# TYNDP // 2024

May 2024

# Draft Scenarios Report

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# FOREWORD //

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We are delighted to jointly take this first step of the development of ENTSO-E and ENTSOG's Ten-Year Network Development Plans (TYNDP) 2024 process and develop together our respective scenarios. Our joint gas and electricity scenarios report is the fourth of its kind, building upon the successive scenario cycle since the first joint edition in 2018.

Scenarios are a prerequisite for any study analysing the future of the European energy system. For the first time, the revised TEN-E Regulation (EU) 2022/869 requires a close alignment between the planning of the electricity, hydrogen and methane networks, which demonstrates the importance of the continued close cooperation between ENTSO-E and ENTSOG.


We believe that the delivery of the EU strategy on Energy System Integration in practice means the implementation of planning and development of all clean carriers in unison, if we want to meet European energy consumers' needs whilst also achieving EU climate neutrality goals by 2050. Without this, a fully integrated energy system to deliver more efficient decarbonisation solutions is not possible. An integrated approach linking electricity, hydrogen and methane networks and countries seamlessly will support the efficient uptake of new technologies, while ensuring reliable energy supplies to consumers throughout the year, including peak demand situations.

Regarding the Scenarios themselves, they must be, according to the TEN-E Regulation, "*fully in line with the energy efficiency first principle and with the Union's 2030 targets for energy and climate and its 2050 climate neutrality objective and shall take into account the latest available Commission scenarios, as well as, when relevant, the national energy and climate plans ('NECPs')*". The scenarios therefore evaluate the interactions between the electricity, hydrogen and methane systems, vital to delivering the best assessment of the infrastructure from an integrated system perspective. For this TYNDP 2024 scenario cycle, there are six scenarios, labelled either National Trends+ (NT+) scenarios or Deviation Scenarios (Distributed Energy [DE] and Global Ambition [GA]).

Notably, the scenarios rely on innovation in new and existing technologies to achieve net-zero emissions. This is required to reduce the costs of energy from renewable energy sources, ensure the uptake of renewable and decarbonised gases, increase the efficiency of user appliances, facilitate demand side response and consumer participation, and develop technologies that will support negative emissions, while ensuring long-term sustainability for future generations.

The process to build our scenarios was guided by principles to ensure open stakeholder engagement from the beginning, with input on key parameters and consultation on published data,not just concepts. The 2024 scenarios building cycle included extensive stakeholder engagement with two innovations: the creation of the Scenarios Stakeholder Reference Group, as required by the TEN-E regulation and by the ACER Framework Guidelines, and the organisation of in-person stakeholder roundtables during our public consultation process to cater for more open discussions.

The development of this wide-ranging set of possible energy futures, as presented in the present Scenarios Report, will allow the electricity and gas TYNDPs to perform sound and comprehensive assessments of European energy infrastructure requirements from a whole energy system perspective. Our TYNDPs provide decision-makers with better information, as they seek to make informed choices that will benefit all European consumers.

Our scenario teams remain available for any further information at **scenarios@entsos-tyndp-scenarios.eu**. We look forward to continuing working with all stakeholders as we follow the next important steps in the TYNDP process.

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GAS CONNECT AUSTRIA

# 1 EXECUTIVE SUMMARY //

Building on the previous scenarios reports, the cooperative work of electricity and gas planning experts across Europe, the joint TYNDP 2024 Scenarios Report is more ambitious, more inclusive, and more transparent than previous editions. The TYNDP 2024 scenarios align with the energy efficiency first principle, the EU's 2030 energy and climate targets, its 2050 climate neutrality objective and ENTSO-E and ENTSOG have gone to great lengths to capture the impact of the fast-moving and fast-paced energy transition on electricity and gas infrastructure. This joint report is the building block of the future electricity and gas TYNDPs and contains a series of important highlights for the future of Europe's energy system:

## 1.1 Energy efficiency is key step to achieve the EU Climate and Energy objectives

All our scenarios are built upon 2030 National Trends Scenario, which demonstrates the union energy efficiency and renewable energy directive objectives. Fast implementation of efficiency first principle is key to achieve both targets but also key to minimise long-term challenges of decarbonising the energy supply:

- Continued improvement of existing technology options, whilst switching to new and emerging technologies where further efficiency gains can be obtained.
- Active participation of end consumers through behavioural adaptation.
- Increased direct electrification contributes to more efficient integration of renewable energy.
- Early development of negative emission options is required to limit further investments post 2050 subject to the carbon budget method.
- Further integration of the hydrogen system into the integrated energy system view.

## 1.2 Net Zero can be achieved by 2050 while ensuring the security of energy supply

All scenarios built on NT+ scenarios which foresee a reduction of GHG emissions of at least 55 % in 2030 compared to the 1990 level and reaches net zero in 2050. These targets are achieved with an ambitious development of energy efficiency, renewable and low carbon technology solutions in EU Member States. This achievement requires a wide range of actions whose impact depends on an appropriate political, societal, and economic framework.

## 1.3 Ambitious development of renewable energy across Europe

Our scenarios meet with the EC's renewable energy share target by reaching up to 45.4 % in 2030, which is possible through high increase on the development of wind and solar. However, all decarbonisation and renewable technologies are needed to support long term European climate and energy targets to reach net zero 2050:

- Long-term climatic targets can be achieved through sustained growth and substantial investment in all European renewable energy sources including wind, solar and biomethane.
- Fostering renewable energy production at consumer level (e.g., prosumers, energy positive buildings, etc.) will contribute to scaling up and embracing clean energy supply.
- Transmission infrastructure is needed to connect areas of high renewable energy potential to the high demand centres.
- Acceptance of energy infrastructure expansion is paramount to achieve climatic targets.

## 1.4 Sector Integration provides efficient decarbonisation solutions

A fully integrated system can deliver efficient decarbonisation solutions and enables the European production of electricity and gas to be carbon neutral before 2050. Integration of electricity, methane and hydrogen infrastructures provides a wide range of opportunities to solve short-term and seasonal flexibility needs in a net-zero energy system:

- Unlocks the potentials of renewable electricity sources and allows the efficient use of electrolysis technologies.
- Allows efficient development of hydrogen and synthetic fuels fostering further development of renewables.
- Allows capturing optimum solutions to support energy system's flexibility needs.

## 1.5 The EU methane and hydrogen production can decarbonise by 2050 to ensure a competitive, resilient, and reliable energy system

Both methane and hydrogen serve as versatile energy carriers across multiple sectors, offering substantial potential to contribute to Europe's decarbonisation efforts. This allows the EU to maintain a more resilient and reliable energy system, based on all available technologies and energy carriers. With the development of renewable hydrogen, biomethane and decarbonisation technologies, the EU can decarbonise nearly 80 % of its gas production by 2030 in National Trends and decarbonise completely until 2050. Furthermore, natural gas import levels are reduced to zero by 2050, contributing to the independence of the EU from fossil fuels imports.

## 1.6 Direct electrification is key to achieve the decarbonisation objectives when it can ensure an efficient use of renewable energy

The notable increase in direct electrification is driven by Europe's shift away from fossil fuels, underscoring the region's commitment to enhancing energy efficiency and accelerating decarbonisation.

- Increase in direct electricity is most energy efficient solution to achieve EU's energy and climate targets.
- Increased electrification is witnessed in all sectors but more significantly in transport, residential & tertiary sectors.
- Direct electricfication through significant uptake of small scale electrification technologies, such as EVs and heat pumps, are key to fulfill the efficiency first principle and reduction of air pollution.

## 1.7 Integrated energy systems: hydrogen is the game changer for gas and electricity systems

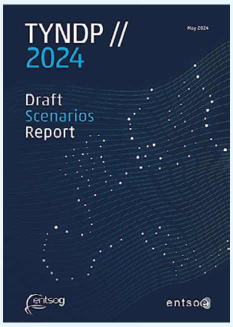
- Hydrogen efficiently contributes to the transition of the current gas system into a carbon neutral and more integrated system.
- Hydrogen unlocks the full potential of renewable electricity resources. It will contribute to a higher European energy autonomy.
- While reducing import dependence from fossil fuels, a European hydrogen market is an opportunity for the EU to take part to a global clean energy market and to import low-carbon energy.

## 1.8 Innovation is key to achieve a sustainable energy future

The scenarios depict several ways in which the European energy system may evolve with the aim of reaching climate neutrality. However, it cannot be ignored that there are additional factors and challenges that go beyond what is needed for energy infrastructure planning like market design, and operational procedures. Further attention is needed to understand the impact in the shift towards a sustainable economy including recycling and repurposing, enabling stable supply chains, use of land space and scarce resources, training of workforce, financing, and citizen engagement. Innovation needed goes beyond technical know-how to ensure the energy system is made sustainable in time for future generations.

The draft joint TYNDP 2024 Scenarios Report comes with wider data sets available through a dedicated scenarios website. These scenario data sets can be used by stakeholders to do their own studies on possible energy futures. ENTSO-E and ENTSOG have also provided full transparency on how scenarios are built and how each factor influencing the development of electricity and gas infrastructure is considered. ENTSO-E and ENTSOG will continue striving to improve their scenarios report, engaging as early as possible with stakeholders, increasing transparency and usability. Both associations hope this report will give readers a qualitative insight into the impact of the energy transition on Europe's future electricity and gas networks.

# 2 CONTENT OF THE SCENARIOS PACKAGE //




### TYNDP 2024 Scenarios Report:

Main report of the scenarios package, explaining the purpose, context and key findings as well as stakeholders' engagement steps taken. The report also includes a description of the main results and a benchmark against other scenarios.

**Download the complete Package**

### Appendices include:


### TYNDP 2024 Scenarios Methodology Report:

Describes the methodology applied to build the 2024 scenarios.
It includes a description of the overall process, detailed explanations of modelling principles and an overview of modelling parameters.


### TYNDP 2024 Scenarios Report Data Figures:

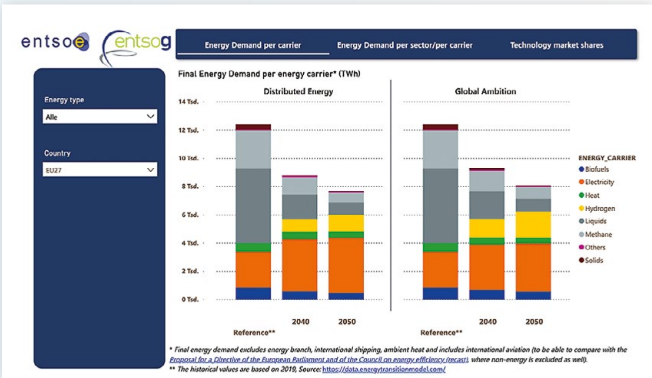
Calculation of the figures in the Scenarios Report.


### TYNDP 2024 Scenarios Storyline Report:

Describes the storylines and how they were developed.

### TYNDP 2024 Scenarios Visualisation Tool:

This interactive tool allows the user to visualise scenarios data, with filters including geographic area, climate year and fuel type.



## Data:

Static graphs and figures

## Inputs:

- Demand Scenarios TYNDP 2024 After Public Consultation
- Supply Inputs for TYNDP 2024 Scenarios After Public Consultation
- Electricity and Hydrogen Reference Grid & Investment Candidates After Public Consultation
- Modelling Methodologies After Public Consultation
- District Heating Supply
- Pan European Market Modelling Database (PEMMDB) 2.5
- Pan European Climatic Database (PECD)_ 3.1
- EV Modelling Inputs
  - Availability Profiles / Driving Profiles / EV Charging Stations / EV Min SOC / EV Vehicles
- Hydrogen Modelling Inputs
  - $CO_2$ Synthetic Fuel Ratios
  - $H_2$ Import Generators Properties / $H_2$ Storage
  - SMR
  - Synthetic Fuel Generators Properties / Lines
- Hybrid Heat Pump Modelling Inputs
  - COP / Heat Pump Capacity & Heat Rate
- Offshore Hub Modelling Inputs
  - Electrolyser / Generator / Grid / Node
- Demand Profiles
  - Electricity / Hydrogen / Synthetic Fuels / Heat (for Hybrid Heat pump)
- Hydro inflows
- Investment Datasets
- Line data including reference grid
- List of nodes
- Commodity Prices
- $CO_2$ emission factors
- TYNDP 2024 Scenarios Input Data – Public Consultation Summary Report
- Annex 1: TYNDP 2024 Scenarios Input Data – Public Consultation – All answers received

## Outputs:

- Readme file
- NT+ 2030 Modelling Results
- NT+ 2040 Modelling Results
- DE & GA 2035 & 2040 & 2050 Modelling Results for Climate Years 1995, 2008, 2009
  - Electricity, Hydrogen, Hybrid Heat Pump and Synthetic Fuel Modelling Results
  - _MMStandardOutputFile_Readme
- Electricity Results
  - Hydrogen Results
  - Offshore Hub Results
  - Heat & Synthetic Fuel Results
- Supply Tool

## Datasets from ENTSO-E & ENTSOG TYNDP 2024 Scenarios Public Consultation Webinar & Stakeholder Roundtables – 13 July 2023

- Webinar presentation and recording
- Webinar Q&A
- Stakeholder roundtable summaries:
  - carbon budget / demand input / methodology / supply input

## Datasets for TYNDP 2024 Scenarios input datasets & methodologies for public consultation – 04 July 2023 and 08 August 2023

- 20230704 – Draft Supply Inputs for TYNDP 2024 Scenarios for consultation
- 20230704 – Draft Supply Tool (EU-level)
- 20230704 – Modelling Methodologies & Draft Assumptions
- 20230704 – Electricity and Hydrogen reference grid and investment candidates
- 20230704 – Draft Demand Scenarios TYNDP 2024*
- 20230711 – Draft Carbon Budget Methodology
- 20230711 – Draft $H_2$ Steel Tank Methodology
- 20230711 – National Trends + Energy Mix Survey (Excel, 1.2MB)*

## ENTSO-E & ENTSOG TYNDP 2024 Scenarios Kick-off and Storyline Review Webinar – 20 July 2022

- Webinar presentation
- Webinar Q&A

# 3 PURPOSE OF THE SCENARIOS //

## Scenarios aim to establish a quantitative basis for the infrastructure assessment and network planning

Scenarios are used in ENTSO-E's and ENTSOG's respective TYNDPs for two main purposes: as a basis to perform the cost-benefit analysis of infrastructure projects; and as a basis for studies analysing future needs for system reinforcement / infrastructure gaps. On ENTSO-E's side, they may also feed into future work on the cost-sharing of offshore infrastructure.

Because their purpose is to support infrastructure planning, the scenarios are designed to reflect the EU energy targets and national policy goals and strategies, such that they explore the uncertainties relevant to the gas and electricity infrastructure development. As such, they primarily focus on aspects which determine infrastructure utilisation. The differences between the scenarios are therefore predominantly related to possible variations in demand and supply patterns. The scenarios within the TYNDP 2024 framework remain neutral in terms of technology, source, and energy-carrier neutral.

It is important to recognise the dynamic nature of the energy transition in Europe. ENTSO-E and ENTSOG acknowledge that some input parameters used in scenario creation may require adjustments as EU and Member States' energy policies evolve to address climate change challenges. Hence, the TYNDP Scenario Building Process is iterative and continues to evolve in tandem with the energy system.

## Legal framework

According to Regulation (EU) 2022/869 ('TEN-E Regulation')[1], ENTSO-E and ENTSOG are mandated to jointly develop scenarios for the future European energy system in the context of their respective Ten-Year Network Development Plans (TYNDPs). These scenarios align fully with the energy efficiency first principle, the EU's 2030 energy and climate targets, its 2050 climate neutrality objective, and consider the latest available Commission scenarios[2], as well as, when relevant, the national energy and climate plans (NECPs).

In January 2023, the European Union Agency for the Cooperation of Energy Regulators ('ACER') published the Framework Guidelines for the joint TYNDP scenarios to be developed by ENTSO for Electricity and ENTSO for Gas "TYNDP Scenarios Guidelines"[3]. The TYNDP 2024 scenarios apply part of the guideline set in the TYNDP Scenarios Guidelines, which were published midway through the 2024 scenario building process. These include guidelines on the extended stakeholder engagement process, the transition to more robust and transparent tools, and improved methodologies to capture increased sectorial integration and flexibilities, all going in the direction of an even more transparent and non-discriminatory process for developing robust scenarios.

1 See here

2 The latest available Commission Scenarios considered for TNYDP 2024 scenarios are Fit for 55 and REPowerEU scenarios.

3 See here

# 4 SCENARIO DESCRIPTIONS AND STORYLINES //

The TYNDP Scenarios aim to maintain robustness by ensuring consistency between successive TYNDPs while also incorporating new elements relevant to the ongoing development of the energy transition.

To achieve this goal, the TYNDP 2024 scenario storylines draw upon the storyline framework established during previous cycles, with extensive stakeholder feedback received on the 2022 draft storyline continuing to provide a solid foundation for the development of our current scenarios.

