAT THE DRAFT TARGET COMPLIANCE AND GAP- FILLING METHODOLOGIES CAN BE IMPROVED AND IF YES, WHY AND HOW?	
Official SRG recommendations in relation to the draft gap-filling methodology: **SRG RECOMMENDATION 1:** The SRG proposes that all energy carriers are considered eligible for FEC reduction (rather than just solid fuels and oil), exception made for those with a strong decarbonisation potential i.e. electricity, hydrogen and biofuels. Given the complexity of the heat sector, this would also be excluded. **SRG RECOMMENDATION 2:** Changes made to FEC in specific sectors and carriers should be reflected in either compensating adjustments in substitute demand areas (especially electricity, methane and hydrogen) or rearrangements in modelling assumptions, to be transparently shared with the public. **SRG RECOMMENDATION 3:** The SRG supports a fair approach for all countries, in line with EU Directives. For this reason, the distribution of FEC reduction should be performed only for the subgroup of countries that submit data exceeding their national contribution as recommended by the European Commission. In future cycles, these figures could be used as upper constraints for TSO input, encouraging the gap-filling to be concluded by the TSOs themselves, where required. **SRG RECOMMENDATION 4:** The SRG, like ENTSOs, identifies 2040 as a key year to be modelled especially for grid infrastructure planning. For this reason, if the gap-filling methodology is in place for 2030, 2040 should be addressed consistently – for example, by aligning with official benchmarks in absence of detailed policy targets. **SRG RECOMMENDATION 5**: The SRG recommends that the gap-filling methodology is performed in the ETM to better calculate overall demand reductions that come from end-use transformation and redistribute the consumption across energy carriers. This approach is considered more realistic than the current assumption of demand destruction.	Based on the feedback received, we are re-vising the gap-filling methodology to enhance its robustness and ensure greater transparency in its implementation at Member State level.

QUESTION 17: DO YOU THINK THAT THE DRAFT CARBON BUDGET METHODOLOGY CAN BE IMPROVED AND IF YES, WHY AND HOW?	
Three stakeholders expressed **concerns about the realism and transparency of the carbon budget methodology**.	The data shown in the carbon budget for the public consultation is from the 2024 Scenarios as we await the results of the 2026 cycle. However, there is an option for TSO's to add CCS to their SMRs for this cycle. We aim to approve the breakdown of the emissions from industry and agriculture, but we will be limited by the sources available.
One stakeholder **questioned the plausibility of the projected oil consumption decline** by 2030 and the increase in emissions from Steam Methane Reforming (SMR) between 2030 and 2040. They suggested that the **use of SMR combined with Carbon Capture and Storage (CCS) should be considered** to avoid this effect. They also requested a clearer breakdown of emission reductions in the industrial sector and a narrative for emissions from food and agriculture.	In the 2026 Scenarios, both LULUCF and CCS will contribute to reach the climate target. We will not perform sensitivities on the levels of these, but the carbon budget will be published so changes to these levels can be performed by anyone with interest.
One stakeholder noted that while the **Scenarios track cumulative emissions, the gross emissions appear significantly higher than the carbon budget**, implying a heavy reliance on removals via CCS, CCU, and LULUCF. They recommended clearly **separating gross emissions from removals** and testing the impact of underperformance in these technologies. They also called for more precise sourcing of key inputs and alignment of infrastructure planning with a Paris-consistent carbon budget.	
One stakeholder welcomed the **reference to ESABCC advice on CCS thresholds but urged for a clearer explanation of how the carbon budget influences Scenario outcomes and infrastructure design**. They referenced a recent comparison by négaWatt (2025[10]), which found that previous TYNDP Scenarios were close to the lower bound of ESABCC ambition. They recommended learning from such analyses to improve future Scenario cycles.	The carbon budget will not affect the outcome of the Scenarios directly rather than being a result. In previous cycles, the CCS values were adjusted to reach the carbon budget. However, we will focus more on the carbon budget in this cycle and come with a more in-depth analysis of the of the results in relation to the use of CCS and other carbon-reduction options (i.e. LULUCF) to reach the climate goals. Further we will clearly highlight the external sources used for input to the carbon budget.

10 Source: Balancing ambition and feasibility: Comparison of major EU energy and climate Scenarios for 2040.

QUESTION 18:
DO YOU THINK THAT THE DRAFT SCENARIOS GRID METHODOLOGY CAN BE IMPROVED AND IF YES, WHY AND HOW?

Five stakeholders commented on the draft Scenarios grid methodology and suggested the following improvements:	We recognise the difficulty of providing an opinion on the electricity and hydrogen grids based solely on the methodology. However, since the electricity grid will be based on projects submitted to the TYNDP 2026, it has been impossible to provide such before the public consultation due to the schedule. The hydrogen grid is based on projects submitted to the TYNDP 2024 (with the corresponding revision) since the project collection for the TYNDP 2026 has not yet taken place.
One stakeholder noted that the **available data supporting the draft grid methodology was more limited than in previous cycles**, particularly with respect to reference grids and investment candidates. The stakeholder found the assumptions reasonable but incomplete, and suggested that **flow-based capacities should be represented** where relevant.	There will be no expansion in this Scenarios cycle: following ACER Framework Guidelines, no deviation (DE & GA) Scenarios will be developed in this 2026 cycle. This is why no expansion candidates have been collected for Scenarios purposes.
One stakeholder suggested that the **methodology should place greater emphasis on non-wire alternatives and smarter grid operations**. They advocated for the inclusion of dynamic line rating, advanced congestion management, and local flexibility markets to improve cost-effectiveness and adaptability. They also recommended stress-testing the grid under climate extremes and improving transparency on how these options are assessed.	Since the infrastructure is built bottom-up, as are market models, only one node per country or price zone was adapted, and interconnection capacities as NTC (Net Transfer Capacity) in the electricity grid, calculated taking into account internal constraints, technologies, etc). On the H_2 side, a higher granularity will take place in this cycle. These are also the reasons why the ENTSOs will not explore new technologies at this point.
Beyond this, one stakeholder suggested that the methodology should consider the **potential role of Grid Acceleration Areas** (GAAs), even if currently non-binding.	
Two stakeholders raised concerns about the **inclusion of conceptual hydrogen projects in the 2050 reference grid**. They emphasised the need for clear criteria and transparent communication regarding project selection to avoid overestimating capacities or relying on optimistic cost assumptions.	The Scenarios grid draws upon project portfolios from ENTSO-E's TYNDP 2026 and ENTSOG's TYNDP 2024. Most of the listed projects – regardless of how advanced they are – are scheduled to be commissioned before 2040. Since there are no expansion plans in this 2026 cycle and few new projects expected beyond 2040, we have included submissions to the TYNDP that are at earlier stages of development. We have also added conceptual projects that were not part of the TYNDP submission process. These conceptual initiatives have been gathered specifically for the Scenarios exercise and will only be considered within the framework of the 2050 grid. Conceptual projects and their justification will be published as part of the TYNDP 2026 Scenarios package.
Integration of gas DSO infrastructure in hydrogen deployment planning One stakeholder also highlighted the **lack of integration of gas DSO infrastructure in hydrogen deployment planning**. They recommended that local-level projects, especially those involving biomethane and hydrogen blending, be considered in Scenario development. Additionally, they called for a more modular approach to project maturity levels to better reflect regional and industry-led initiatives.	The TYNDP scenarios and in general does not go down to distribution level regarding system planning. A PAN-EU market model at distribution level is currently beyond the scope of our activities. Whilst we welcome any inputs, the grid relies on the projects submitted to the previous TYNDP. In short the system is not yet mature enough, certainly at the distribution level, to dive into such level of detail.
Integrated approach to hydrogen and biomethane infrastructure One stakeholder emphasised the need for a **more integrated approach to hydrogen and biomethane infrastructure planning**. From a DSO perspective, both gases would likely coexist in local networks, making it possibly essential to move beyond siloed modelling and consider shared assets, injection hubs, and hybrid systems to better reflect real-world interactions.	While we are not modelling the methane market, we do model the production of synthetic fuels from hydrogen. Currently, the prices of both carriers are decoupled in our models. This is an inconsistency we have identified and included in the Innovation Roadmap, with the intention of resolving it in future cycles.
In addition, one stakeholder observed that the **criteria for electricity grids appear stricter than those for hydrogen grids**.	Indeed, the criteria applied to electricity and hydrogen grids differ in terms of stringency. For the inclusion of projects in the grid representation of our Scenarios, we have followed the respective CBA guidelines of each TYNDP – electricity and hydrogen – applying the maturity criteria defined in each guide, which are specific to each sector.