The TYNDP Scenarios Guideline emphasises the importance of stability between scenarios as a key element of robustness. It states that stability contributes to robustness by ensuring that the choice of storylines does not unnecessarily deviate from one TYNDP cycle to the next. To address the evolving landscape of the energy sector, an adapted storyline update process was initiated at the outset of the TYNDP 2024 cycle, involving a public workshop to gather stakeholder feedback. Detailed information about the storylines and its development process is outlined in the Storyline Report published in July 2023[4]. This chapter aims to summarise the key insights from the storyline report at a high level.

## 4.1 Scenario Framework

The scenarios must fulfill their intended purpose as described in Section 3 and adhere to a framework that is constrained to ensure the TYNDP is published every two years. TYNDP 2024 scenario cycle include six scenarios, which are labelled either **National Trends+ ('NT+') scenarios or deviation scenarios (Distributed Energy 'DE' and Global Ambition 'GA')** based on development approach. Figure 1 illustrates how ENTSO-E and ENTSOG cover different time horizons in their scenarios for TYNDP 2024.

**TYNDP 2024 SCENARIOS STRATEGY**

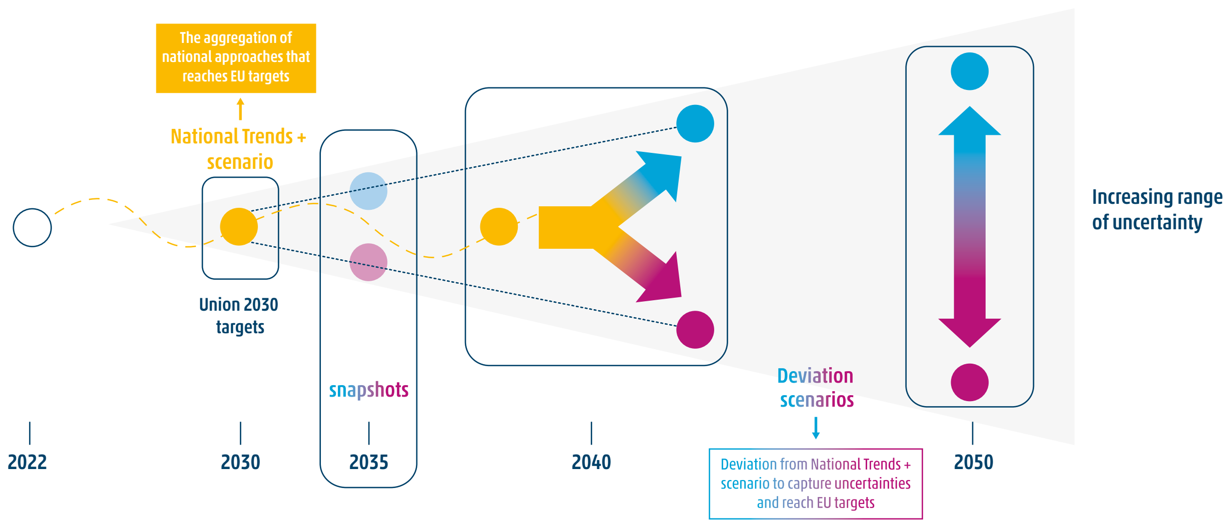



**Figure 1:** TYNDP Scenario horizon and framework

4 See here

**National Trends+ ('NT+')** scenario aligns with national energy and climate policies (NECPs, national long-term strategies, hydrogen strategies ...) derived from the European targets. The datasets for this scenario are collected from the TSOs, reflecting the latest policy- and market developments scrutinised at national level. These scenarios are developed for the 2030 and 2040 time-horizons, as datasets for the 2050 time-horizons are not available in all Member States. For TYNDP 2024, the dataset collection is finalised in 2023 Q1[5], prior to the publication of the draft updated NECPs, which were due to be published in summer 2023. Consequently, differences between updated NECPs and the datasets are anticipated.

Moreover, for the first time in this edition, the National Trends+ scenario is quantified for all energy carriers, expanding beyond electricity and gas. This facilitates an assessment of the European Union's 2030 targets for energy and climate, as mandated by the Regulation. The gap between the EU targets and this scenario, is transparently presented during the consultation process and addressed according to the consulted 'NT+ Energy mix gap filling methodology'[6].

In addition to the NT+ scenario, ENTSO-E and ENTSOG developed **two deviation scenarios ('DE' and 'GA') to address increased uncertainties after 2030**. These scenarios diverge from the NT+ scenario starting from the NT+ 2030 baseline and extend into the 2040 and 2050 time horizons, following their respective storylines detailed in Section Scenario Storylines. Additionally, a snapshot for the 2035 time horizon is provided in the datasets and in the visualisation platform, representing an average between the 2030 and 2040 time horizons. Like NT+ scenario, these scenarios encompass all sectors and energy carriers, enabling the quantification of compliance with EU targets. For 2035 and 2040, the objective is to achieve a meaningful transition from 2030 EU targets, while reaching carbon neutrality by 2050 is mandatory.[7]

## 4.2 Scenario Storylines

The storylines aim to ensure sufficient differences on future energy demand and supply patterns to cover uncertainties related to infrastructure development. ENTSO-E and ENTSOG use a top-down methodology to identify and define contrasting political, societal and technology underlying choices – so called "high-level drivers" which are green transition, driving force of energy transition, energy efficiency and technologies as illustrated in Figure 2.

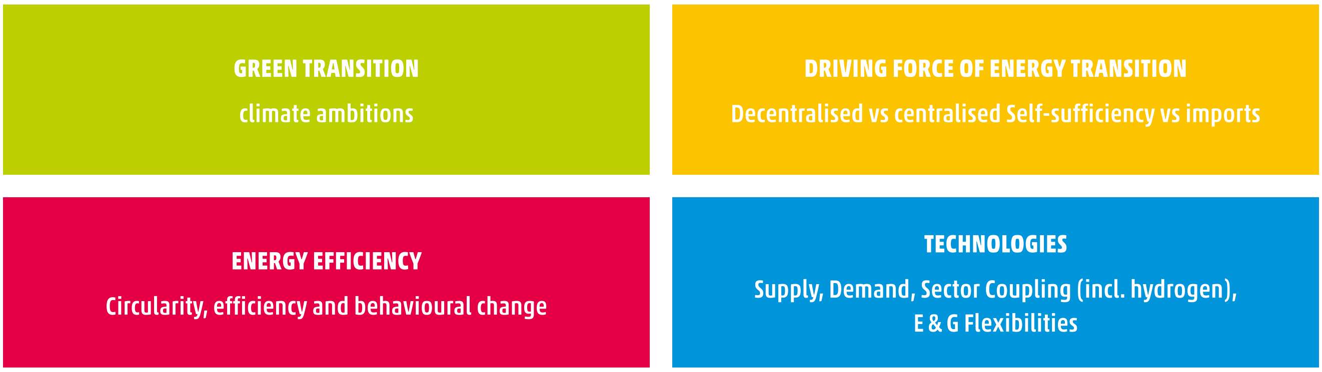



**Figure 2:** High-level drivers for deviation scenarios

5 Except for offshore figures, which are updated in 2023 August to align with MS Non-binding Agreements.

6 See TYNDP 2024 Scenarios Storyline Report, Annex 2

7 Wind offshore minimum capacities align with the MS's non-binding agreements.

Figure 3 represents the distinct storylines based on the identified high-level drivers that form the basis for the development of Distributed Energy and Global Ambition scenarios. **These storylines guide the quantification of the scenarios and inform the development process of input parameters.** The input parameters are developed according to these storylines and have undergone public consultation, culminating in their finalisation alongside scenario building methodologies.

| | **DISTRIBUTED ENERGY**<br>Higher European autonomy with renewable and decentralised focus | **NATIONAL TRENDS +**<br>The aggregation of national pathways to reach EU targets | **GLOBAL AMBITION**<br>Global economy with centralised low carbon and RES options |
|---|---|---|---|
| **GREEN TRANSITION** | Fully in line with the energy efficiency first principle and with the Union's 2030 targets for energy and climate and its 2050 climate neutrality objective | | |
| **DRIVING FORCE OF THE ENERGY TRANSITION** | Transition initiated at a local/national level (prosumers) | Deviation extent will depend on "National Trends + " setting resulting from national perspectives | Transition initiated at a European/ international level |
| | Aims for EU energy independence and strategic independence through maximisation of RES and smart sector integration (P2G/P2L/P2M) | | High EU RES development supplemented with low carbon energy and diversified Imports |
| **ENERGY EFFICIENCY** | Reduced energy demand through circularity and better energy consumption behaviour | | Reduced energy demand with priority is given to decarbonisation and diversification of energy supply. |
| | Digitalisation driven by prosumer and variable RES management | | Digitalisation and automation reinforce competitiveness of EU business. |
| **TECHNOLOGIES** | Focus of decentralised technologies (PV, batteries, etc.) and smart charging | | Focus on large scale technologies (offshore wind, large storage) |
| | Focus on electric heat pumps and district heating | | Focus on a wide range of heating technologies e.g. hybrid heating technology |
| | Higher share of EV, with e-liquids and biofuels supplementing for heavy transport | | Wide range of technologies and energy carriers across mobility sectors (electricity, hydrogen, e-liquids and biofuels) |
| | Minimal CCS and nuclear | | Integration of nuclear and CCS |

**Figure 3:** Storyline Matrix

This report presents the results of these scenarios at the EU27 level. For further details on the building blocks of the scenarios, explanation of the tool chain and modelling methodologies, please refer to the '2024 Scenario Building Guidelines' available on the dedicated webpage for 2024 TYNDP Scenarios[8].

8 See here

# 5 STAKEHOLDER ENGAGEMENT AND HOW IT SHAPED THE SCENARIOS //

## 5.1 Three core principles/values for Stakeholder Engagement

### Transparency

Developing three scenarios that project energy demand and supply until 2040 and 2050 is a highly complicated process. ENTSO-E and ENTSOG recognise that it is not sufficient to merely publicise the results of scenario modelling or to provide only a general overview of the methodologies used. Therefore, the TYNDP scenarios aim to provide full transparency for all stakeholders. This entails delivering a full explanation of all assumptions that have been made and making all raw data fully accessible via the dedicated website. Our goal is to create scenarios that could be replicated plausibly by third parties.

### Inclusiveness

Due to the significance of the TYNDP scenarios for EU infrastructure planning, it is important to ensure that the scenarios reflect the general opinions of EU citizens both in their scope and in their goals. ENTSO-E and ENTSOG believe that any organisation or individual who wishes to share their views on the scenario building process should be offered sufficient opportunities to do so. This is made possible through the organisation of multiple fully public stakeholder events (such as consultation workshops and subject-specific webinars) and written stakeholder consultations.

### Efficiency

The energy transition is dynamic and fast-paced. New technologies and new developments are constantly influencing the long-term outlook for the energy system of the future. ENTSO-E and ENTSOG recognise that thorough stakeholder engagement is necessary to ensure that the most up-to-date data and assumptions are utilised in the TYNDP scenarios. Interacting with stakeholders offers us the chance to learn from their experiences and to test our methodologies against real world conditions. An efficient scenario building process relies on timely stakeholder input.

## 5.2 Overview and learnings from the main stakeholder engagement activities in Scenarios 2024

Stakeholder feedback played a key role in shaping the 2024 scenarios from the outset. The publication of full datasets, the interactive data visualisation tool as well as a detailed Scenarios Methodology Report allow stakeholders to have a deep insight into the development process and the subsequent results.

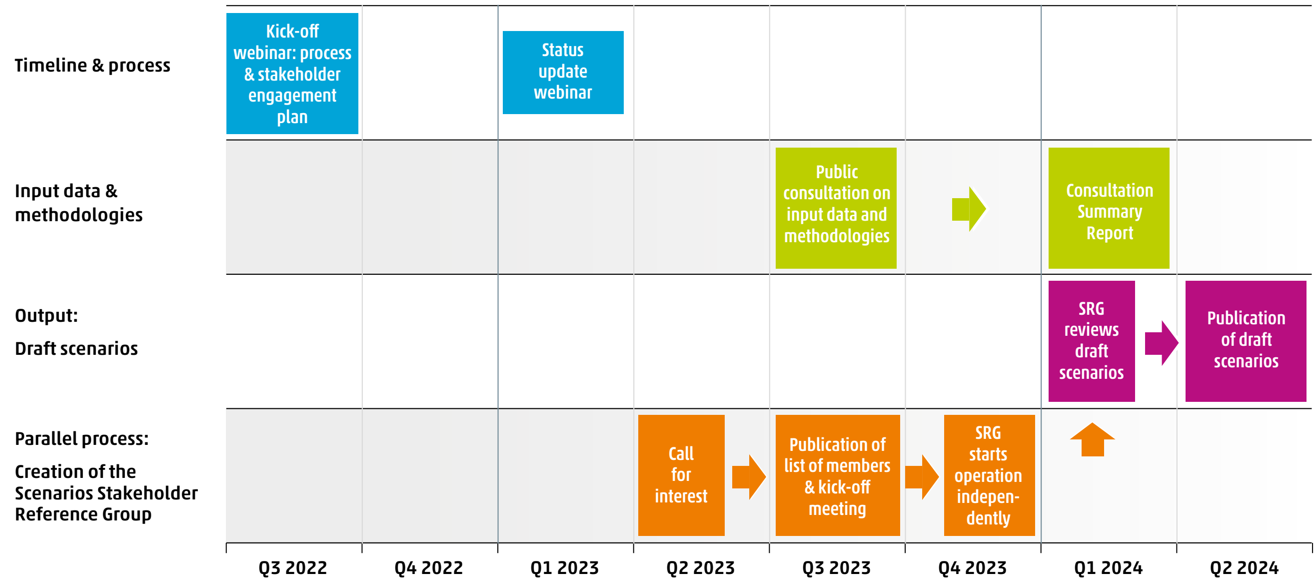



**Figure 4:** TYNDP 2024 Stakeholder Engagement Timeline

### Learnings on stakeholder engagement from the 2024 cycle:

- The public consultation on input data and assumptions and methodologies allowed stakeholders deeper insight into and impact on the development process and the subsequent results. It has proven beneficial to concentrate the stakeholders' engagement effort early in the process, at the time of definition of inputs and methodologies, rather than on the scenarios output.
- While it was initially planned to run a second formal written public consultation on the draft scenarios, it has not been possible because of the challenging timeline. Instead, the draft scenarios have been shared with the Scenarios Reference Group ('SRG'), which had just been set up, for a shorter revieww period. ENTSO-E and ENTSOG welcome the contribution of the SRG to the scenarios building process for the very first time. Capturing input from external experts via continuous engagement with the SRG rather than via an ad hoc formal written public consultation process has the potential to further increase stakeholders' impact on scenarios. It also has potential to make the overall stakeholder engagement in scenarios more efficient, as each stakeholder contributes via the group on his/her specific field of expertise, at the time when that expertise is needed to feed into the process.
- However, it is important that the membership of the SRG remains balanced and representative of all relevant sectors. ENTSO-E and ENTSOG will remain attentive to any future evolution of the SRG membership and will re-assess the involvement of the SRG in the scenarios building process should the SRG no longer be able to contribute recommendations from a balanced variety of interests.
- In addition, it is important to find the right balance between efficiency and transparency, especially for stakeholders who are not represented in the SRG membership. To that end, ENTSO-E and ENTSOG will pay even more attention to ensuring that information, including on the process, timeline and engagement opportunities, is public and easily available. To that end in 2023 a central scenarios website[9] was launched, meant to serve as a gate to access all information on the ongoing and past scenario cycles.
- Stakeholder feedback on the 2024 cycle called for additional efforts in explaining datasets and tools. ENTSO-E and ENTSOG have invested more work this cycle in the development of interactive data visualisation of input data and of scenarios results. Efforts in data visualisation pay off as they help stakeholders understand the data and therefore provide more useful feedback.

9 See here

## 5.3 Main stakeholder engagement steps – In more details

### Early public consultation focused on the input data and methodologies

The public consultation addressed the following topics:

- Data consistency with respect to the storylines of the DE & GA Scenarios;
- Technology costs and energy prices;
- Modelling methodologies used;
- Technology-specific assumptions; and
- Potential improvements for future TYNDP Scenarios editions.

In total, 30 stakeholders from diverse sectors engaged in the public consultation. Almost 3 out of 4 responses came from the following categories (the categories considered are those used in the TEN-E Regulation): Associations involved in the electricity, gas and hydrogen markets (9), supply-side operators (8) and civil society representatives (5).

This consultation gave stakeholders the opportunity to directly influence the underlying assumptions for the scenarios. ENTSO-E and ENTSOG released in January 2024 a consultation summary report, providing an overview of the comments received per topic and sub-topic and explaining how the comments were considered.

In addition to the public consultation, ENTSO-E and ENTSOG organised a hybrid workshop and stakeholder roundtables on 13 July 2023. In this event, stakeholders were prompted to share their views and discuss key topics and datasets with the Scenario Building Team. Summaries of the discussions held in each roundtable are available online.

Following up on the roundtables and to answer stakeholders' requests, ENTSO-E and ENTSOG released a list[10] clarifying what is input to the model and what is output to the model.

**Consultation Summary Report**

All answers received to the public consultation

Including summaries of stakeholder roundtables:

- Carbon budget
- Demand
- Methodology
- Supply


**Download the complete Consultation Summary Report**

### Creation of the Scenarios Stakeholder Reference Group

As required by Article 12(3) of Regulation 2022/869 (TEN-E Regulation), ENTSO-E and ENTSOG initiated the creation of an independent Scenarios Stakeholder Reference Group (SRG). The SRG is meant to provide expert input to the development of scenarios by ENTSO-E and ENTSOG in accordance with the scenario development timeline.

ENTSOG and ENTSO-E have proposed draft Terms of Reference and have launched a call for interest from 5 May to 5 June 2023. An additional call for interest took place between 12 to 19 June, to supplement categories with less applicants. In total, 30 applications were received. After assessing the relevance of applications with the requirements specified in ACER's Framework guidelines and in the proposed Terms of Reference, ENTSO-E and ENTSOG established a draft list of 22 members which was shared with ACER and the European Commission for a two-week review period. No comments were received and the list of members of the SRG was published on 16 August 2023. After an initial kick-off call organised by ENTSO-E and ENTSOG, and the election of two co-convenors and two vice-convenors, the group started operating independently in November 2023.

The Terms of Reference approved by the SRG, list of members and minutes of meetings are available online[11].

10 Included in the Scenarios Methodology Report.

11 See here

## Consultation of the Scenarios SRG on the draft scenarios

In December 2023 in the first weeks of existence of the SRG it was agreed between ENTSO-E, ENTSOG and the SRG that ENTSO-E and ENTSOG would share the draft scenarios with the SRG, who may share recommendations. From the point of view of ENTSO-E and ENTSOG, this exercise served a dual purpose: firstly to allow for collection of stakeholders feedback on the draft scenarios, as it had proved impossible to organise a second formal written consultation process, and secondly as a 'learning by doing' experience for the SRG, to help the group become fully operational and gain expertise in how TYNDP scenarios are built – including gaining understanding of the models and tools used. This was seen as a good preparation before the 2026 TYNDP cycle, for which the SRG is expected to be active from the very start of the process.

Draft scenarios under the form of datasets, a glossary and a visualisation tool were shared with the SRG on 12 January 2024. ENTSO-E and ENTSOG also organised a workshop for SRG members on 16 January to explain the tool architecture and the structure of the datasets.

The SRG shared informally its recommendations with ENTSO-E and ENTSOG on 14 February and the formal SRG feedback to 2024 TYNDP Scenario Preliminary Results, including a summary of the voting process, was shared with ENTSO-E and ENTSOG on 4 March 2024. SRG recommendations are meant for the 2024 cycle and for the 2026 cycle. Annex 3 lists SRG recommendations for the 2024 cycle and how they were taken into account in the final scenarios.

The SRG also provided feedback on the interactive data visualisation tools of the 2024 scenarios.

# 6 IMPROVEMENTS IN THE TYNDP 2024 SCENARIOS //

Both ENTSOG and ENTSO-E consistently strive to enhance their data, tools, and methodologies with each TYNDP scenario release. The TYNDP 2024 scenarios have benefitted from the lessons learned from previous editions, with improvements being prioritised based on stakeholder feedback received during previous TYNDP scenario consultations.

## 6.1 Proactive and early stakeholder engagement

As detailed in Chapter 5, there were several changes and improvements to stakeholder engagement in the 2024 scenarios cycle. In particular, since end 2023 the SRG complements existing engagement methods, and Stakeholder Roundtables are a new tool providing a forum for deeper discussions on crucial assumptions, supplementing written feedback and Consultation Workshop input. These initiatives aim to achieve more comprehensive stakeholder involvement, promoting transparency in scenario development.

## 6.2 Increased transparency

For the first time in TYNDP 2024, the Energy Transition Model (ETM)[12] is utilised for demand quantification. Developed by Quintel Intelligence, the ETM is a comprehensive and openly accessible online model designed to construct and explore energy system scenarios, covering all relevant sectors and energy carriers. Interested third parties can leverage the model for scenario creation and replicate scenarios by accessing the input parameters through published scenario links. Furthermore, extended datasets are published to provide access to all datasets, including country-level hourly modelling results.

## 6.3 Robust methodologies

Given the evolving energy sector and increased interlinkages among sectors, methodologies have been enhanced to ensure robustness of results. Explicit modelling of sectors has been implemented to better capture these increased interlinkages, albeit at the expense of more complex and time-consuming methodologies. Summaries of these improvements are provided below, with detailed methodologies available in the TYNDP 2024 Scenario Building Guidelines report.

### 6.3.1 Prosumer and EV Modelling

The emergence of e-mobility, residential batteries, and solar panels presents fresh opportunities for individuals to engage with the broader electricity infrastructure. In this edition, akin to TYNDP 2022, passenger cars and prosumers have been expressly integrated as distinct elements within the electricity framework. This enables the tracking of their progression based on hybrid signals: the wholesale electricity market price on one side and particular factors like decreased connection expenses or mobility demands on the other.

12 See here

### 6.3.2 Offshore Modelling Methodology

The offshore modelling methodology is a major innovation in this scenario cycle. Instead of modelling offshore wind as radial capacity connected to the respective home market, the offshore territory has been divided into offshore zones where the wind power infrastructure for each zone as well as the interconnectors between zones are modelled explicitly. This allows the model to optimise the expansion of an offshore grid for transporting wind energy between different offshore hubs, which may be more efficient than having radial connections from wind farms to shore. The model can also invest in an offshore hydrogen grid in parallel with the electricity grid, in a similar manner as for the onshore grid. This combined offshore electricity and hydrogen grid expansion allows the model to answer questions like:

- Should wind power be oversized compared to transmission capacity?
- Should wind farms be radially connected to the home market or integrated into an offshore grid?
- Should the energy be transported as electricity or hydrogen, or a combination of the two?
- Additionally, the offshore zones have been split into smaller sections with differentiated costs, by using a combination of geodata and bathymetry data. The offshore wind potential and investment costs for each section are modelled explicitly, thus further increasing the granularity of investment options available in the expansion model.

### 6.3.3 Hydrogen Modelling

The P2G methodology utilised in the TYNDP 2024 scenarios represents a notable evolution from the TYNDP 2022 Scenarios Report. In the earlier report, P2G was modelled with various configurations envisioning diverse operational setups. This methodology has since undergone further refinement, now encompassing additional sources of hydrogen demand, such as those for synthetic fuel production and gas turbine usage. Moreover, supplementary supply sources, including ammonia, have been incorporated, alongside an exploration into different colors of hydrogen production through steam methane reformers. Consequently, the initial five hydrogen configurations have been streamlined to two, one centered around a hydrogen market and another addressing hydrogen demands operating independently from said market.

This methodology aims to accurately depict the interplay between electricity and hydrogen markets while also assessing the potential advantages of a European hydrogen infrastructure within the broader context of optimising the European energy system with a holistic approach.

An additional innovation compared to the previous edition is the explicit model of the hydrogen system, which is explained in more detail with its limitations in the Scenario Methodology Report.

### 6.3.4 Synthetic Fuel Modelling

In this scenario development cycle, synthetic fuels have been included as a notable innovation. These are fuels such as e-kerosene, e-diesel and synthetic methane which are produced by converting hydrogen and biogenic $CO_2$ through processes like the Fischer-Tropsch and methanation. This approach leverages $CO_2$ and promotes a shift away from fossil fuels. It also impacts the hydrogen demand, ensuring that hydrogen demand for synthetic fuels is accounted in the supply side of the model. This development supports our storyline of decarbonising energy.

### 6.3.5 Hybrid Heat Pump Modelling

The TYNDP 2024 DE and GA scenarios incorporate Hybrid Heat Pumps as a heating solution, combining electric heat pumps with either hydrogen or methane boilers. This addition to the model offers improved insight into the interaction among these three carriers in meeting the demands of another sector, heat.

# 7 SCENARIO RESULTS //

This chapter provides an overview of the scenario results for demand, supply, and emissions at EU27 level.[13]

## 7.1 Final energy demand

In Global Ambition and Distributed Energy scenarios, the overall final energy demand of the European Union significantly decreases. This reduction is attributed to a combination of energy efficiency measures, such as building renovations and the adoption of more efficient technologies, coupled with the enhanced integration of the energy system. The extent of this transition and the specific technology choices varies based on the respective storylines and are further detailed at country level – see scenario links published online[14].

Figure 5 shows the final energy demand for the different scenarios and covers all sectors including the energy sector, non-energy use, international aviation, ambient heat and international shipping.

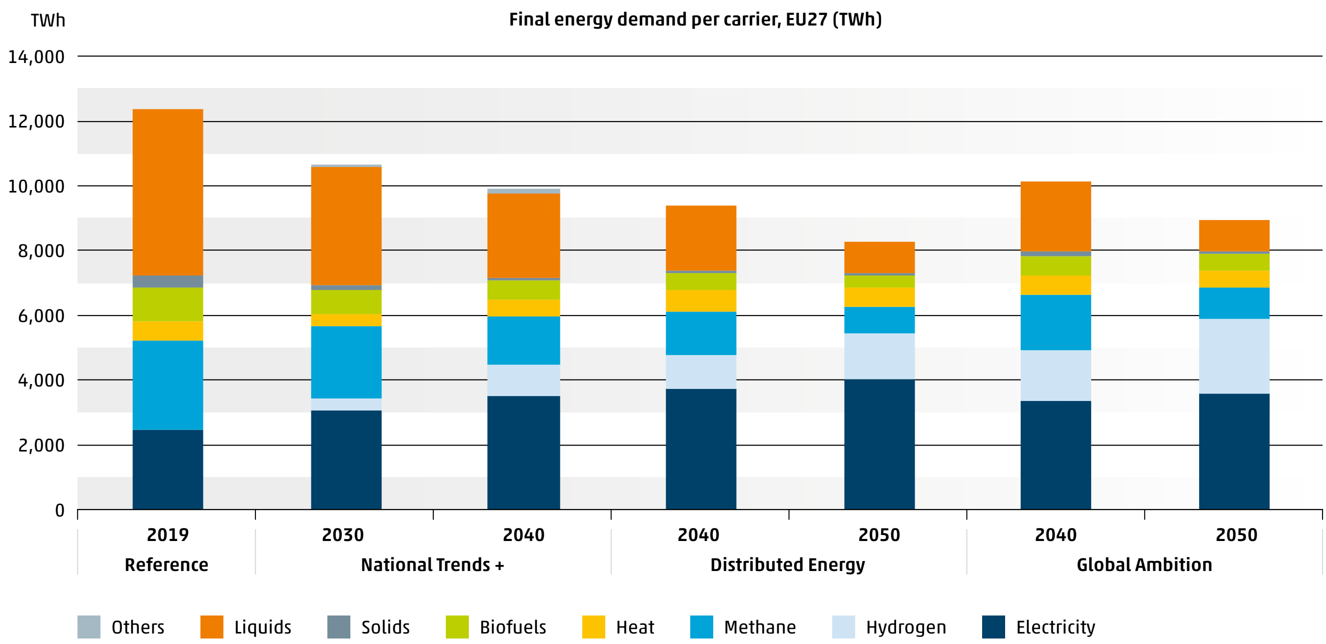



**Figure 5:** Final energy demand per carrier, EU27 (TWh)[15]

13 All figures are expressed in net calorific value.

14 See here

15 For NT+ "Others" include geothermal, industrial excess heat, power to gas excess heat and solar.

## 7.2 Demand per energy carrier

### 7.2.1 Electricity demand

Direct electricity demand increases by over 50 % in the Distributed Energy scenario and over 35 % in the Global Ambition scenario by 2050, compared to the reference year.

**The notable increase in direct electrification is driven by Europe's shift away from fossil fuel use, underscoring the region's commitment to enhancing energy efficiency and accelerating decarbonisation.**

The growth in electricity demand is evident across all sectors, but significant emphasis on efficiency measures temper the extent of this trend. High-efficiency consumer appliances and enhanced thermal insulation of buildings play significant roles in this regard.

The transportation sector stands out as the primary driver behind the growth in electricity demand. Currently reliant on oil as its primary energy source, this sector is undergoing a significant shift towards electric transportation. This transition not only eliminates local emissions from vehicles but also enhances energy efficiency, as electric motors are considerably more efficient than internal combustion engines (ICE). In the Global Ambition and Distributed Energy scenarios, electricity demand from the transport sector is projected to increase significantly, by an order of magnitude between 15 and 17 times compared to the reference year, by 2050.

Heat pumps contribute significantly to electrification efforts owing to their energy efficiency and capability to provide both heating and cooling using electricity, consequently reducing carbon emissions.

Figure 6 illustrates the projected final electricity demand, which surpasses 3,600 TWh in Global Ambition and exceeds 4,000 TWh in Distributed Energy by 2050.

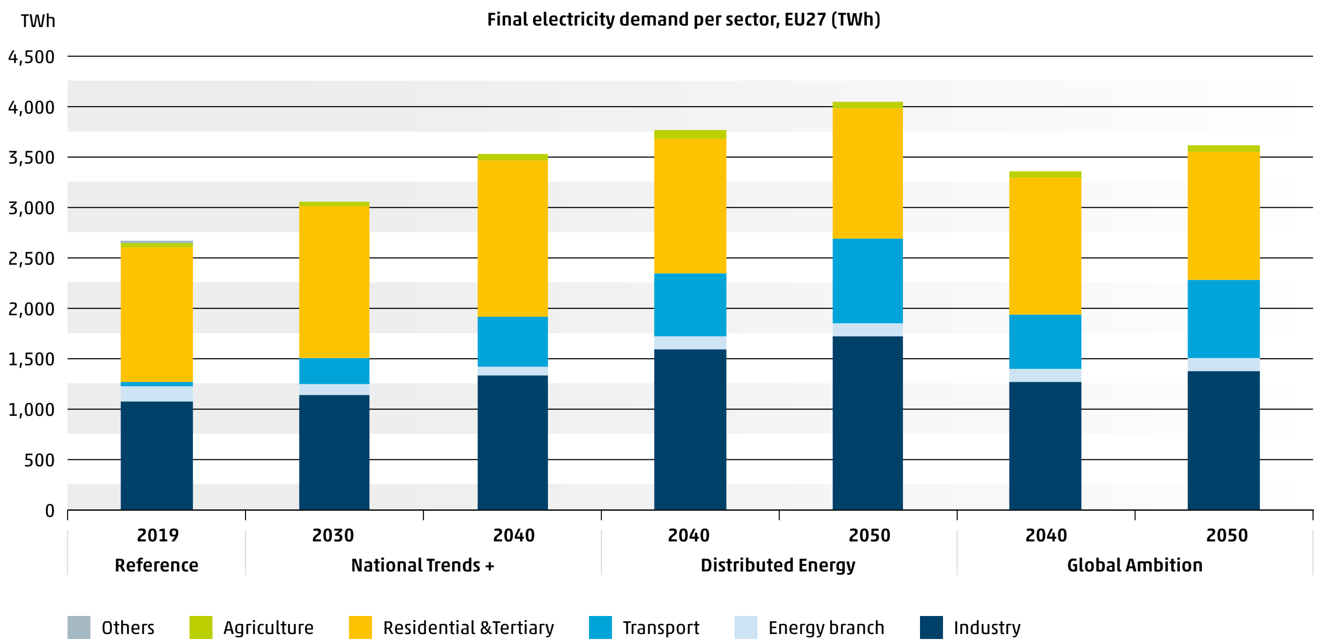



**Figure 6:** Final electricity demand per sector, EU27 (TWh)

### 7.2.2 Gas demand

**The importance of gas molecules as energy carriers is foreseen in all scenarios, where methane remains predominant in 2030 and hydrogen becomes more prominent in the long-term.**

The role of gas molecules, particularly methane and hydrogen, is crucial in the energy transition scenarios. By 2040, gas demand is expected to surpass current levels in Global Ambition scenario. Methane remains the dominant energy carrier in 2030 and hydrogen's prominence increasing in the long-term. Methane, often associated with carbon capture and storage (CCS) technologies, can be decarbonised and transformed into hydrogen through various methods such as steam methane reforming (SMR), autothermal reforming (ATR), or pyrolysis.

Both methane and hydrogen serve as versatile energy carriers across multiple sectors, offering substantial potential to contribute to Europe's decarbonisation efforts. The efficient decarbonisation of the EU and the reduction of dependency on imports necessitate the utilisation of all available sources of renewable energy. Consequently, the demand for methane and hydrogen coexists in all scenarios, albeit to varying degrees and with different trajectories depending on the specific storyline.