QUESTION 19:
DO YOU THINK THAT THE DRAFT SCENARIO WEATHER YEARS SELECTION METHODOLOGY CAN BE IMPROVED AND IF YES, WHY AND HOW?

Seven stakeholders broadly welcomed the shift to a more advanced weather year selection methodology. However, there are some suggestions for improvement:	We introduced the use of multiple weather years and advanced statistical techniques such as Principal Components Analysis and clustering. However, it does not yet provide detailed documentation of the methodology or explicitly addresses the inclusion of extreme weather events. The purpose of the weather years selection was to find characteristically different years, which would present the energy system with various conditions to deal with, not necessarily but possibly extreme ones. It is important to note that the TYNDP for electricity performs Security of Supply (SoS) loop with several climate years, including extreme weather ones, under the Monte Carlo approach. Given the topic raised a lot of feedback, we included a detailed response as an annex to this report.
One stakeholder appreciated the change but requested **more detail on the number and interpretation of principal components used in the k-means clustering process**. They also suggested **comparing the selected years and their weights with those from the previous methodology** and questioned whether **more weight should be given to years with greater supply stress**.	
Beyond this, one stakeholder acknowledged the value of adding three climate years but warned that the use of **Principal Components Analysis and clustering might exclude extreme events**. They suggested including stress tests for such events, even if the number of weather years remained limited.	
Furthermore, one stakeholder **expressed concern that relying on median weather years may overlook the system's ability to handle extreme conditions**. They proposed including a historical year, a cold year, and a meteorological forecast to better test system resilience under stress.	
In addition, one stakeholder supported the improvements but emphasised the **need for greater transparency in how extreme weather events – such as Dunkelflaute periods – were identified and incorporated**. They also recommended that the methodology explicitly accounted for the effects of global warming on future weather patterns, including changes in temperature extremes, renewable availability, and the frequency of extreme events.	**Future updates will aim to:** • Provide a more detailed methodological note, including the number and interpretation of principal components and the clustering process. • Include or test against historical and extreme weather years to assess system resilience. Currently, a methodology to determine Dunkelflaute events in climate data is in preparation, which could be used for selecting Dunkelflaute Scenarios as further test cases. • Clarify the implications of weather year selection for cross-sectoral infrastructure planning and energy demand projections.
Two stakeholders raised similar concerns, arguing that using **only predicted weather years may fail to capture the full range of variability, particularly extreme conditions**. They **recommended including past extreme years** to ensure safe and reliable grid operation.	
One stakeholder welcomed the inclusion of future simulated weather years but called for a more comprehensive methodological note. They also highlighted the need to explain the **real-life implications of the methodology, particularly the interaction between gas and electricity networks under changing weather conditions**.	

QUESTION 20: IS THERE ANYTHING THAT YOU WOULD LIKE TO ADD?	
Five stakeholders provided additional feedback:	The feedback underscores the importance of transparency, realism, and flexibility in Scenario development.
One stakeholder expressed **concern about the short consultation period**, stating that two months would be necessary to properly analyse the extensive data and provide meaningful feedback. They noted the **absence of key data points – such as minimum and maximum ranges for RES and price assumptions – and highlighted the lack of dashboards to help interpret the fragmented Excel data**. They also regretted that no questions were included on the modelling inputs themselves.system is economically viable under market conditions. They recommended a hybrid approach that combines fixed near-term developments with cost-optimised capacity expansion in the long term. They also stressed the importance of transparency in modelling choices and their implications.	We take note of the need for more user-friendly dashboards to help interpret the data, and we will explore ways to improve the visualisation tools in future iterations. Regarding renewable generation, minimum and maximum ranges are not provided because the Scenarios do not include capacity expansion. The generation figures are based on data provided by the TSOs, in line with their respective NECPs. These values reflect national planning assumptions and are therefore fixed inputs in the modelling.
RECOMMENDATION 9: SRG suggests that transparency should be interpreted as sufficient information and time (see also Recommendation no. 3) provided to all stakeholders, allowing them to engage with the underlying assumptions and methodology used throughout the scenario cycle, also considering modelling complexity (as a sequence of modelling choices over the entire scenario-building process).	We support the SRG's interpretation of transparency as the provision of sufficient information and time for all stakeholders to engage meaningfully with the assumptions and methodology applied throughout the Scenarios cycle, including the modelling sequence and its inherent complexity.
Furthermore, one stakeholder raised **concerns about the shift to using fixed capacities** in the TYNDP Scenarios **instead of modelling endogenous capacity expansion**. While they acknowledged that this approach **aligns with national plans and policy commitments**, they warned that it may **obscure whether the system is economically viable under market conditions**. They recommended a hybrid approach that combines fixed near-term developments with cost-optimised capacity expansion in the long term. They also stressed the importance of **transparency in modelling choices** and their implications.	We acknowledge the need for improved transparency and stakeholder engagement and are actively working on further integrating the Stakeholder Reference Group as a reliable peer review grouping in the data and modelling process.
One stakeholder provided detailed **feedback on the Czech Republic's figures**, questioning the projected growth in methane use for cars, which they argued was unrealistic given the phase-out of CNG vehicles. They suggested focusing instead on buses and trucks. They also noted **inconsistencies in hydrogen use projections for the chemical and household sectors**, referencing the Revised Czech Hydrogen Strategy (2024).	**In response to modelling concerns:** • We support the call for improved documentation of assumptions through the development of a Quality Assurance Tool (QAT). • Future Scenario cycles may explore hybrid modelling approaches that combine fixed and cost-optimised capacity assumptions.
Moreover, one stakeholder submitted updated **sources for offshore wind capacity projections in several countries**, highlighting delays and policy uncertainties that could affect the feasibility of 2030 targets. They recommended revising the figures accordingly.	• The total final demand for hydrogen is in line with the Czech NECP, with no demand allocated to households. Final hydrogen demand in NT+ follows the same sectors as in the NECP; except we anticipate greater industrial use, whereas the NECP anticipates greater transport use. However, as the purpose of scenarios for TYNDP is to perform the cost-benefit analysis of transmission infrastructure projects or analysing future needs for system reinforcement/infrastructure gaps, we do not exclude the potential use of locally produced hydrogen at the distribution level, e.g., in the form of methane admixture.
Additionally, one stakeholder raised **concerns about methane demand projections in Spain**, noting that the figures for power generation exceeded historical maximums and were physically implausible. They also pointed out that **sectoral demand projections deviated from the NECP** and that **recent legislative developments supported a more prominent role for renewable gases in hard-to-abate sectors**.	• The Czech NECP does not provide sufficient detail on methane demand in the transport sector. While the information in the NECPs is taken in the account, the missing parts are complemented based on the approved methodology (calculation based on the Global Ambition and Distributed Energy scenarios in the TYNDP 2024). We are grateful for the suggestion; however, the impact of the proposed change is estimated to be minimal compared to the effort required to implement it as scenarios does not model the methane transport sector explicitly. Nevertheless, we noted your suggestion and will consider it for the next TYNDP cycle.