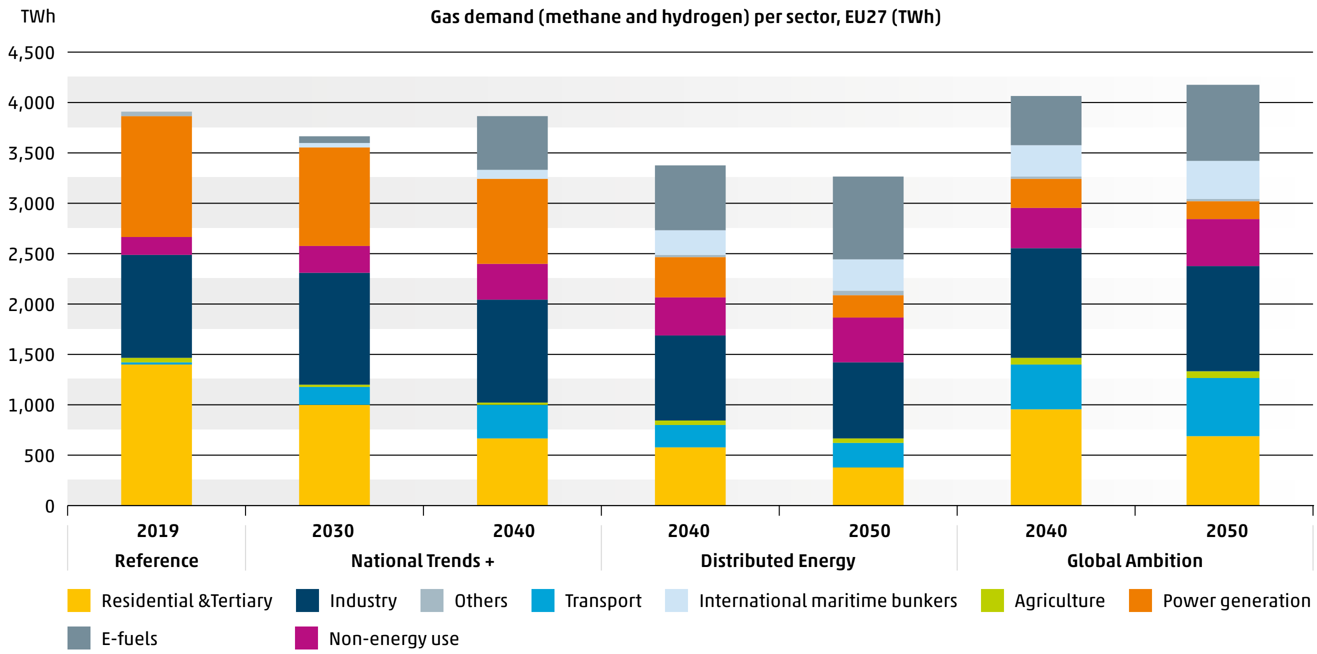



**Figure 7:** Gas demand (methane and hydrogen) per sector, EU27 (TWh)[16]

### 7.2.3 Methane demand

**Up to 2030, only a slight decrease in methane demand is anticipated, followed by a more pronounced decline thereafter.**

At the EU level, national policies underscore the critical role of methane as an energy carrier. Until 2030, only a modest reduction in methane demand is expected. This reduction is primarily due to increased electrification in residential, tertiary, and industrial sectors. However, it is partially offset by new applications in other sectors. Additionally, the power sector will experience a decrease in demand due to higher renewable energy generation (RES).

Looking ahead, after 2030, the demand for methane is expected to decline more rapidly. This shift is driven by national strategies that anticipate a surge in hydrogen demand. Despite this trend, methane will be needed for balancing of energy markets.

In deviation scenarios, methane demand primarily relies on final uses, including non-energy applications. Furthermore, there is indirect demand for abated natural gas for hydrogen production[17]. Global Ambition projects higher methane levels in final uses in 2040 compared to National Trends. However, Global Ambition and Distributed Energy scenarios show a very low methane use in the power sector by 2040 due to a decrease of up to 83 % in full load hours compared to National Trends scenario. This outcome of the used optimisation model is driven by the extensive use of flexibility options such as demand-side response (DSR), vehicle-to-grid

16 Methane for SMR is excluded from the graph above to avoid double counting.

17 Where relevant, the gas balance also includes residual (methane) gasses from industry that are used for hydrogen production.

(V2G), hydro pump storage, and electrolysers connected to hydrogen networks and storage. These results are significantly different from both the current situation and National Trends. The analysis of this outcome is further explained in 7.4.3 Electricity supply section.

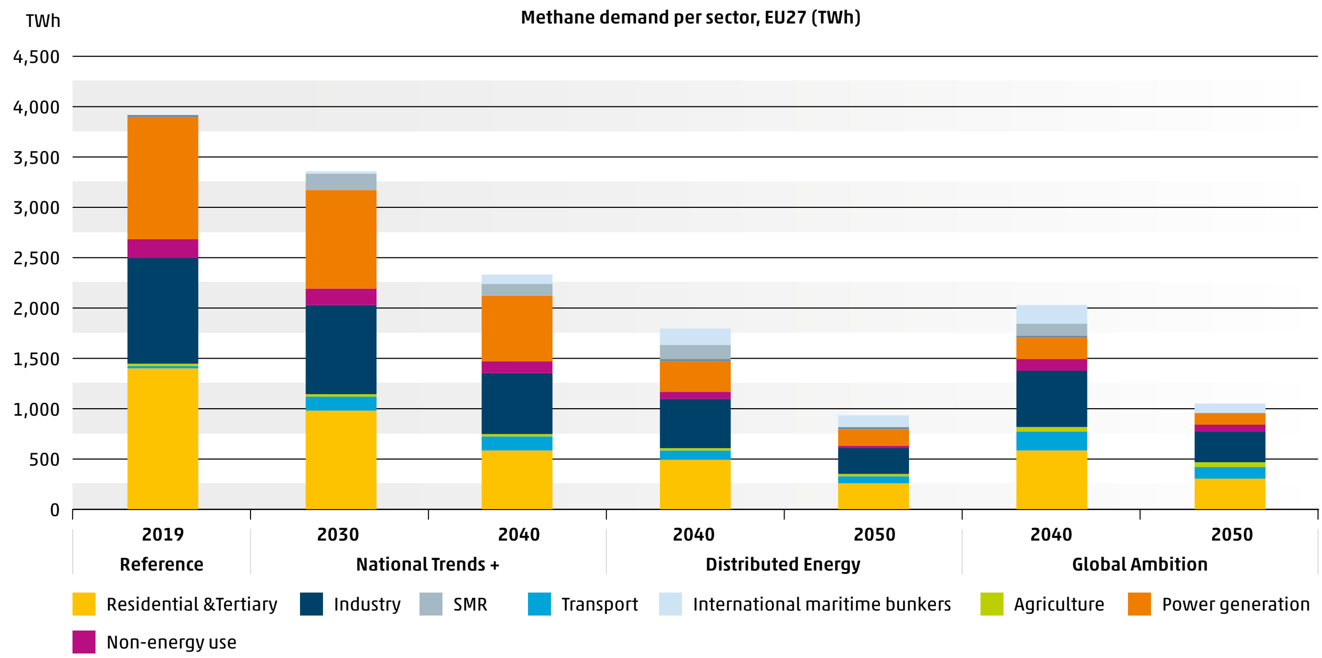



**Figure 8:** Methane demand per sector, EU27 (TWh)

## Peak methane demand

The methane demand in high demand cases reflects the changing nature of residential and commercial demand, as temperature-depending space heating typically drives peak methane consumption. As a result, the methane demand for end use during peak days and Dunkelflaute decreases in all scenarios due to efficiency measures. National Trends observes the most limited change as consumers invest in more traditional technologies, although they are considered less efficient.

The significant development of variable electricity RES capacities influences the role of the gas infrastructure to backup the variable power generation. With significant variable RES capacities in the energy system, the methane demand may be impacted by Dunkelflaute events more often and more intensely.

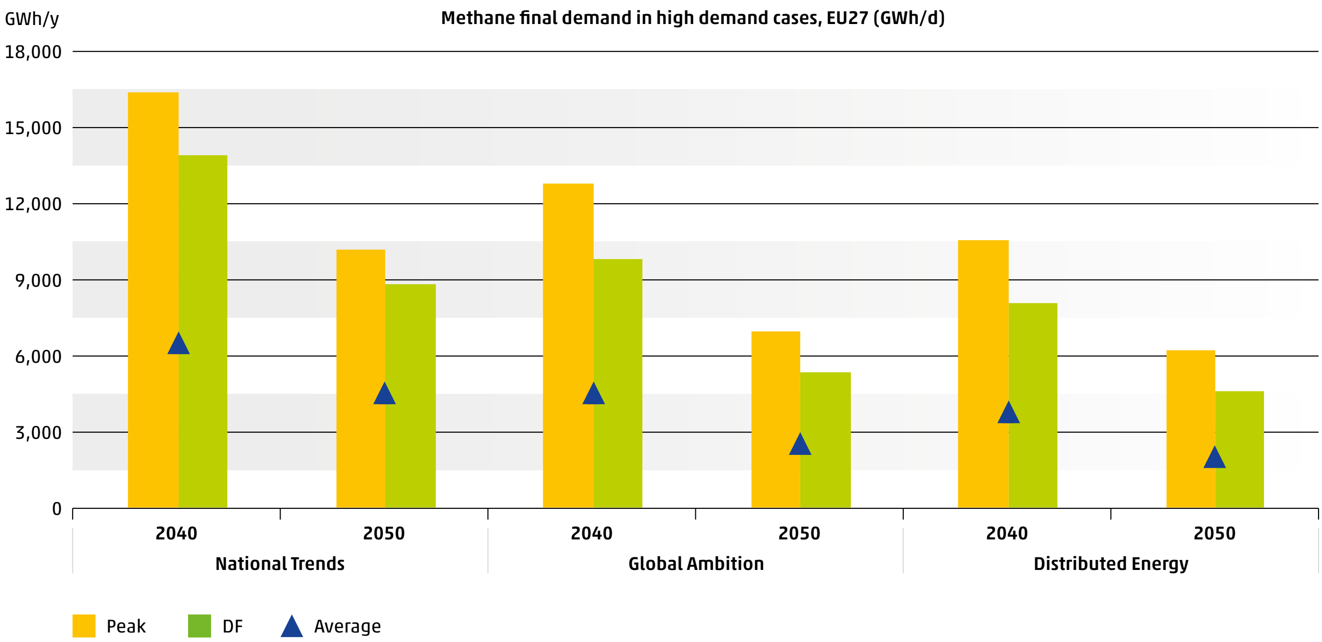



**Figure 9:** Methane final demand in high demand cases, EU27

## 7.2.4 Hydrogen demand

**By 2050, clean hydrogen is projected to reach levels comparable to current methane usage. Its role will continue to expand across various sectors, playing an increasingly vital role.**

The evolution of hydrogen demand across different sectors presents a strong narrative of potential growth and diversification. In Europe, hydrogen consumption is already making a tangible impact across various industries. Currently, the industrial sector dominates hydrogen usage, with refineries, steel production, and ammonia and methanol manufacturing as primary consumers[18]. Fast forward to 2030, the National Trends scenario foresees a marked increase in demand across multiple fields, with transport showing a notable uptick. This trend persists into 2040, suggesting a recognition of hydrogen's versatility as an energy vector.

The deviation scenarios clearly show that although the initial demand is focused on industry, the future forecasts predict a broader use of hydrogen. This shift reflects the evolving perspectives on integrating this clean energy source into our global economy.

Furthermore, an ever-growing portion of hydrogen demand will be allocated to synthetic fuel production. Synfuels offer a promising pathway for decarbonising energy systems. These fuels are generated through processes that convert renewable energy sources into liquid or gaseous fuels. Their potential to accelerate the global shift toward cleaner energy becomes significant as early as 2030, gains traction by 2040, and reaches a substantial hydrogen demand of 800 TWh by 2050 – equivalent to the energy currently used by gasoline-fueled road vehicles.

The Distributed Energy and Global Ambition scenarios show only a very limited hydrogen demand for power generation. As is the case for methane fired power plants, this is an outcome of the optimisation model. For hydrogen fired power plants the full load hours are even lower, often close to zero[19]. The analysis of this outcome further explained in 7.4.3 Electricity supply section.

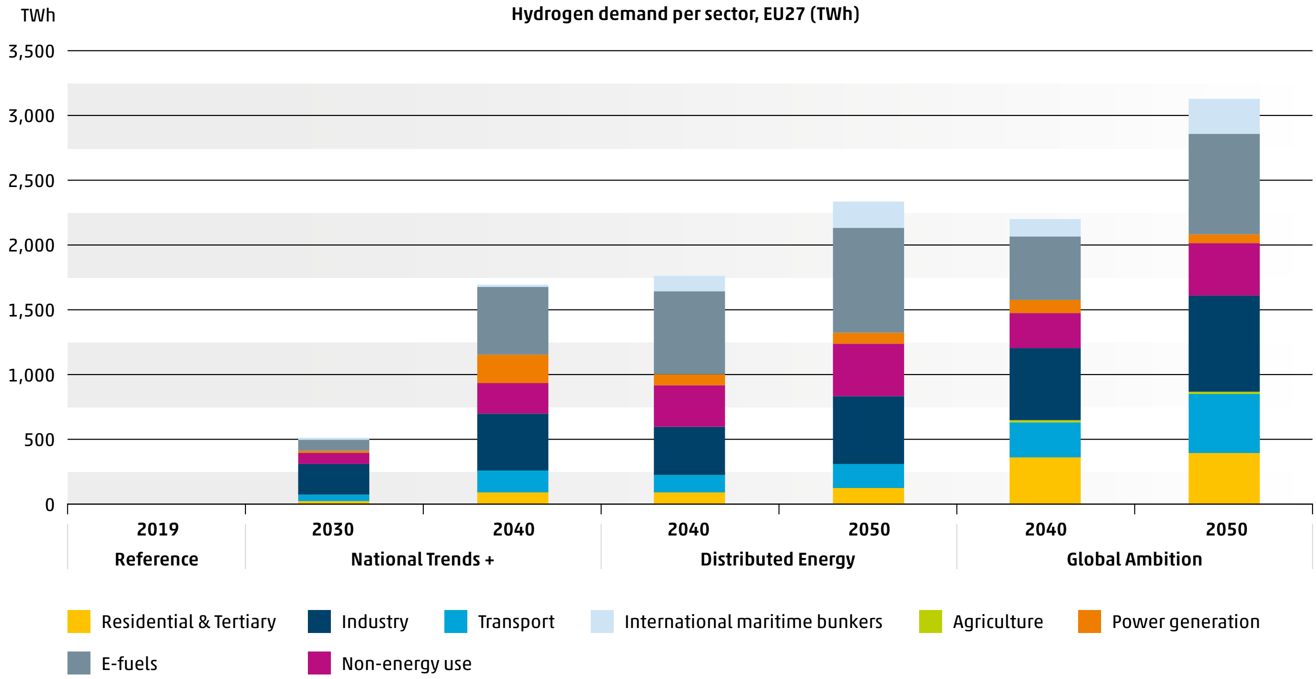



**Figure 10:** Hydrogen demand per sector EU27, TWh

18 These TYNDP scenarios only consider the hydrogen that has a transmission requirement. This means that captive onsite production is not visible in the hydrogen graphs. The energy feedstock associated with captive onsite hydrogen production is considered in the fossil fuel (i.e., methane) balance.

19 Low dispatch of hydrogen fired power generation also leads to an underestimation in the need for hydrogen flexibility (i.e., storage). This is further elaborated in the hydrogen supply chapter (7.4.6).

### Hydrogen peak demand

The development of hydrogen-based technologies results in increasing peak and Dunkelflaute demand, especially in the Global Ambition scenario.

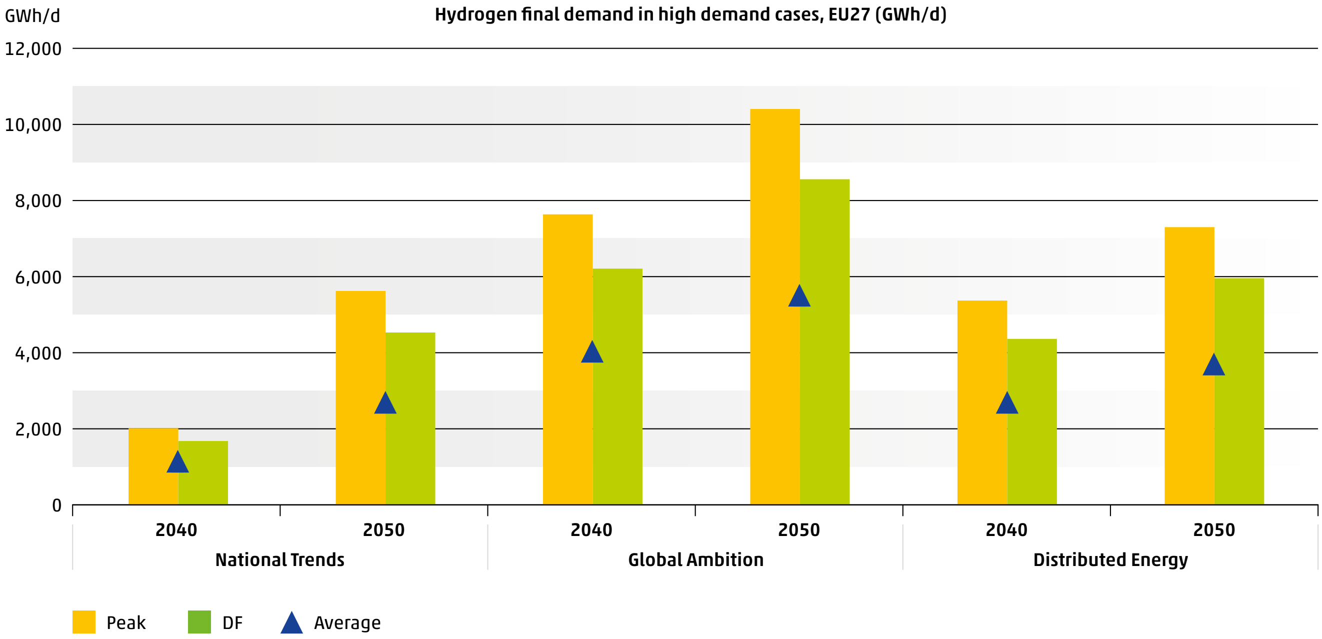



**Figure 11:** Hydrogen final demand in high demand cases, EU27 (GWh/d)

## 7.2.5 Heat

The following graph shows how the heat distributed through heating networks is produced at the EU-27 level for the different scenarios and years. While the heat generated by methane and solids will decrease over time, more heat will be produced by electricity.

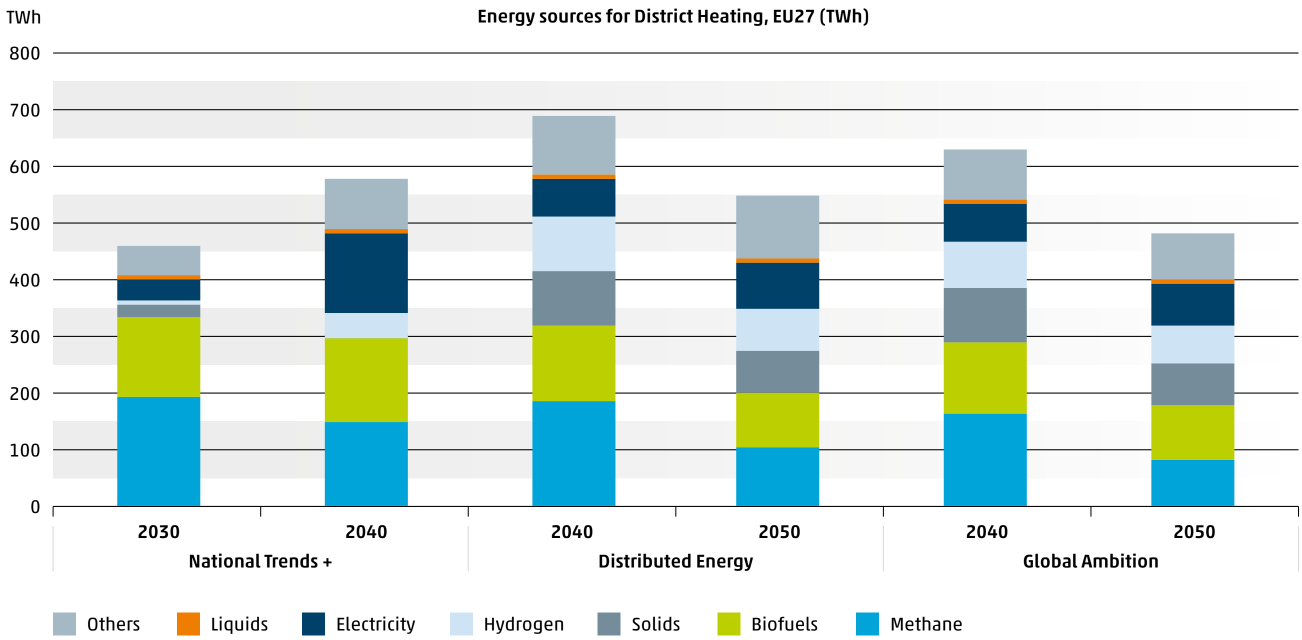



**Figure 12:** Energy sources for District Heating, EU27 (TWh)

*Others in National Trends+ include geothermal, industrial excess heat, power to gas excess heat and solar.

## 7.3 Demand per sector

### 7.3.1 Built environment

**Built environment in transition**

Households and buildings require energy for lighting, power, cooking, heating and cooling. Today, most of the energy consumption comes from fossil fuels. In order to meet the climate ambitions for 2030 and beyond, a vast transition of the building sector is needed. The decarbonisation of the sector can be achieved though energy efficiency and technical innovation. More efficient appliances and insulation of buildings will not only decrease energy demand, but also improve living standards.

**Decarbonisation of heating through heat pumps and renewable gas**

The majority of energy demand in the building sector is for heating. Figure 13 illustrates how the use of different heating technologies change over time in the Distributed Energy and Global Ambition scenarios. Today the use of conventional boilers is dominant, but this changes in both scenarios. Both scenarios foresee an increase in the use of heat pumps, which are much more efficient than conventional boilers. By 2040 the households market share of heat pumps (full electric and hybrid) has grown to around 50 %[20]. In the following years, this market share increases further, up to 63–69 % by 2050.

In Distributed Energy most of the installed heat pumps only require electricity to operate (up to 63 %). In Global Ambition the market share of all-electric heat pumps is lower (up to 50 %) while hybrid heat pumps play a bigger role. This is an electric heat pump coupled with a gas (methane or hydrogen) boiler to enhance the overall heating efficiency. The electric heat pump will run for most of the year, but in periods of very cold weather, the gas boiler will complement to provide peak capacity. Hybrid heat pumps are in particular viable in countries that already have an established gas distribution grid. On an EU level, the market share for hybrid heat pumps reaches 13 %.

The share of homes that use a traditional gas boiler drops from 37 % in the reference year to 6–10 % in 2050. Gas boilers in 2050 make use of renewable gas like biomethane and hydrogen.

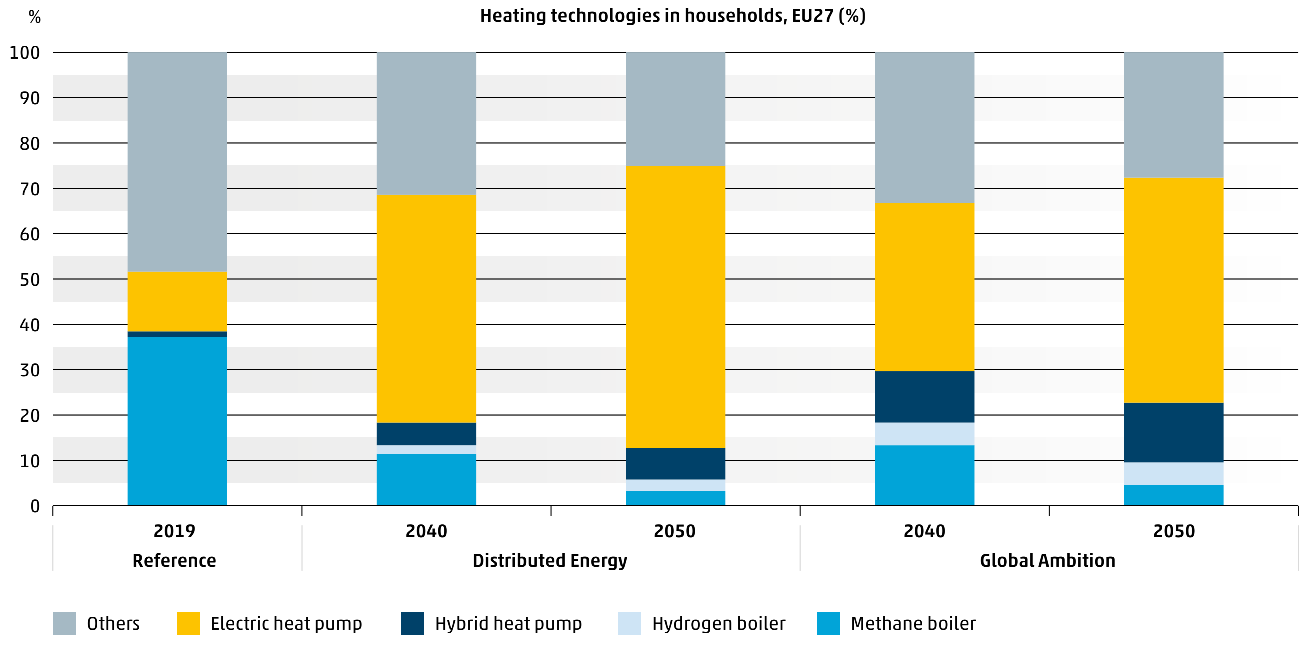



**Figure 13:** Heating technologies in households, EU27 (%)

20 Excluding heat pumps used for district heating.

**All scenarios show a sharp decrease in overall energy demand for households and buildings.**

This is illustrated in the graph below. By 2050 the total energy demand declines by 40–48 %. This increased energy efficiency is the result of both an ambitious renovation rate[21] and the use of more efficient appliances like heat pumps.

The use of oil and coal will almost completely disappear. Gas demand also shows a sharp decline. Part of the methane demand is replaced with hydrogen, in particular in Global Ambition. The share of electricity in total energy demand increases from 31 % in 2019 up to 58 % in Distributed Energy 2050. This is mainly driven by the increased use of heat pumps for space heating and hot water.

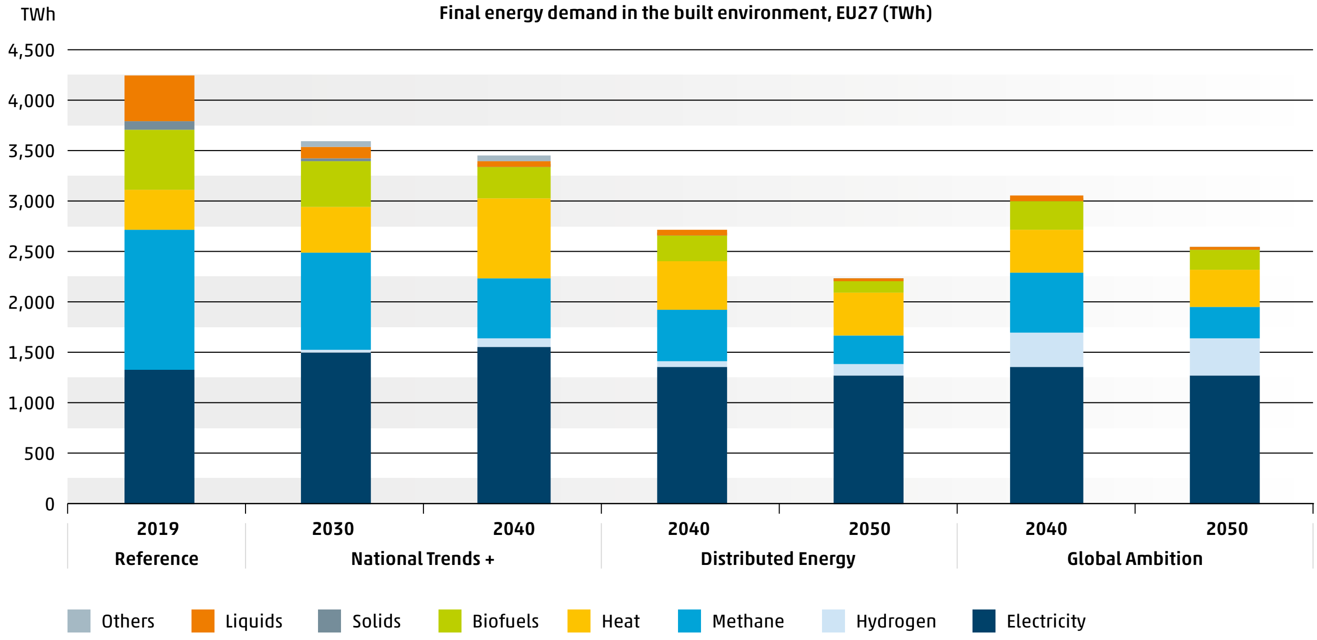



**Figure 14:** Final energy demand in the built environment, EU27 (TWh)

### 7.3.2 Industry

**Final energy consumption in industry sector**

In the various scenarios considered, the industrial sector is seen to decrease its overall energy consumption while simultaneously increasing the integration of hydrogen and electricity. Distributed Energy 2050 stands out with the lowest energy demand, amounting to 2561 TWh, and the highest use of electricity, reaching 1669 TWh. Conversely, the Global Ambition 2050 scenario showcases the most significant hydrogen usage at 653 TWh. Despite these variations, electricity is consistently the predominant energy carrier across all scenarios, favored for processes that do not require high temperatures. Hydrogen's importance grows, especially in sectors that are challenging to decarbonise, such as those requiring temperatures above 200 degrees Celsius, making electrification difficult. Industries such as steel, cement, aluminum, and petrochemical production are examples where hydrogen plays a crucial role. Methane's relevance continues until 2040 but is eclipsed by hydrogen by 2050, which then becomes the second-most utilised energy carrier after electricity. The use of solid and liquid fuels, currently dominant in energy-intensive processes, is projected to diminish over time.

21 Distributed Energy and Global Ambition assume a renovation rate of 2.3 % per year, of which 2.1 % is medium or deep renovation (only 0.2 % light renovation).

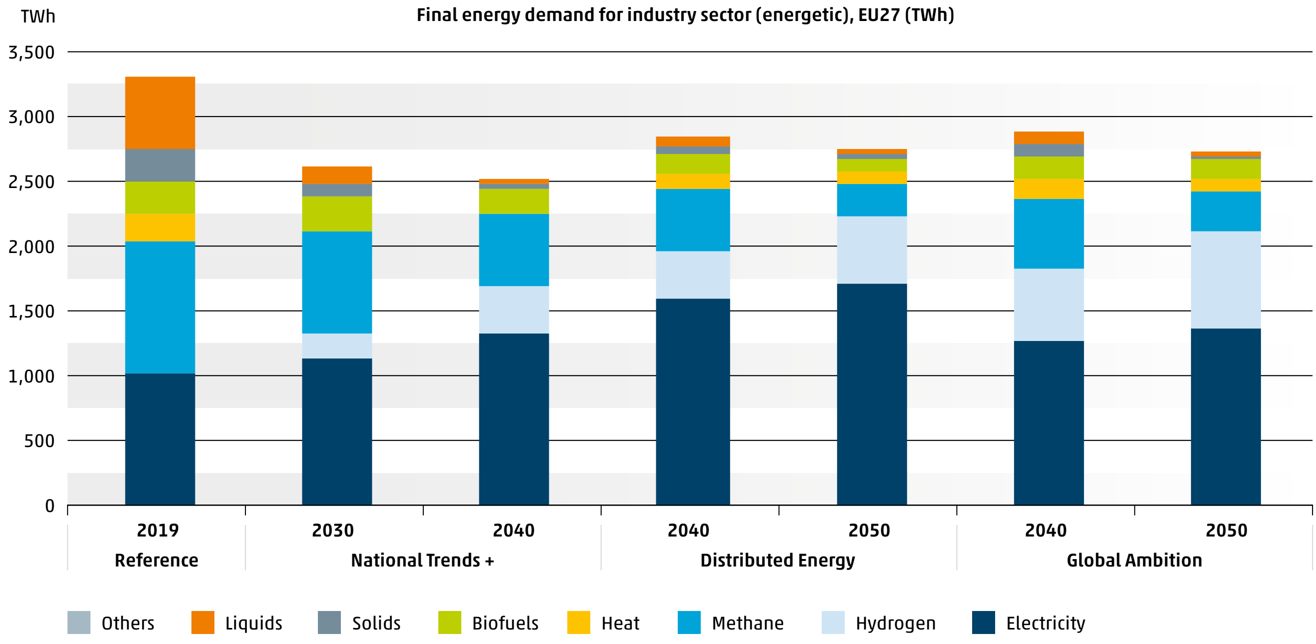



**Figure 15:** Final energy demand for industry sector (energetic), EU27 (TWh)[22]

*Includes refineries

### Final non-energy consumption in industry sector

Regarding non-energy consumption within the industry, current usage predominantly involves liquids and methane, serving mainly two purposes: the production of chemicals, particularly liquid-based petrochemicals for plastics, and the manufacture of fertilisers, with ammonia being a key component produced through Steam Methane Reforming (SMR). The graph illustrates a significant reduction in liquid fuels in both the Distributed Energy and Global Ambitions scenarios. However, liquids continue to be the primary energy carrier until 2040, after which hydrogen takes the lead, driving the sector's transition in all scenarios. In contrast, the National Trends scenario relies more heavily on liquids and methane.