QUESTION 20 (CONTINUATION) IS THERE ANYTHING THAT YOU WOULD LIKE TO ADD?	
One stakeholder made several methodological suggestions: They **questioned the selective application of Scenario 3 from the EC's 2040 Impact Assessment** and proposed applying it more broadly across the TYNDP Scenarios. They also recommended c**onducting sensitivity analyses on the central Scenario (NT +), factoring in demographic decline in demand projections, and validating past Scenario projections against realised data**. Finally, they encouraged a **more proactive and ambitious approach to Scenario design** to avoid reactive adjustments in future cycles.	• Country-specific feedback will be reviewed and considered for adjustments in national projections. • Methodological suggestions including broader application of Scenario 3, demographic sensitivity, and historical validation, will be evaluated for integration into the TYNDP 2028 cycle.
RECOMMENDATION 10: SRG suggests that the role of alternative demand projections to energy infrastructure, including the effects of lower demand, should be explored in more detail. In the European Commission 2040 climate target Impact Assessment, LIFE Scenario (Scenario 3) exemplifies how different demand patterns influence supply. As an example, building renovations, changes in mobility, or industry transformation could affect, or even help optimise demand in the TYNDP Scenarios. As an example, it could be possible to perform a sensitivity analysis on the role of demand to study system benefits, cost savings, and any other related gains.	We acknowledge the SRG's suggestion. Exploring alternative demand projections and their impact on infrastructure – such as through sensitivity analyses – offers valuable insights and will be considered as Scenario development advances.

METHODOLOGY ON THE CALCULATION OF ECONOMIC VARIANTS	
RESPONDENTS' VIEWS (5 RESPONDENTS)	**ENTSOs' VIEWS**
QUESTION 1.A: HOW WOULD YOU OVERALL RATE THE DRAFT ECONOMIC VARIANTS METHODOLOGY (1–10)?	
The draft economic variants methodology received a moderate overall rating, with a mean score of 5.8 on a scale from 1 to 10. Among the six respondents, individual ratings ranged from 3 to 8, indicating a diversity of perspectives and a balanced but cautious level of support.	We acknowledge that the spread of ratings suggests that while the methodology is seen as a promising foundation, there is still room for refinement.
QUESTION 2A: DO YOU THINK THAT THE DRAFT METHODOLOGY FOR BUILDING ECONOMIC VARIANTS COULD BE IMPROVED AND IF YES, WHY AND HOW? (TEXT BOX, OPTIONAL)	
Stakeholders welcomed the streamlined planning process and clearer link to policy through a central Scenario but expressed concerns that the economic variants may oversimplify the complexity and uncertainty of the energy transition, particularly beyond 2035.	The feedback suggests that the current methodology, while efficient, may not fully support long-term infrastructure planning considering the high degree of uncertainty the European energy system faces.
Limited stress-testing value While one stakeholder found the ±15 % as sufficient in magnitude for economic testing, most stakeholders perceived variants too close to the central Scenario. Some see this as insufficient for generating meaningful insights from the stress test. Requests for variants to test against a wider set of risks: weather, environmental, policy shifts, technology breakthroughs, supply chain shocks, behavioural shifts etc.	We agree that a diverse and transparent Scenario framework enhances the robustness of system analysis, improve stakeholder confidence, and enables better alignment with EU policy objectives such as the European Green Deal.
Over-reliance on a single base Scenario Several stakeholders emphasised that focusing solely on macroeconomic parameters limits the exploration of structural uncertainties and resilience needs. Some stakeholders stressed the need to incorporate weather-dependent and resilience-focused Scenarios to better account for climate variability and extreme events. Calls for at least one alternative structural Scenario (e.g. high-electrification, decentralised systems, weather-stress case).	As set out in ACER's Scenarios Framework Guidelines, this cycle's Scenarios are designed as stress tests of the central (National Trends +) Scenario rather than standalone narratives. The economic variants provide a sensitivity analysis of the central model topology under differing macroeconomic consumption conditions, using a bottom-up approach that adjusts activity levels and technology mixes across sectors and subsectors in each country. Adjustment factors of ±7.5 % for activity and ±15 % for the technology mix were selected to strike a balance between generating meaningful variations in demand while limiting the risk of model non-convergence, given that supply capacities are held constant and only commodity prices vary accordingly and in a harmonised way (±10 %) for the economic variants from a supply point of view. Depending on the model results and convergency, we will be able to understand how system responds and how to further enlarge the variation.
Transparency and Methodological Clarity Some stakeholders emphasised the need for greater transparency in how Scenarios are constructed, including access to underlying assumptions, sectoral breakdowns, and justification for selected parameter values.	

QUESTION 3.A: IS THERE ANYTHING THAT YOU WOULD LIKE TO ADD? (TEXT BOX, OPTIONAL)	
Five stakeholders provided additional feedback.	We acknowledge that addressing these points would improve the robustness of the TYNDP and its value for long-term infrastructure and policy decisions.
Consultation Process One stakeholder questioned whether the new TYNDP 2026 framework allows enough flexibility and imagination. They noted that the **tight timeline limited the ability to test Scenarios and recommended improving the TYNDP 2028 cycle by allowing time for systematic sensitivity analyses on key transition issues**. They also called for better **integration of political, social, and environmental dimensions**, and for documenting lessons learned from TYNDP 2026. Additionally, they found the 2,000-character limit in consultation boxes too restrictive.	
RECOMMENDATION 11: SRG proposes that stakeholders outside the SRG can provide new ideas and suggestions, aligned with updates to the Innovation Roadmap, also in the future.	We support maintaining the Innovation Roadmap as a dynamic document that continuously incorporates input from SRG Working Groups and other stakeholders to guide future innovation priorities.
RECOMMENDATION 12: SRG requests visibility on what the Innovation Roadmap after the 2026 cycle is with a view to the TYNDP Scenarios 2028 cycle.	We acknowledge the SRG's request and confirm that the Innovation Roadmap will be updated at the start of the 2028 cycle, ensuring alignment with the evolving priorities of the TYNDP Scenarios process and continued stakeholder engagement.
Variation of supply capacities Furthermore, one stakeholder agreed that supply capacities should remain fixed in stress tests but noted that any adjustments due to non-convergence should be transparent. They also recommended sharing system cost impacts, especially from renewable imports.	
Including Biomethane in Scenarios Moreover, one stakeholder stressed the importance of including biomethane in Scenarios, especially given its absence in Germany's NECP. They highlighted the link between biomethane and biogenic CO_2, which is relevant for CCU/CCS applications, and referenced the BIP report[11] on this topic.	