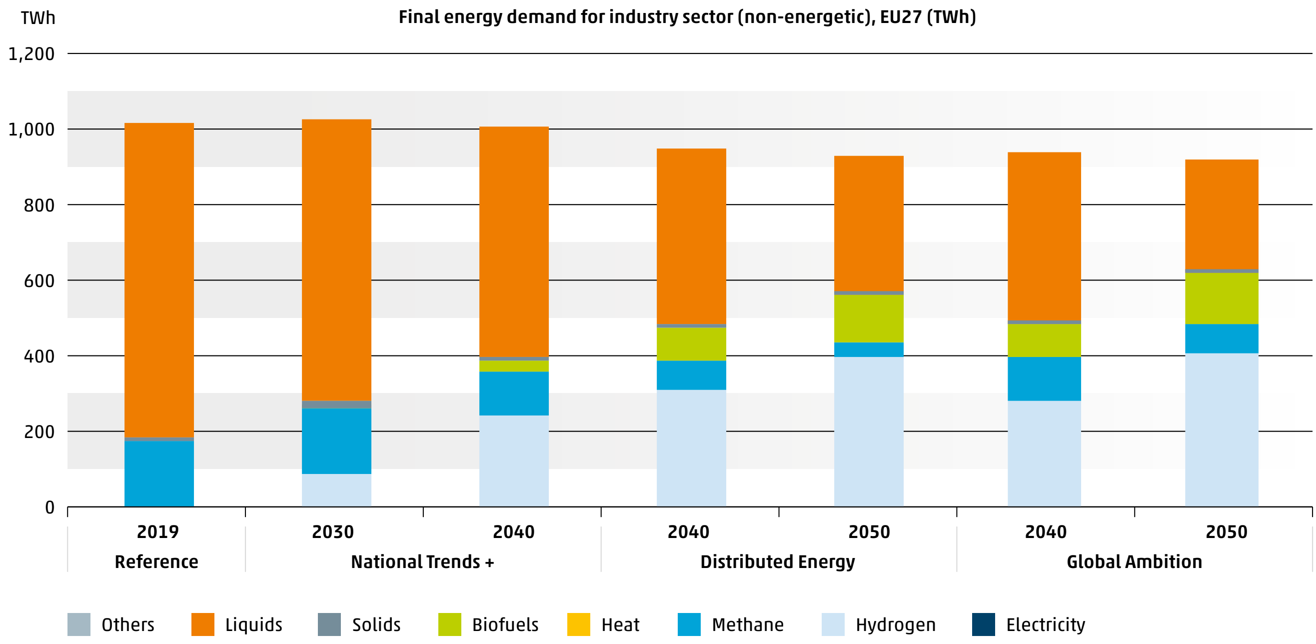



**Figure 16:** Final energy demand for industry sector (non-energetic), EU27 (TWh).

22 Refineries are included in the industry sector for DE and GA scenarios according to the definitions used in the Energy Transition Model.

## 7.3.3 Transport

**The transport sector is undergoing a significant energy transition to address environmental concerns and reduce dependency on fossil fuels.**

This transition encompasses various initiatives aimed at promoting sustainable mobility, enhancing energy efficiency, and decarbonising transportation. One notable aspect is the growing adoption of electric vehicles (EVs), spurred by advancements in battery technology, supportive government policies, and increasing consumer awareness. EVs are emblematic of the energy transition and strong growth in sales is evident across Europe. From a demand perspective their development is driven by air pollution concerns, energy efficiency and $CO_2$ emission reduction. Passenger vehicles currently account for the highest share in the total transport fleet. To reach the climatic targets, the decarbonisation of the passenger sector will be driven mainly by a fast uptake of EVs. For passenger cars a strong uptake of EVs is considered in Distributed Energy. Global Ambition shows a smaller market share for BEV passenger cars in 2050, considering a wider range of clean mobility technologies with FCEV and renewable methane (CNG) as meaningful options for long distance travel, high usage rate and power requirement. In 2050 ICEs and (non-plug-in) hybrid vehicles have a residual market share.

For heavy-duty trucks the Distributed Energy scenario also follows a higher electrification rate. Global Ambition also shows a strong push of new technologies in this segment but with higher share of FCEVs. Overall, the uptake of BEVs in the heavy goods transport category is lower than for passenger cars. This is linked to the specific challenges of transporting heavy loads over long distances. Beyond road transport, electric engines have a role in shipping and aviation since they can be powered by batteries or hydrogen fuel cells. Furthermore, whatever technology they use (hydrogen or batteries) they can provide flexibility to the electricity system with Vehicle-to-Grid (V2G) services provided by prosumers' EVs. Both scenarios consider a significant development of all technologies but to a different extent depending on the scenario storyline.

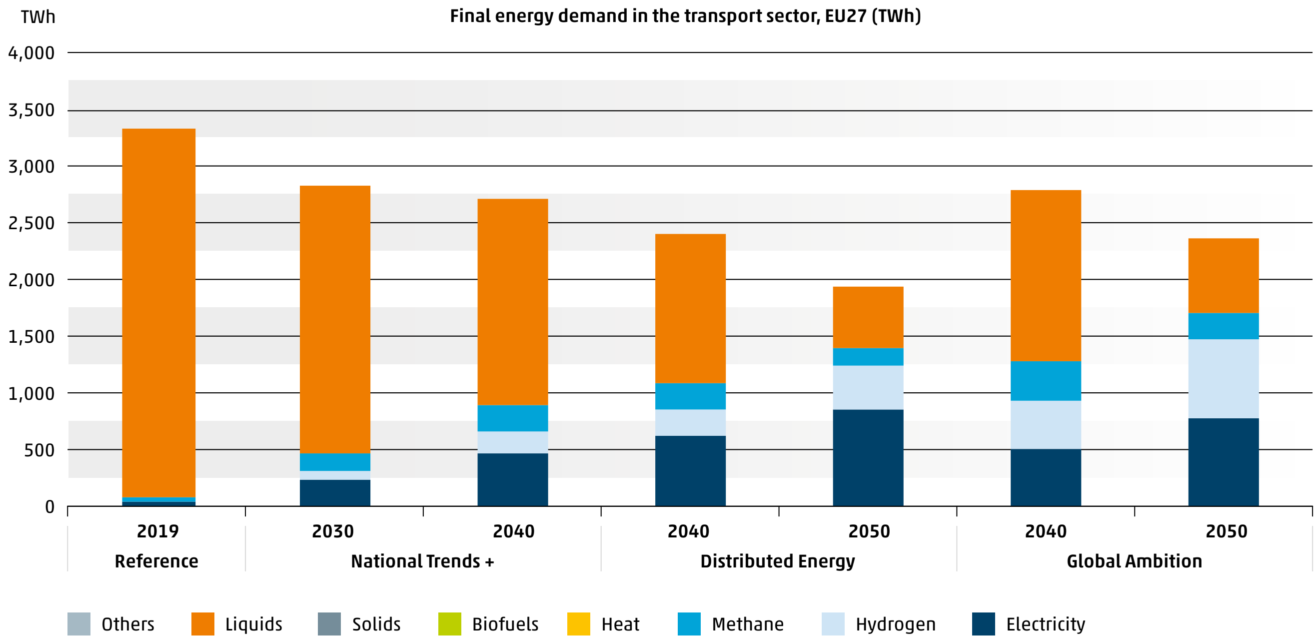



**Figure 17:** Final energy demand in the transport sector, EU27 (TWh)

Transport includes international aviation and international shipping. However, reference year, coming from Energy Transition Model (ETM), excludes international shipping.

### 7.3.4 Agriculture

The agriculture sector holds considerable importance in the energy transition, given its significant greenhouse gas emissions. Vital operations such as irrigation, machinery use, and transportation heavily rely on fossil fuels. Yet, this sector also holds immense potential for driving positive change. Through the adoption of energy-efficient practices and technologies, such as precision farming and optimised irrigation systems, farms can markedly reduce their energy consumption and carbon footprint. Moreover, the agriculture sector plays a pivotal role in bioenergy and biofuel production, harnessing organic materials such as crop residues and animal waste. These renewable energy sources not only bolster energy independence but also present a sustainable alternative to conventional fossil fuels.

In all the scenarios analysed, agriculture reduces its total energy consumption and gradually increases the quantities of electricity as well as hydrogen in the energy mix. Global Ambition 2050 is characterised by the lowest total energy demand (258 TWh), but the Distributed Energy 2050 has the highest electrification level (75 TWh). Nevertheless, both electricity and methane remain significantly used energy carriers in all scenarios. The use of oil gradually reduces in the energy mix up to 2050 in both scenarios.

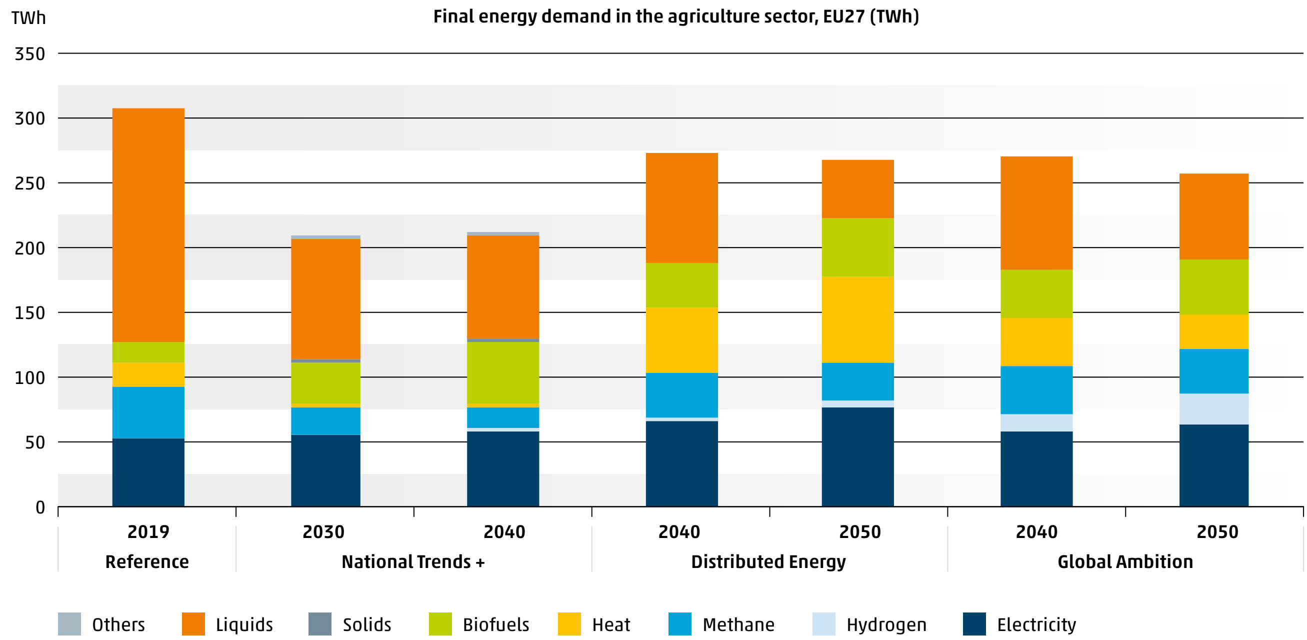



**Figure 18:** Final energy demand in the agriculture sector, EU27 (TWh)

## 7.4 Supply

### 7.4.1 Total primary energy supply

**The European energy supply decarbonises through the development of renewable capacities and implementation of energy efficiency measures.**

TYNDP 2024 Scenarios achieves a 27 % reduction in total primary energy supply across all sectors by 2030 (including international maritime bunkers, international aviation, non-energy use) as compared to 2022 levels. By 2050, this reduction reaches to 35 % in Global Ambition Scenario and 40 % in Distributed Energy Scenario. Achieving this reduction in energy supply is facilitated by the adoption of energy efficiency measures, switch to more efficient technologies, and the integration of flexibility solutions to uphold energy security.

Figure 19 provides insights into the total EU27 energy supply mix, illustrating a significant decline in natural gas supply post-2030, ultimately phased out by 2050 in all TYNDP Scenarios. By 2040, both electricity and gas production are nearly fully decarbonised, while coal and oil are nearly phased out by 2050, with the increased amount of renewable energy supply sources. Solar and wind generation witness remarkable growth, reaching threefold by 2030 and approximately ninefold by 2050 in the envisioned scenarios.

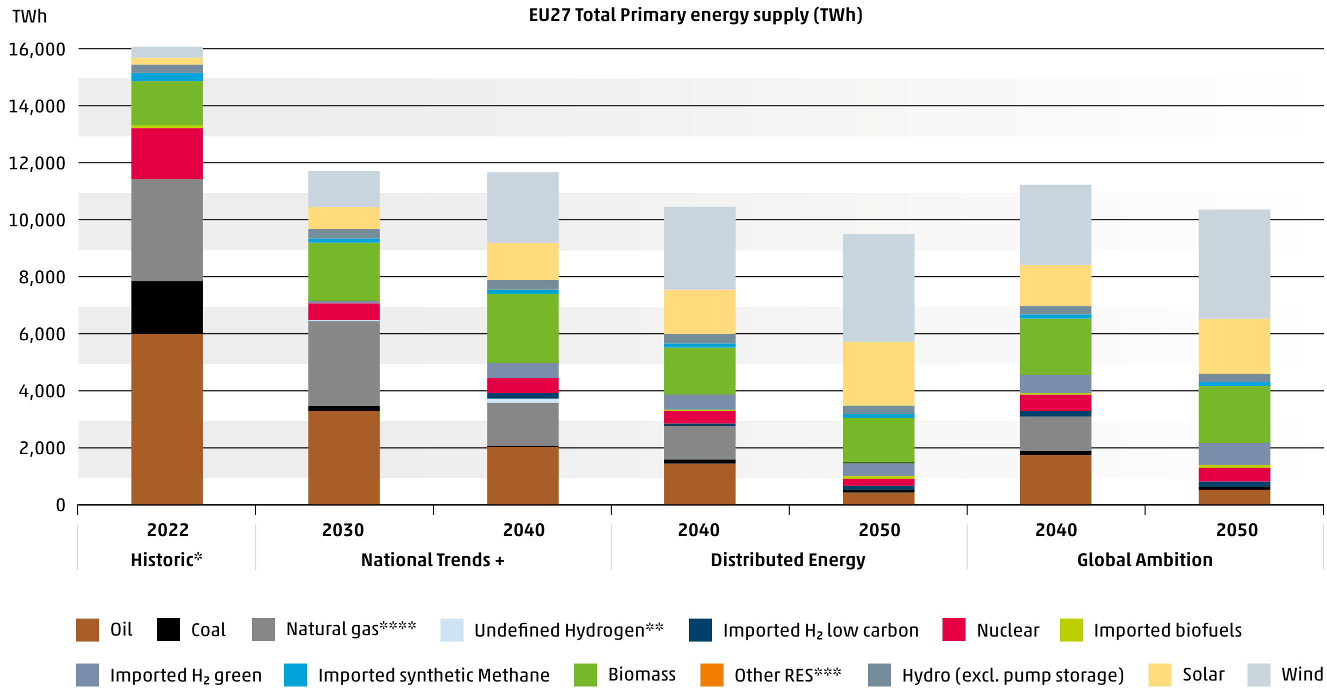



**Figure 19:** EU27 Total Primary energy supply in TWh (including international maritime bunkers & international aviation & non-energy use)

* Historic data is coming from Eurostat

** The supply of $H_2$ required for Power Generation is not explicitly modelled for the National Trends+ scenario. Therefore, it referred as 'undefined', meaning either import or domestic production which is assumed to be renewable hydrogen in our calculations.

*** Other RES includes tide, wave, ocean, geothermal for all and additionally Ambient Heat for historic datasets.

**** Natural gas includes non-renewable waste in the historic data

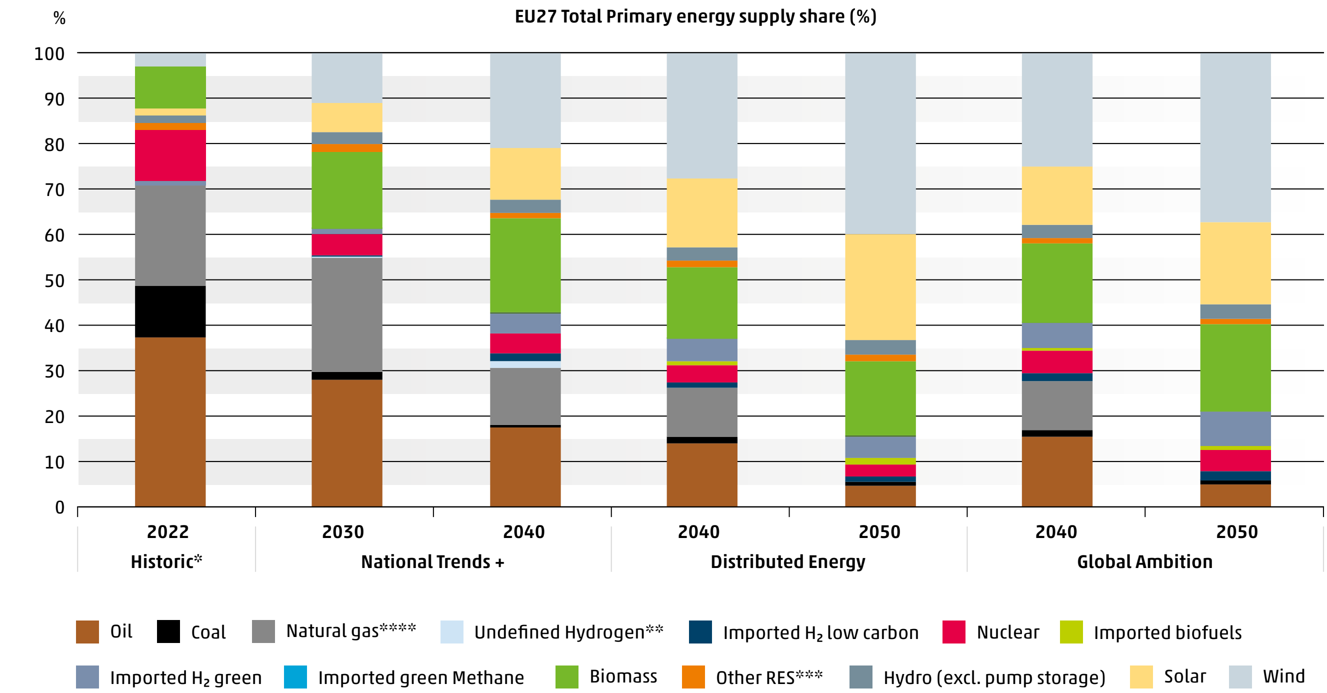



**Figure 20:** EU27 Total Primary energy supply share (including international maritime bunkers & international aviation & non-energy use)

* Historic data is coming from Eurostat

** The supply of $H_2$ required for Power Generation is not explicitly modelled for the National Trends+ scenario. Therefore, it referred as 'undefined', meaning either import or domestic production which is assumed to be renewable hydrogen in our calculations.