11 Industrial Partnership (BIP) report "BIP_Task-Force-4.1_BioCO2-And-Biomethane_Apr2024.

6 ADDITIONAL QUESTIONS RAISED DURING THE PUBLIC CONSULTATION WORKSHOP NOT COVERED IN POINT 5. SUMMARY OF RESPONSES TO QUESTIONS //

12 participants asked a question in the Q&A. Upvotes represent the interest signalled by individual participants by using the upvoting option in the Q&A tool, Slido.

- *(3 upvotes) Regarding H_2 import by pipeline, do you perform an assessment of the green H_2 production potential in the countries of origine for each time horizon?*

  The import potentials are a mix of H_2 import infrastructure projects delivered to TYNDP 2024 and long-term strategies coming from the TSOs. In the projects and strategies assessment of the potentials are made and are therefore not directly assessed by the group.

- *Regulatory Assistance Project (RAP) (2 upvotes) The approach to offshore wind changed radically between the 2024 and 2026 cycles, top down to bottom up. How does this change the outcomes?*

  For both cycles, in 2024 and 2026 cycles, the National Trends Scenario is aligned with the Member States Non-Binding Agreements (MS NBA) for offshore figures.

- *(0 upvotes) I want to ask a question for the shared RES, you mentioned possibility to sell electricity to the market Is it happening only during surplus?*

  For the shared RES, indeed, the prioritisation is to supply the electrolysers located in the shared zone, only the surplus is going to the electricity market.

- *(0 upvotes) How will the evolving legal framework under ENTSO-E/ENTSOG ensure that vPPAs, including those incorporating batteries, can enable certified green hydrogen production through Guarantees of Origin, especially when generation and consumption are not temporally aligned? GO with timestamps?*

  Currently, our models restrict electrolysis from operating during hours when thermal generation is present. This is based on a marginalist approach, where the electrolyser is only allowed to run if the marginal price in the electricity market is lower than that of the cheapest gas-fired unit. In practice, this means electrolysers will only operate when electricity is being genserated from renewable or nuclear sources.

- *(0 upvotes) Is it fair to say that the hydrogen demand has decreased from the previous TYNDP cycle? What is the driver behind this?*

  Pre-modelling, the H_2 demand does seem lower than last cycle, especially for 2030. This could be a reflection of a more conservative approach to the speed of H_2 deployment in the EU.

– *(2 upvotes) What's the current development and application of grid-forming technologies, and how does Europe plan to address the challenge of decreasing system inertia?*

In the past, inertia was intrinsically provided by the rotating masses of connected synchronous generators, and the lack of resilience due to inertia was not an issue. Today and in the future, maintaining this resilience requires investments in either dedicated network assets or the technical capability of third-party assets, which must be applied in a balanced and efficient manner. ENTSO-E highlighted in its most recent studies that there is no single solution, but several categories of measures for improving system resilience have to be considered and weighed against each other. Assuming the importance of limiting the likelihood of system splits, the following actions can be categorised and listed:

- Foundational measures
- *Tackle the root cause. Keep inertia (rotational energy) above a certain limit, through a mix of infrastructural assets, capabilities ensured by the connection Network Codes and market-based services. For all possible aspects and combinations, there is a need to consider a balance between the system needs, the capability of different technologies, the expectations from decision-makers, system operators, grid users, market participants and social welfare.*
- Enhanced response measures (necessary in addition to the foundational measures)
- E*nhanced withstand capabilities for stable grid operation during high frequency gradients*
- *Frequency containment support to limit the nadir/zenith of the frequency*

In relation to Grid Forming Capabilities, the draft amended Network Codes on Requirements for Generators (NC RfG 2.0) and on HVDC (NC HVDC 2.0) set the grid-forming connection requirements and the contribution to the inertial support of the transmission system for Power Park Modules (PPMs, which includes Energy Storage Modules) and HVDC converters, respectively. ENTSO-E is currently working on defining exhaustive grid-forming requirements and certification schemes based on the amended NC RfG 2.0 via the Technical Group on Grid Forming Capability (TG GFC) together with key stakeholders.
ENTSO-E proposes a step-by-step approach, aiming at no-regret and realistically achievable steps to gradually and sustainably recover system resilience while continuously reassessing system needs and suitable solutions. It is necessary to establish a framework to implement the minimum inertia targets and continuously monitor its implementation and effectiveness. This will support the necessary TSO investment decisions in terms of necessary assets (e. g. SCs or STATCOMs), the specification of non-exhaustive grid connection requirements, and the mandatory application of such requirements, e. g. grid-forming convertors (GFCs) with stored energy requirements for generators. For more information you can check Project Inertia latest publication https://www.entsoe.eu/2025/01/23/entso-e-releases-the-latest-work-from-project-inertia-which-studie...

– *Regulatory Assistance Project (RAP) (2 upvotes) Can you elaborate on the reference grids. It strikes me that there is a difference in approach, with the H_2 grid allowing less certain projects earlier in the model. What does this have as impact?*

The H_2 grid was based on TYNDP 2024 projects with the most up to date information available at the time of consultation. This is due to the fact that the ENTSOG TYNDP 2026 project collection is scheduled for Q3 2024 which is after the Scenario modelling commences. A full review has taken place and while results are not known at this time, the impact is thought to be low. The introduction of conceptual projects for 2050 is also welcome.

– *(2 upvotes) I am not sure I quite understand the Scenarios grid methodology: should I understand that all candidate projects (and even more than that) will be included in the reference grid 2050?*

No "candidate" projects have been collected for the TYNDP 2026 Scenarios. The Scenarios grid is based on the project collections from ENTSO-E's TYNDP 2026 and ENTSOG's TYNDP 2024. Most of the projects included – regardless of their maturity level – have a commissioning date before 2040. Due to the absence of expansion in this cycle and the limited availability of new projects beyond 2040, we have incorporated projects submitted to the TYNDP with lower maturity levels. Additionally, we have included "conceptual" projects that were not submitted to the TYNDP.-These conceptual projects have been collected exclusively for Scenarios purposes and will only be considered as part of the 2050 grid.

– *European Commission, DG ENER (2 upvotes) On Scenarios grid, how do you intend to address possible adequacy issues? How the plans for expansion of national grids are considered. Do you intend to verify consistency of national grid and of conceptual projects coming from the TSOs with the TYNDP projects proposed by third party promoters?*

No expansion will be applied. Only projects submitted by TSOs/promoters will be part of the Scenarios grid:

- *TYNDP projects: Justified by promoters during the submission phase (environmental assessment, inclusion in NDPs, commissioning dates, etc).*
- *Conceptual projects: We have asked TSOs/promoters for a justification that will be published.*

- *(1 upvote) It seems that interconnections between Northern Africa and Europe do not currently have a completely developed framework. Could you please clarify if there are any specifics about that to be considered for 2026 TYNDP?*

  On the electricity side, these interconnections are not modelled in Scenarios. Exchanges with Northern African countries are included as demand timeseries in EU nodes (fixed exchanges provided by TSOs in PEMMDB). In ENTSO-E's TYNDP, MedTSO countries are modelled, and submitted projects connecting these countries with European ones will be assessed. On the H_2 side, import flows from North African countries are modelled under consideration of the volatile and seasonal characteristics of local renewable hydrogen production and the currently planned interconnector capacities. Potential import flows are therefore both limited by the availability of renewable hydrogen produced in North Africa and the reported interconnector capacities.

- *European Scientific Advisory Board on Climate Change (2 upvotes) Regarding the GHG budget methodology, are there any assumptions around carbon removals coming from DACCS, and the effect this may have on overall energy demand?*

  Direct Air Carbon Capture and Storage (DACCS) is a part of the Carbon Capture and Storage (CCS) numbers given by the TSOs (energy consumption and CCS values are collected) but are not given explicitly.

- *ACER (0 upvotes) For emissions "outside the scope of the TYNDP" it is explained that an European Commission source will be used. Which one? Any risk of underestimating/reaching a more favourable carbon budget if the chosen source sees significant reduction of non-energy related emissions?*

  The Impact Assessment report from the European Commission is used for estimates for "other emissions", "emissions from industrial processes" and "removals from LULUCF". The carbon budget will be dependent on the source chosen. The impact assessment is chosen because it estimates trajectories for the emissions and removals for the period for EU and under different policies.

- *CAN Europe – (2 upvotes) The Weather Year Selection for the future seems very welcome. Thanks for presenting the methodology and results. Can you give us concrete examples of how these results then are translated into the overall TYNDP results?*

  Please see Annex I of this report, the sub-section "Impact of Weather Year Selection on TYNDP Outcomes" for a detailed answer. It is important to note that the TYNDP for electricity performs Security of Supply (SoS) loop with several climate years, including extreme weather ones, under the Monte Carlo approach.
  On the hydrogen side, weather years are used to inform the renewable load profiles for wind and solar, as well as temperature profiles which impact heating demand profiles. The inputs can be used to perform adequacy studies.

7 ANNEX I: POSSIBLE IMPROVEMENTS TO WEATHER SCENARIO SELECTION METHODOLOGY //

Energy models rely on representative weather scenarios to capture variability in renewable generation and demand. The current methodology (as outlined in the draft guidelines) uses principal component analysis (PCA) on various annual metrics and then applies K-means clustering to select three representative weather year scenarios out of 30 candidates for each target period. While this approach provides a systematic selection, there are several opportunities to enhance the robustness and representativeness of the weather scenarios. Below four key improvement areas are described: using more granular data, broadening the pool of scenario candidates, providing stronger analytical reasoning for scenario choices, and exploring alternative clustering techniques (K-means vs. K-medoids, etc.).

Using more granular (hourly) data for key variables

One clear improvement is to increase the temporal granularity of input data for certain weather variables. In the current dataset, some variables are aggregated at weekly or daily levels – for example, hydro reservoir inflows are only available at weekly resolution and heating/cooling degree days (HDD/CDD) at daily resolution. Such coarse time resolution can obscure short-term fluctuations and extreme events. Important intra-day variations (e.g. hourly wind ramps or temperature spikes) may be averaged out in daily/weekly data, leading to scenarios that underestimate variability.

Why Hourly Data Matters: Power system models often require high-frequency weather inputs (hourly or sub-hourly) to capture volatility in supply and demand. For instance, wind power and solar PV output can change significantly within hours, and electricity demand (linked to temperature) has strong diurnal patterns. Using hourly data for these variables allows the scenario selection to account for within-day variability, not just daily averages or totals. This is crucial because extreme ramps or brief calm periods can stress the energy system even if the annual averages look normal. In practice, this means incorporating finer temporal data for weather scenarios whenever possible.

Preserving Variability and Extremes: Many climate model projections are only available at daily (or coarser) time steps, which poses a challenge for capturing hourly variability. An improvement is to employ downscaling techniques or high-resolution reanalysis to derive hourly series that are consistent with the climate model's daily output. For example, methods like quantile delta mapping can add projected climate shifts (e.g. monthly changes) onto historical hourly weather patterns. This preserves real-world characteristics that coarse climate models might miss – such as location-specific extreme events and natural variability. By using more granular data, the selected weather scenarios will better reflect phenomena like short cold snaps, heat waves, or wind droughts, leading to more resilient energy system planning. In summary, **upgrading to hourly resolution for key variables** (hydro, temperatures, etc.) and incorporating techniques to retain extremes will produce scenarios that capture the full variability spectrum of future weather.

Preselection of a broader and more diverse scenario pool

Another improvement is to broaden the initial pool of candidate weather scenarios for each target year, ensuring it encompasses the full variety of plausible climate outcomes. Currently, the approach considers 30 candidates per target year (e.g. for 2030, using 3 climate models × 10 years in the 2025–2035 window). While this yields a manageable set, it might inadvertently omit important outliers or combinations of conditions.

Using a Wider Range of Years and Models: Instead of drawing candidates only from a single decade and a few models, one could expand the selection space. This might include leveraging **multiple climate models or ensemble members** beyond the current three, to cover a wider range of climate projections. Each model can have different biases and variability, so more models increase the chance of capturing unusual patterns (e.g. a particularly dry year or an extremely windy year). Additionally, even though we focus on a target period (e.g. 2030s), considering a slightly larger range of years (or multiple decadal slices) for candidate scenarios could introduce rarer events. For example, if an extreme drought year is projected in 2040, it might be worth including as a stress-test scenario for the 2030s, after adjusting for any systematic trend. The guiding principle is that the **candidate set should represent the breadth of future climate variability**, not just the average conditions of one period.

Including Extreme and Diverse Cases: It is especially important to ensure that extreme weather years are present in the pool before clustering. Clustering algorithms tend to focus on grouping typical patterns and could overlook tail-end scenarios if those are absent or few. Therefore, a preselection step might deliberately add a few known extreme cases into the mix. For instance, one could identify the year with the highest peak load (or highest HDD, lowest wind output, etc.) and the year with the lowest renewable output in the broader dataset, and include those as candidate scenarios.

In our context, that means making sure the worst-case weather years (for supply or demand) are considered alongside more average years. This approach aligns with the IPCC Criterion 4, which states that scenarios should be **representative of the potential range of future climate change** so that a realistic range of impacts is assessed (ipcc-data.org). By populating the initial 30 candidates with a well-spread variety – across models, years, and extreme vs. typical conditions – the subsequent selection of representative scenarios will be more robust. It increases the likelihood that the final chosen scenarios cover *best-case, worst-case, and median* weather situations, rather than clustering around the mean. In summary, **expanding and diversifying the scenario pool** (through additional models, longer time spans, and targeted inclusion of extremes) provides a stronger foundation for selecting truly representative weather scenarios.

Stronger analytical reasoning for scenario selection

Improving the methodology is not only about data or algorithms, but also about how we **justify and explain the chosen scenarios**. After the mathematical selection (e.g. PCA plus clustering) identifies representative years, it's valuable to perform additional analysis to ensure these scenarios make intuitive and practical sense for energy modeling. Developing more rigorous reasoning around why each scenario was selected will enhance transparency and confidence in the results.