*** Other RES includes tide, wave, ocean, geothermal for all and additionally Ambient Heat for historic datasets.

**** Natural gas includes non-renewable waste in the historic data

TYNDP scenarios register a significant increase in renewables energy production. The RES share in Global Ambition reaches 88 % and 91 % in Distributed Energy by 2050. The vast majority of the energy supply stems from solar PV and wind generation. Renewable electricity production is complemented with biomass and energy from waste materials. Low carbon sources like nuclear and blue hydrogen supply also contribute to decarbonise the energy system, with a market share 7 % in Global Ambition Scenario and 4 % in Distributed Energy Scenario of primary energy supply. The share of fossil fuel is decreasing with 1 % coal and 4 % oil which is mainly used in international aviation & shipping and non-energy sectors.

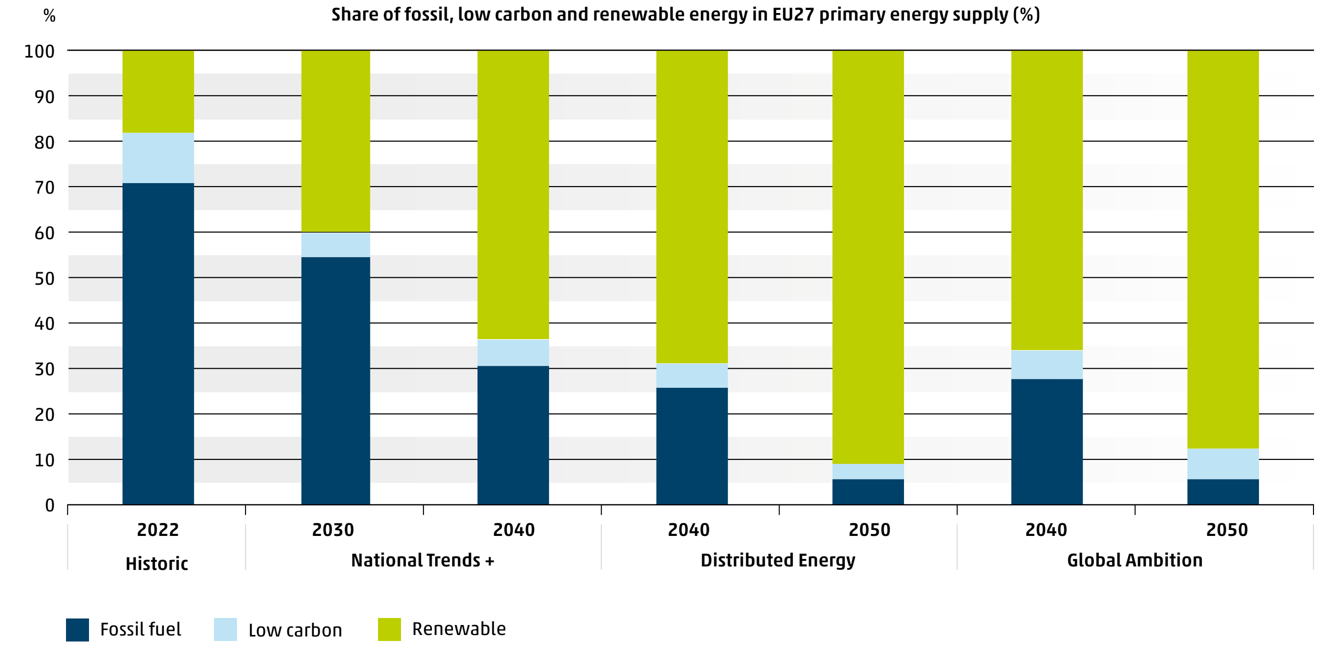



**Figure 21:** Share of fossil, low carbon and renewable energy in EU27 total primary energy supply (including international maritime bunkers & international aviation & non-energy use)

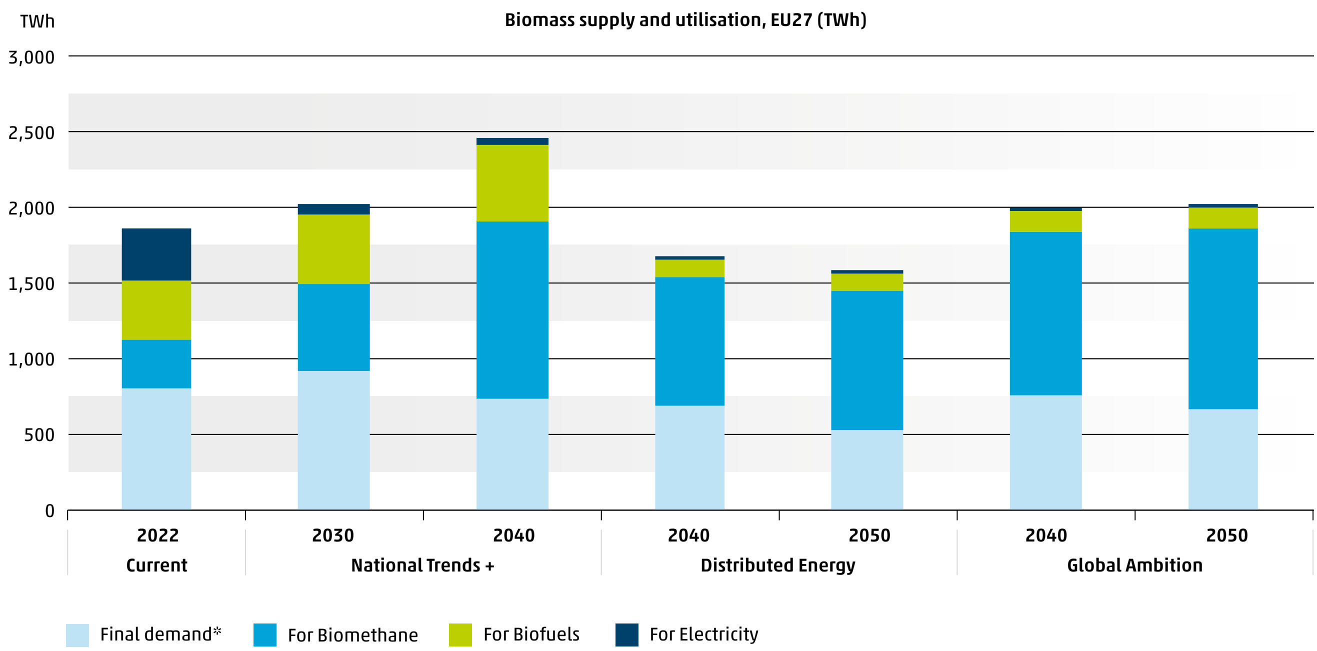



**Figure 22:** Biomass supply and utilisation, EU27 (TWh)

### 7.4.2 Biomass supply

Compared to today's level[23], the NT+ scenario foresees the biggest increase in the biomass supply, while it is rather limited in Global Ambition. In the Distributed Energy scenario, the supply of biomass is slightly lower than the current level. This is illustrated in Figure 21. Biomass is used for different purposes in the scenarios. It is directly used as final demand for heating and in industrial processes. Furthermore, biomass is used as a feedstock to produce biofuels, biomethane and electricity[24]. As such the biomass is converted to other energy carriers, which are subsequently used in the end use sectors for mobility, heating and other applications. The biomass potential used in both scenarios are well below the max potentials stated by JRC[25] and in line with the consumption in the Impact Assessment[26]. A clear trend in the scenarios is that more biomass will be used in the future for production of biomethane while less will be used directly for electricity generation.

### 7.4.3 Electricity supply

**To achieve carbon neutrality by 2050, decarbonising power generation is essential. This becomes increasingly crucial given the growing reliance on renewable fuels contingent on electricity.**

Sector coupling accelerates power generation development to meet the rising demand from direct electrification and the production of renewable fuels via electrolysis. The projected growth of electrolysis-based fuels varies across scenarios, influencing the associated electricity demand. This chapter's generation figures account for both the final electricity consumption and electrolysis needs.

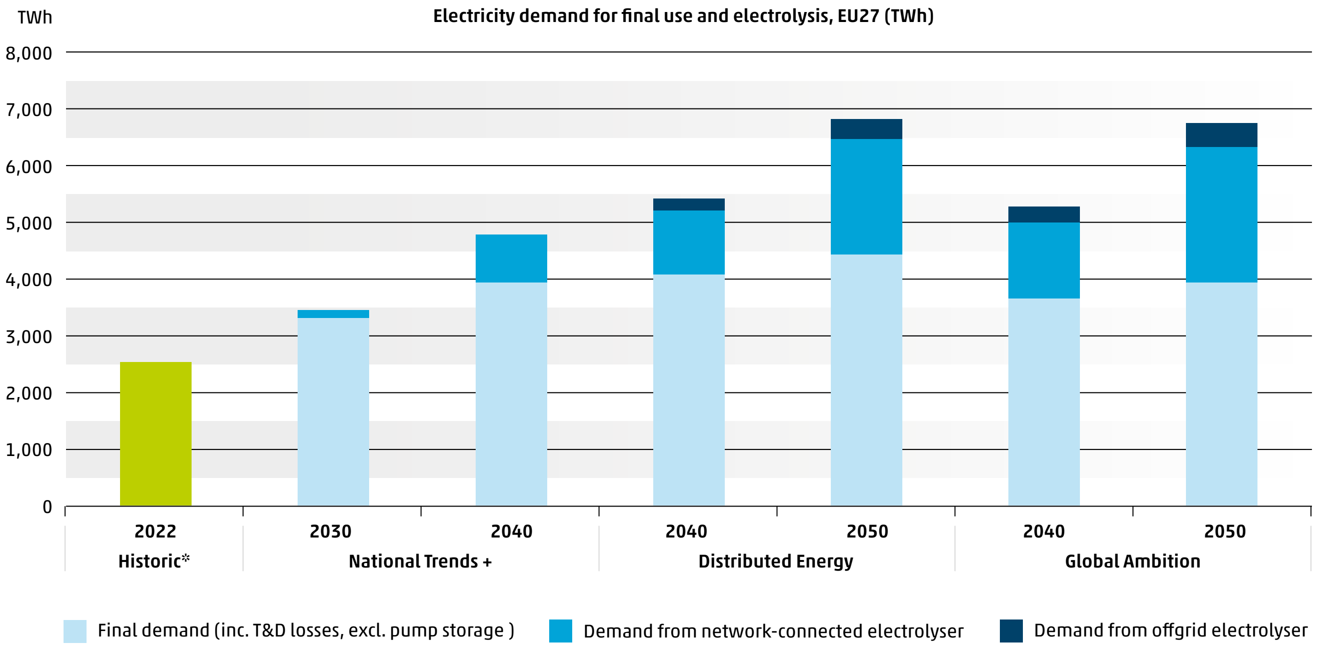



**Figure 23:** Electricity demand for final use and electrolysis, EU27 (TWh)

*** Historical figures are coming from ENTSO-E Statistical Factsheet[27]**

**By 2050, the electricity required for electrolysis is expected to represent nearly one-third of the total electricity demand in both deviation scenarios.**

These scenarios envision achieving carbon neutrality in power generation early on. By 2040, renewables such as wind, solar, and gas-fired power plants using renewable gases, along with nuclear energy and decarbonised

23 The current level is quoted from Eurostat energy balances – biofuels 2022 level. Biomethane and bioliquids are transformed into a biomass demand using the conversion factors 0.58 % for biomethane and 0.55 % bioliquids. See here

24 The final demand and power generation categories only include the direct use of biomass. However, the biomethane produced from biomass is subsequently also consumed for these purposes.

25 See here

26 Impact assessment from European Commission: See here

27 See here

hydrogen, are projected to supply 99.8 % and 99.3 %[28] of the EU27's electricity in Global Ambition and Distributed Energy scenario, including power dedicated to electrolysis. By 2050, variable renewable sources like wind and solar become predominant, contributing 89 % and 86 % to power generation in the Distributed Energy and Global Ambition scenarios, respectively, a significant increase from 56 % in 2030 and 23 % in 2022. Consequently, by 2050, electricity generation is fully decarbonised[29].

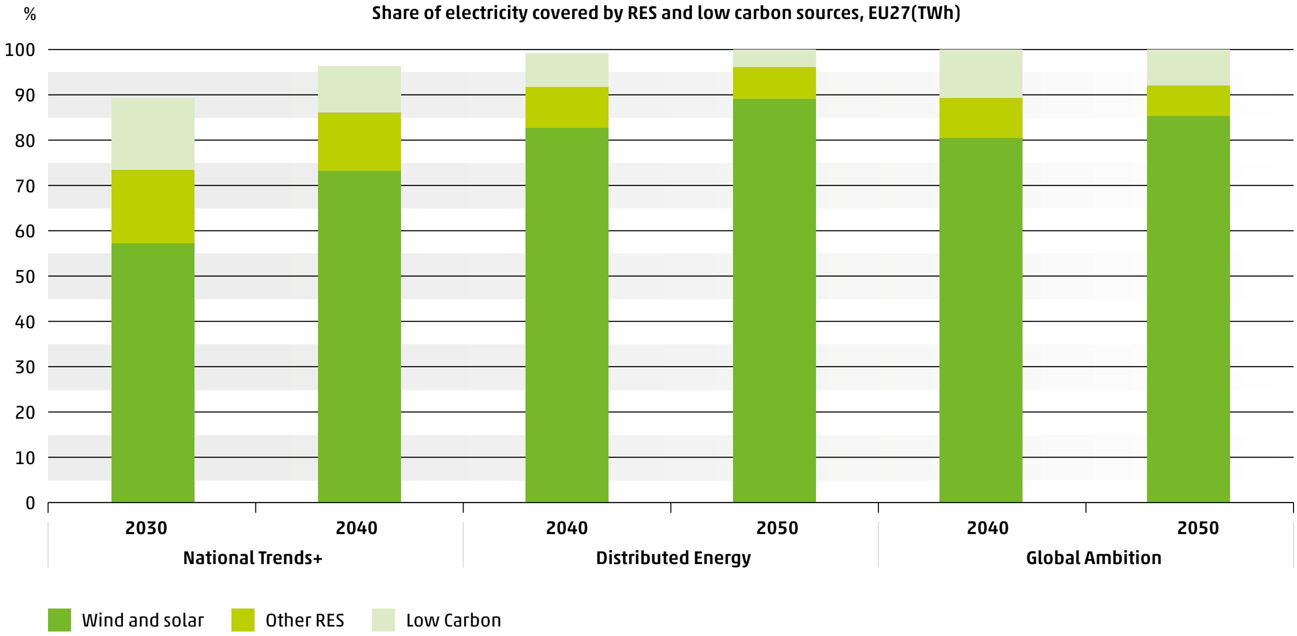



**Figure 24:** Share of electricity covered by RES and low carbon sources, EU27(TWh)

* Low carbon includes nuclear and decarbonised $H_2$

While wind, solar and nuclear capacity differs between DE and GA scenarios, these technologies are complemented by other renewable energy sources which capacity remains constant for all scenarios. This includes hydro, biomass, and gas-fired power plants utilising renewable methane or hydrogen, with hydro being the most significant among them.

**A sharp increase in wind and solar capacity is constitutive of all scenarios. The magnitude of the increase varies less depending on the storyline, as their expanded role is essential in every scenario to meet efficiency, renewable energy, and decarbonisation targets.**

In Distributed Energy, a focus on lowering nuclear capacity and reducing import dependency supplement the decarbonisation objective. As a result, investment in wind and solar capacity reaches the highest level in order to meet both direct electrification and the need for synthetic fuels to replace imports. From a technology perspective, there is a slight preference to decentralised sources such as onshore wind and solar PV. In accordance with more developed prosumer behaviour, in Distributed Energy, solar PV capacity reached 2008 GW in 2050 in comparison to 1,670 GW for Global Ambition.

In Global Ambition, final direct electricity demand is lower than in Distributed Energy. However, the increased demand for synthetic fuels is not fully offset by imports, leading to rise in electricity demand for synthetic fuels. Nuclear capacity remains relatively stable with a slight increase. While the need for wind onshore is on a par with Distributed Energy, the need for solar capacity is strong but slightly lower. The differentiation in wind offshore capacity between deviation scenarios is less pronounced, as the capacities align with the MS's non-binding agreement[30] on minimum capacities.