Interpreting the Scenarios: A recommended step is to analyze the characteristics of each selected weather year in terms of the original variables. For example, once three representative scenarios are chosen, we should examine their profiles: Is one scenario a "wind-rich year" with above-average wind capacity factors across regions? Is another a "dry year" with low hydro inflows? Does one correspond to an extremely cold winter (high HDD) driving up heating demand? By mapping the principal components or cluster features back to physical terms, we can give each scenario a narrative. In the current process, PCA loadings can indicate which variables drive the differences – for instance, if the first principal component heavily weights wind and solar output, then the clustering along PC1 essentially separates high-renewable vs. low-renewable years. Understanding these drivers allows us to say why scenario A, B, or C was picked (e.g. "Scenario A represents a high renewable generation year with mild demand, Scenario B represents a low renewable year with extreme winter demand," etc.). Providing such reasoning makes the scenarios **straightforward to interpret and apply**, which is a recognised best practice.

Data-Based Justification: We can bolster the reasoning with additional metrics and visualisations. For instance, calculate where each selected year lies in the distribution of key variables (annual wind output, peak demand, total hydro, etc.) compared to all 30 candidates. This can show that *Scenario B had the lowest 5th-percentile wind output of all candidates*, justifying it as an important stress scenario. Likewise, we might show that *Scenario A was near the median for most variables, making it a good central case*. Plotting the hourly profiles or duration curves of demand and generation for each scenario can further illustrate their unique features. Such analysis ensures that the selection isn't a black-box outcome of clustering, but rather a well-reasoned choice grounded in the data. It also helps identify if any important condition is still missing – for example, if none of the three scenarios had an extremely hot summer, one might reconsider whether an additional scenario or a different selection is needed.

Communicating the Rationale: Finally, documenting the selection rationale is crucial for stakeholders who will use these scenarios in energy models. We should clearly state the reasoning: e.g., "*We selected Year X (Model A 2033) as Scenario 1 because it had an exceptionally high wind year (wind output 20 % above average) representing a low-stress renewable-rich case. Scenario 2 (Year Y) reflects a difficult winter with record high heating demand (HDD +15 % anomaly) and low wind, posing a high-stress case for resource adequacy. Scenario 3 is a moderate case close to average conditions, to represent a typical year.*" Backing these statements with analysis builds trust. In summary, **enhancing the reasoning and analysis** around scenario selection – through interpreting principal components in physical terms, checking coverage of extremes, and clearly describing each scenario's significance – will make the methodology more rigorous and the outcomes more actionable.

Exploring improved clustering approaches (K-means vs. K-medoids vs. others)

Clustering is at the heart of the scenario selection method, and the choice of clustering algorithm can influence which scenarios get picked. The current method uses K-means clustering on the PCA-transformed data. It is worthwhile to investigate alternative clustering approaches – such as K-medoids or hierarchical clustering – to determine if they yield better representative scenarios for our purposes. Each approach has strengths and weaknesses in this context.

- **K-Means Clustering:** K-means is a popular partitioning method that minimises the within-cluster variance by averaging points. Its advantage is simplicity and efficiency; however, a major drawback is that the "centroid" produced by K-means is an average of points and **may not correspond to an actual observed year**. In practice, after running K-means one would choose the actual year closest to each centroid as the representative scenario. This two-step approach can work, but the averaging nature of K-means can smooth out extremes. For example, if one cluster contains one very windy year and one calm year, the centroid might be a moderately windy pseudo-year that never truly occurred. This could downplay the variability when selecting representatives. Indeed, research has noted that K-means tends to **bias towards mean conditions and can dilute extreme values** by using cluster means. It can, however, provide a good overall fit to the dataset and often yields smaller clustering error, which might translate to better representation of "typical" system behavior. If K-means is retained, one improvement could be to run it multiple times with different initialisations (or use K-means++ initialisation) to ensure stable clusters, and then always map centroids to the nearest real year to maintain realism.
- **K-Medoids Clustering:** K-medoids (exemplified by the Partitioning Around Medoids algorithm) is a similar clustering approach that restricts cluster centers to be **actual data points (medoids)** rather than arithmetic means. In our case, this means the algorithm would directly pick actual years as cluster centers. The benefit is clear: the representative scenarios are guaranteed to be real, internally consistent weather years from the dataset. This avoids the problem of unrealistic averaged scenarios. Studies in energy modeling have found that **k-medoids often performs better than k-means in preserving extreme characteristics**, since it doesn't smooth them out. By selecting a real day/year as the cluster exemplar, extreme events in that year remain intact. Another practical advantage is transparency – it's easier to explain "we chose Year 2034 from Model B" than to interpret a synthetic centroid. The trade-off is that K-medoids may not minimise variance as tightly as K-means (since it's constrained to pick existing points, it could yield a slightly larger clustering error). However, given our relatively small dataset (30 candidates), computationally we can even solve the optimal medoids via MILP if needed. **Comparing the results from both:** if K-medoids yields a very different set of representative years (perhaps highlighting an extreme year that K-means missed), that might actually be desirable for stress-testing the model.
- **Hierarchical Clustering:** Hierarchical methods (agglomerative or divisive clustering) offer another alternative for scenario selection. Agglomerative hierarchical clustering would start with each year as its own cluster and merge clusters stepwise until three clusters remain. A benefit is that it does not require pre-specifying the number of clusters (you can examine the dendrogram to decide an appropriate cut), and it can capture structure in the data that k-means/medoids might miss (especially if clusters are not globular in PCA space). Using hierarchical clustering with an appropriate distance metric (e.g. Euclidean on the normalised feature set) could produce slightly different groupings. We could then choose one representative year from each of the three dendrogram groups (for example, the medoid of each). Hierarchical clustering has been used in energy systems time-series aggregation in prior studies. Its results might be more stable (less dependent on random initialisation) and it provides a full landscape of how scenarios relate to each other. The downside is potentially less optimal within-cluster variance for a given k, and it might be

computationally heavy if the dataset were large (though 30 points is trivial). It's worth experimenting to see if hierarchical clustering yields clusters that better separate, say, a distinct extreme scenario cluster.

- **Other Clustering Techniques:** Beyond these, there are more advanced or specialised methods that could be explored. For instance, **shape-based clustering** methods consider the *time-series pattern* explicitly (using metrics like dynamic time warping or correlation) rather than summary statistics. Such methods (e.g. DTW barycenter averaging, k-Shape clustering) have been shown to capture intra-day and seasonal patterns effectively. They might cluster years by similarity in the shape of their hourly profiles (e.g. how wind and solar profiles co-vary through the year) rather than by just annual averages. This could be useful if two years have the same annual totals but very different temporal distributions of generation/demand. Additionally, one could consider **fuzzy clustering** (which would allow a year to belong partially to multiple clusters) or **Gaussian mixture models**, though the end goal of picking discrete scenarios makes hard clustering methods more straightforward.

In summary, **investigating K-medoids and other clustering alternatives** is a worthwhile enhancement. K-medoids ensure realistic representative years and can better handle extremes, whereas K-means is efficient but can oversmooth important variations. Hierarchical clustering provides a different perspective that could validate or challenge the K-means/Medoids results. A prudent improvement to our methodology is to **compare the outcomes from multiple clustering techniques** and choose the one (or a combination) that best meets our needs for diversity and realism of scenarios. For example, we might adopt K-means for its cluster optimality but then use the nearest actual year (medoid) as the representative, merging the strengths of both approaches. By doing so, and by possibly incorporating shape-based clustering for time-series patterns, we ensure the weather scenario selection is robust and defensible.

Conclusion

By implementing the improvements above, the weather scenario selection methodology will better serve energy modeling objectives. **Using more granular hourly data** for weather inputs will capture the fine-scale variability and extremes that impact power systems, aligning scenario data with model needs. **Broadening the candidate pool** (additional years, models, and explicit extreme cases) will make the selection more representative of the full range of future climates. Coupling the quantitative selection with **strong analytical reasoning** and clear interpretation ensures the chosen scenarios are transparent and justifiable to stakeholders. And finally, **exploring clustering alternatives** like K-medoids and others provides confidence that the method isn't missing better ways to characterise the data. These enhancements will result in a set of weather scenarios that is not only statistically more sound but also richer in information – covering diverse conditions from mild to extreme – thereby strengthening the reliability of subsequent energy model analyses. Each scenario can then be used in capacity expansion or production simulations with the assurance that it represents a distinct and important facet of what the future might hold.

Impact of Weather Year Selection on TYNDP outcomes

Weather Year Selection in Electricity System Modelling

TYNDP 2024 Scenario Modelling: In ENTSO-E's TYNDP cycle, the electricity system simulations are driven by detailed scenario data, including hourly profiles for demand and renewable generation. These profiles are derived from historical (TYNDP 2024 approach) or projected (TYNDP 2026 approach) climate years to represent typical weather-driven variations (e.g. wind, solar irradiance, temperature). Rather than relying on a single arbitrary year, ENTSO-E selected **three representative climate years within TYNDP 2024 process** (1995, 2008, 2009) from the 30-year Pan-European Climate Database (PECD). These years were chosen for their statistical representativeness of long-term weather patterns. In practice, the market modelling (generation dispatch and cross-border exchanges) for each future scenario (2030, 2040, etc.) was run for all three climate years, and the results were **combined as a weighted average** (with 2009 carrying the highest weight, as it was deemed most representative). This approach ensures that the **electricity system modelling captures weather variability**, rather than reflecting just one specific year's conditions. For example, a scenario run with a windy year might show different flows and prices than a calm wind year; using multiple years blends these effects to get a robust outcome.

Dynamic Demand & RES Profiles: The "weather year" selection influences demand (especially for temperature-sensitive heating demand) and renewable supply. In TYNDP 2024's modelling tool (the Energy Transition Model, ETM), a single historical weather year was initially used to model demand and supply profiles. Stakeholders recognised this as a limitation, since one year cannot capture extremes. ENTSO-E has since enhanced the ETM to allow using **multiple historical and even climate-change-based weather years** for future scenarios. The value of this improvement is high: relying on a single climate year misses the variability in energy demand and renewable output due to weather. Thus, by incorporating diverse weather years, the **electricity system model** can simulate conditions like cold, low-wind winters or sunny, mild summers, revealing how the system performs under each. This yields concrete results such as different levels of **renewable curtailment, fuel burn, or power transfers** between countries under varying weather conditions. Those results directly feed into identifying where the grid might be stressed and need reinforcement in the TYNDP. In short, the weather-year methodology improves the **realism and resilience** of scenario modelling, which underpins all TYNDP analyses.

Influence on Cost-Benefit Analysis (CBA) Results

Project Assessment Under Multiple Climate Conditions: Once the scenarios (with their weather-year-based hourly data) are defined, TYNDP 2024 evaluates individual grid and storage projects via a standardised Cost-Benefit Analysis (using the CBA 4.0 methodology). Each project (transmission line, storage facility, etc.) is assessed by comparing the system's performance with and without the project across the scenario(s). Here, the **selected weather years play a key role** in ensuring the CBA captures a project's benefits under realistic conditions. For TYNDP 2024, ENTSO-E's all 3 selected climate years were used in all project evaluations. By doing so, the CBA can quantify benefits like reduced generation cost (socio-economic welfare gain), CO_2 emissions avoided for a weighted average weather year.

Concrete Example – Robustness of Benefits: Including multiple weather years in CBA means, for instance, that a new interconnector's value is proven in both high-wind and low-wind situations. In a **wind-rich year**, that line might alleviate curtailment and enable exports of surplus renewable energy; in a **low-renewable year**, it might carry power from other regions to cover a supply shortfall. If only one year were used, the project might seem less beneficial or overly beneficial depending on that year's conditions. TYNDP 2024 mitigated this by weighted averaging results over the three reference years for core economic indicators. Thus, the **cost-benefit indicators reported (e.g. Annual Socio-economic Welfare gain)** reflect a weather-weighted outcome rather than a one-year anomaly. Notably, for **system adequacy and security of supply metrics**, an even broader approach was taken – ENTSO-E simulated **30 different climate years** from the PECD dataset to evaluate adequacy (indicator B6). This means metrics like **Expected Energy Not Served (EENS) or Loss of Load Expectation** for each scenario incorporate all the available weather extremes. As a result, when a project is credited with improving adequacy, that credit is valid across a wide range of historical weather situations, not just an average case. In summary, the weather-year methodology ensures that TYNDP's CBA of projects is **robust and future-proof**, giving decision-makers confidence that a project's benefits hold up under varying climate conditions.

Identification of System Needs and Infrastructure Gaps

Weather-Driven Needs Assessment: The "System Needs" analysis in TYNDP is a broad **pan-European study of where the grid requires reinforcement** or additional resources in future scenarios. It uses the same scenario data (with weather-year profiles) and simulates the European power system "as is," to find where **bottlenecks, congestions, or adequacy issue**s arise if no further infrastructure is built beyond already committed projects. By applying multiple weather year conditions in the model, ENTSO-E ensures that identified needs aren't tied to a single benign climate year. For example, a particular cross-border corridor might not appear overloaded in an average wind year, but **under a low-wind or high-demand winter scenario it could become critically congested**, indicating a need for expansion. The TYNDP 2024 needs study indeed considered the range of climate years, which gave a comprehensive view of such stress points. It found significant needs even in a scenario where renewables and flexibility are advanced – highlighting that **additional grid capacity is required to meet decarbonisation goals cost-effectively**.

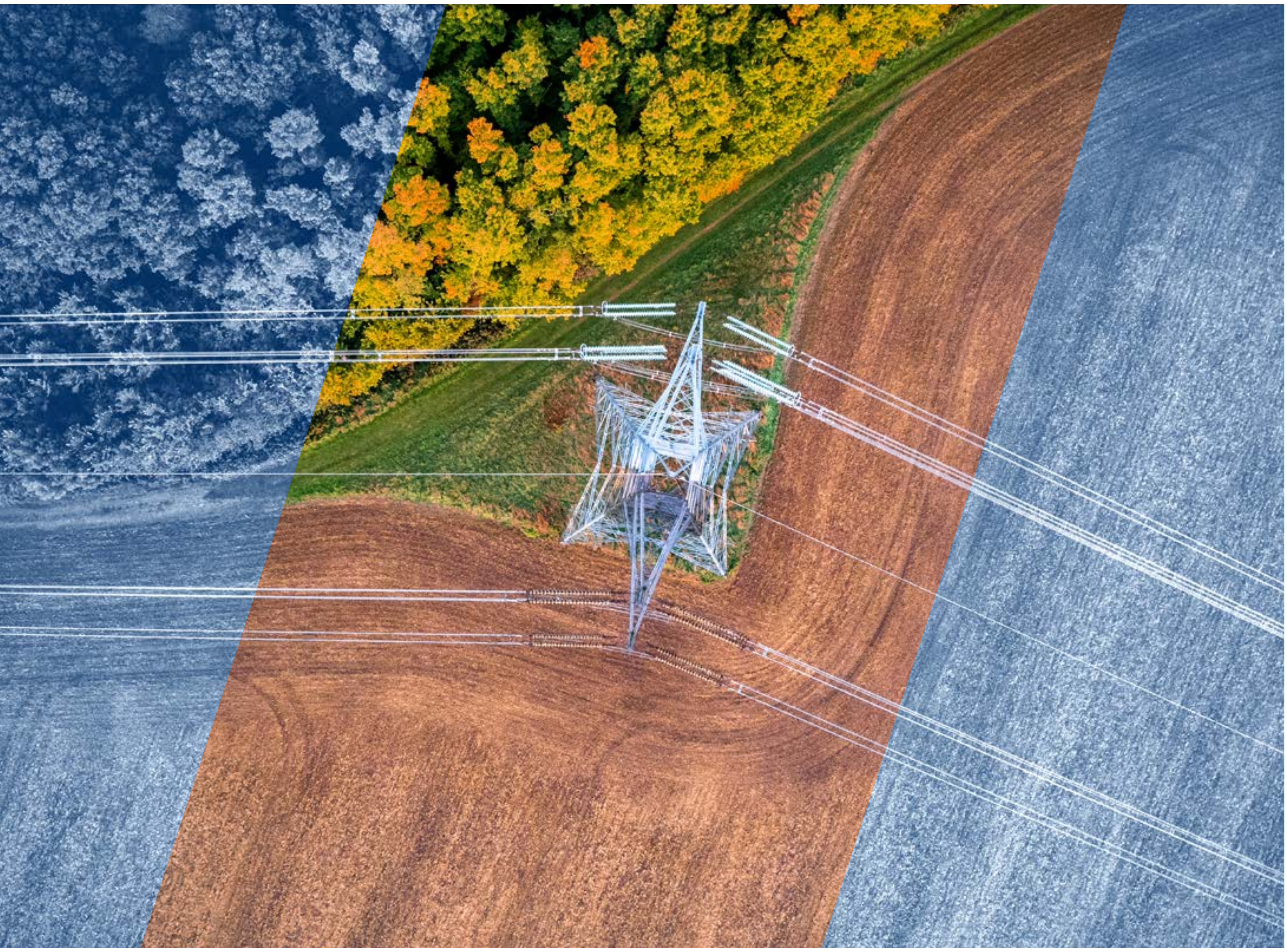
Concrete Example – TYNDP 2024 Needs Results: One headline result of the TYNDP 2024 System Needs assessment was that by 2040 there are about **108 GW of additional cross-border capacity opportunities** (i.e. transmission upgrades or new lines) that would be economically beneficial beyond what's already planned. These needs were identified using the National Trends and other scenarios, which incorporated the representative climate-year data (3 climatic years). Meanwhile, the portfolio of projects currently in the TYNDP 2024 (under development) would add roughly 80 GW by 2040, still leaving a gap – meaning further projects or non-wire solutions are required. The inclusion of diverse weather conditions in the analysis adds confidence that this 108 GW figure isn't underestimated or overestimated due to a fluke year: it is a **resilient finding**, since the model saw consistent congestion or price separation across many weather patterns.

Translating Methodology to TYNDP Outcomes: In summary, the new weather year selection methodology improves the **fidelity of TYNDP results in several ways**. In the **electricity system modelling**, it yields more realistic dispatch and flow patterns, which feed into identifying system needs. In the **Cost-Benefit Analysis**, it ensures each project's valuation accounts for weather variability, leading to more robust prioritisation of projects. And in **System Needs identification**, it guarantees that the highlighted infrastructure gaps (like the 108 GW cross-border capacity need) are valid across a spectrum of climate conditions – not just an artifact of one scenario year. This comprehensive approach aligns the TYNDP with the reality of a changing climate: planners can no longer assume yesterday's weather will repeat, so the TYNDP now explicitly tests future grids against a richer set of weather futures. As a result, stakeholders and policymakers get a TYNDP 2024 that better reflects **both typical and extreme system conditions**, ultimately helping to design a more resilient and efficient European grid.

8 ANNEX II: ANSWERS RECEIVED FROM THE PUBLIC CONSULTATIONS

Annex 2 containing answers received from the public consultations on the draft TYNDP 2026 Scenarios input assumptions, data, parameters and methodologies (publicly consulted upon between 16 June – 14 July 2025) and economic variants methodology (publicly consulted upon between 1 – 29 July 2025) can be accessed in the download section of the TYNDP 2026 Scenarios Public Consultations Summary Report via the joint TYNDP Scenarios website by searching for the file name.

Please note that two respondents to the public consultation on the TYNDP 2026 Scenarios' draft input assumptions, data, parameters and methodologies did not wish their responses to be published, which has been taken into account by deleting their feedback from the publicly available answers received to the public consultations.



GLOSSARY

ACER	European Union Agency for the Cooperation of Energy Regulators
CAPEX	Capital Expenditure
CBA	Cost-Benefit Analysis
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
CDD	Cooling Degree Days
CMIP6	Coupled Model Intercomparison Project Phase 6
DACCS	Direct Air Carbon Capture and Storage
DE	Distributed Energy
DSO	Distribution System Operator
DSR	Demand Side Response
EC	European Commission
EENS	Expected Energy Not Served
EIA	Environmental Impact Assessment
ENTSO-E	European Network of Transmission System Operators for Electricity
ENTSOG	European Network of Transmission System Operators for Gas
ERAA	European Resource Adequacy Assessment
ETM	Energy Transition Model (ETM)
ETM	Energy Transition Mode
ETM	Energy Transition Model
GA	Global Ambition
GAAs	Grid Acceleration Areas
GFCs	Grid-Forming Convertors
GHG	Greenhouse Gas
HDD	Heating Degree Days
HICP	Harmonised Index of Consumer Prices
HVDC	High Voltage Direct Current
ICT	Information and Communication Technology
LULUCF	Land-Use, Land-Use Change and Forestry
NECPs	National Energy and Climate Plans
NGO	Non-Governmental Organisation
NT+	National Trends+
NTC	Net Transfer Capacity
OPEX	Operational Expenditure
P2G	Power to Gas
PCA	Principal Component Analysis
PCA	principal component analysis
PCI	Project of Common Interest
PECD	Pan-European Climate Database
PEMMDB	Pan-European Market Modelling Database
PMI	Project of Mutual Interest
PPA	Power Purchasing Agreement
QAT	Quality Assurance Tool
RAP	Regulatory Assistance Project
RES	Renewable Energy Sources
SMRs	Small Modular Reactors
SoS	Security of Supply
SRG	Stakeholder Reference Group
TSO	Transmission System Operator
TYNDP	Ten-Year Network Development Plan
TYNDP	Ten-Year Network Development Plan
V2G	Vehicle to grid
WGSB	Working Group Scenario Building

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