Compared with the deviation scenarios, the buildout of RES capacities in National Trends+ goes along with a lower electricity demand – mainly driven by a reduced demand from the electrolysers. Therefore, both wind and solar capacities are lower. The share of low carbon and renewable generation reaches 89 %[31] in 2030 and 96 % in 2040. Wind and solar capacity reach 1,127 GW in 2030 and 1936 GW in 2040.

28 The renewable shares of methane and hydrogen can be found in methane and hydrogen supply sections in this report.

29 At the exception of (up to 1TWh) small thermal power plants such as CHP answering local needs.

30 As of August 2023.

31 Assuming a share of renewable methane of 4 % National Trends in 2030.

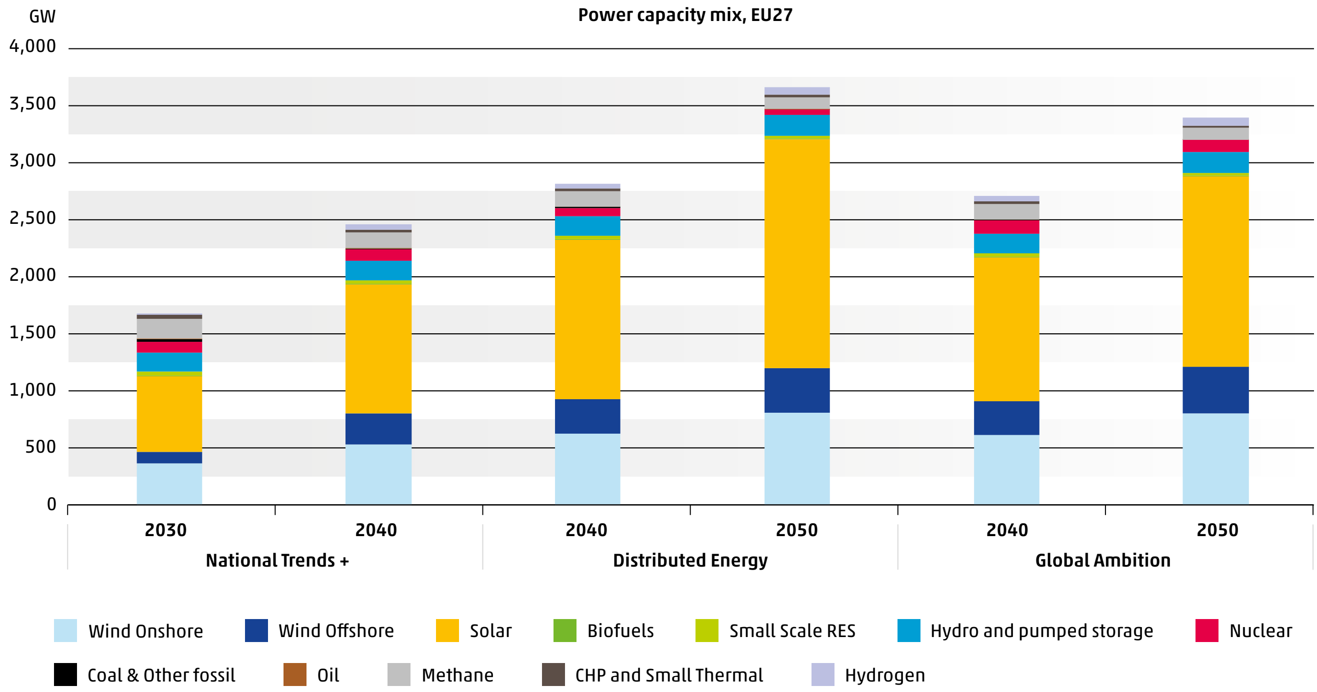



**Figure 25:** Power capacity mix for EU27 (including prosumer PV, hybrid and dedicated RES for electrolysis)

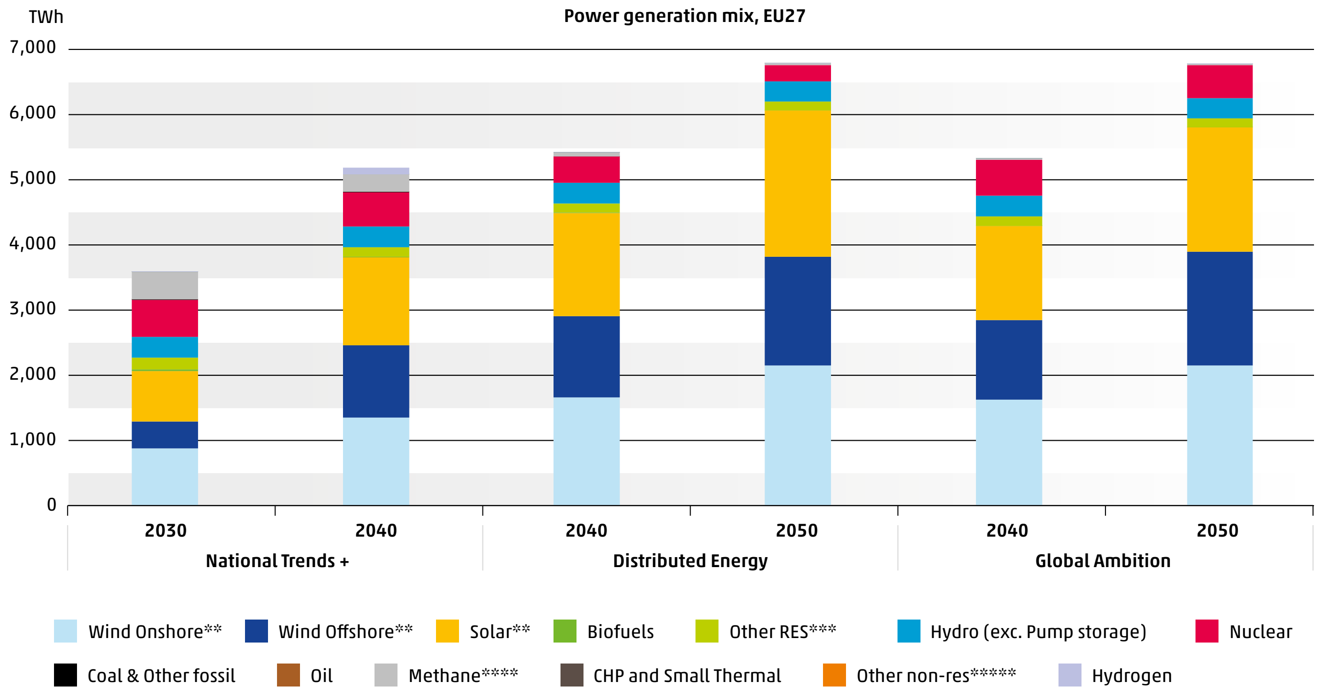



**Figure 26:** Power generation mix for EU27 (including prosumer PV, hybrid and dedicated RES for electrolysis)

* Figures includes all sectors ** Wind and Solar figures include dedicated wind/solar *** Other RES includes tide, wave, ocean, geothermal
**** Methane includes small thermals answering local needs ***** Other non-RES includes CHP and small thermals running with coal, oil and lignite

In all scenarios, coal and lignite are under pressure of phase-out policies in many countries as well as high $CO_2$ price. At European level, the role of these two sources in electricity generation becomes almost negligible from 2030 on.

**The role of gas in power generation undergoes significant changes over time.**

Methane is progressively decarbonised offering the opportunity of flexible renewable and low carbon generation. While methane is currently mostly natural gas, the share of biomethane as well as synthetic methane increases along the time horizon. As illustrated in Chapter 7.4.4 Gas Supply, the methane as well as the hydrogen supply is decarbonised by 2050.

The overall gas power plant capacity, sum of hydrogen and methane fired power generation, is considered nearly constant from 2030 till 2050; as the decrease on methane fired power plant capacities being replaced with hydrogen fired power plants.

From an energy perspective, in 2040, gas-fired power generation significantly differs from National Trends to deviation scenarios. Indeed, in National Trends the decrease between 2030 and 2040 is equivalent to 11 % while in Distributed Energy and Global Ambition 2040 varies between –85 % to –96 % with respect to National Trends 2030.

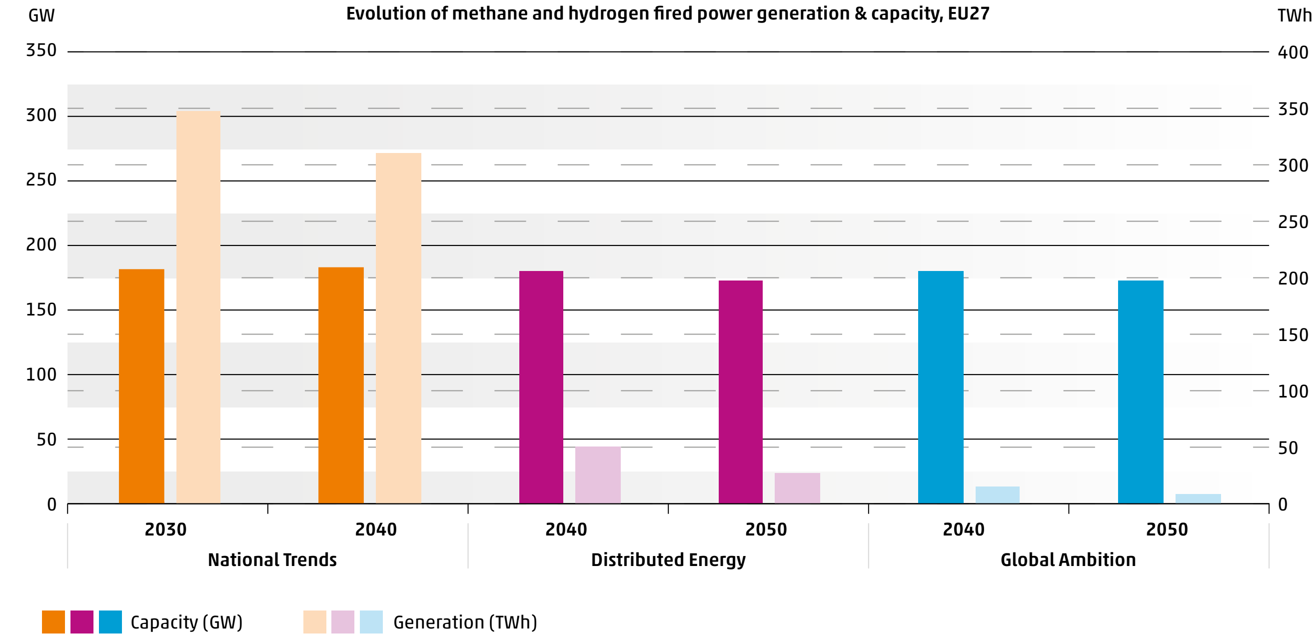



**Figure 27:** Evolution of the main[32] methane and hydrogen fired power capacity and generation for EU27

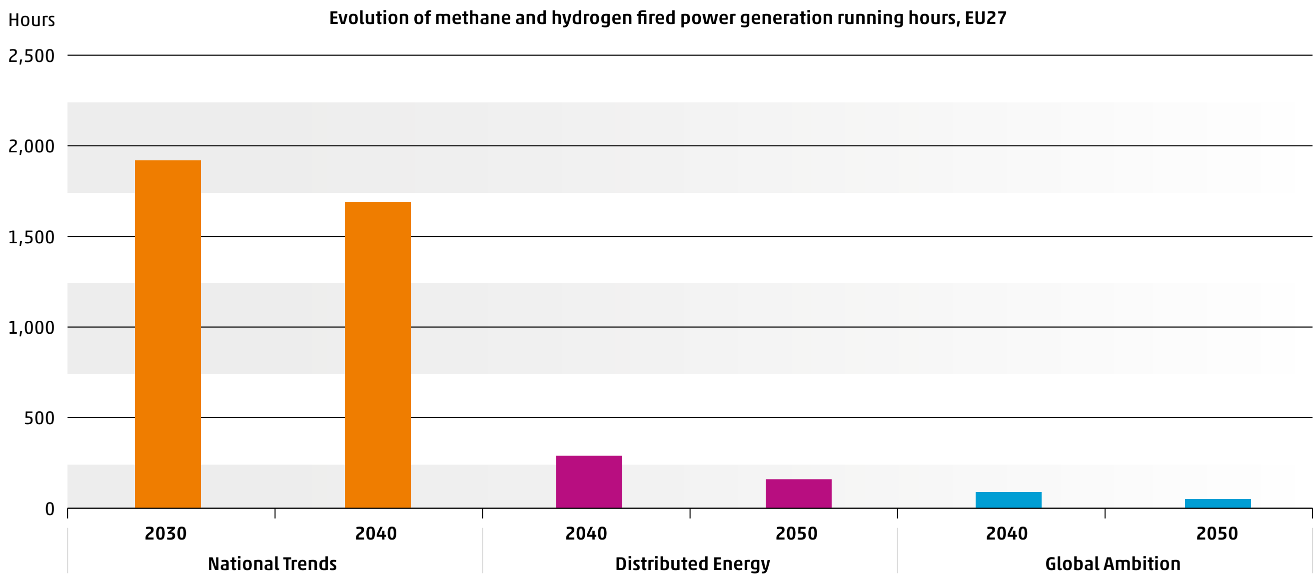



**Figure 28:** Evolution of gas fired power generation full load hours for EU27

32 Excluding Small Thermal and CHP which operation can be driven by other factors such as heat production.

In both deviation scenarios, the role of gas-fired power generation changes to mainly providing flexibility, especially in periods with low feed-in from renewables. In fact, full load hours of methane and hydrogen fired power generation, which are 287 and 87 in 2040 in Distributed Energy and Global Ambition respectively, are significantly lower than current level and national scenarios (i.e., 1,689 hours in National Trends 2040). Although the overall utilisation is low, they still are essential to overcome pronounced periods with little generation from renewables: In several hours all gas-fired power plants are dispatched.

**This result arises from several factors:**

Firstly, the installed capacities of gas-fired power plants (aligned between electricity and gas TSOs) in the Distributed Energy and Global Ambition scenarios are equivalent to those in the National Trends scenario.

In the National Trends+ scenario, the capacities of gas power generation, as well as those of renewable energy sources and other forms of generation, are predetermined by TSOs. Conversely, in the Distributed Energy and Global Ambition scenarios, the installed capacity of renewable generation begins at 2030 NT+ levels and is then optimised for expansion until 2050. Since the electricity and hydrogen sector are optimised jointly, renewables are not only expanded to cover the rising direct electricity demand, but also to cover large shares of the hydrogen demand via electrolysis (see Figure 23). This results in higher levels of renewable generation capacity compared to the National Trends scenario, which represents the minimum capacity available in DE and GA.

The high levels of renewable generation are complemented by ample of short-term flexibility in the form of batteries, flexible charging of EVs and demand side response like (jointly expanded) electrolysers (see Figure 29). The greater capacity for renewable generation in DE and GA combined with the flexibility options lead to a reduced reliance on thermal generation.

Furthermore, according to the storyline, no must run obligations are considered in the deviation scenarios. Taking into account eventual must run obligations or additional revenue streams (e.g. providing system stability, heat for district heating) might increase utilisation of gas-fired power plants above the actual levels observed in the Distributed Energy and Global Ambition scenarios.

It is important that potential limitations that might impact the feasibility of the identified flexibility options will be further thoroughly examined in the upcoming TYNDP scenario cycles but also in other reports like the European Resource Adequacy Assessment (ERAA).

**Flexibility need will increase as well as the range of technologies to answer it.** The electrification of the heating sector and the development of wind and solar will increase the climate dependency of the electricity system. At the same time, the impact of global warming on the variability of weather conditions can already be observed. As a result, the decarbonisation of the electricity mix must go in parallel with the development of flexibility solutions in order to maintain the security of supply. The extent of the flexibility needs and the development of technologies to meet depend on the scenario storylines. Beyond hydro pump storage which capacity follows the same path, the deviation scenarios show a different usage of upstream flexibility (generation side) and downstream flexibility (consumer side) – between the scenarios as well as over time.

In Distributed Energy, the climatic exposure will be at the highest as a result of heating electrification and maximum wind and solar development. At the same time dispatchable power generation (including nuclear) will decrease. In addition, the development of prosumer behaviours will result in a high development of residential batteries and V2G services providing short term storage solutions. Finally, the need to produce synthetic fuels to replace imports may also offer the opportunity of seasonal flexibility by coupling the electricity and hydrogen systems. Electrolysis and hydrogen storage will then be beneficial to the security of the energy system.

In Global Ambition, the climatic exposure of the electricity system will increase relatively slower both on the demand and supply side. Less direct electrification, less variable renewable production, more nuclear generation and more flexibility of the hydrogen infrastructure are lowering the need for flexibility compared to Distributed Energy.

Distributed Energy shows a more flexible consumer behaviour. Both deviation scenarios have PV-connected household batteries and bidirectional usage of electric vehicles, with a higher share in Distributed Energy compared to Global Ambition. In addition to that utility-scale batteries are used in the same order of magnitude as hydro pump storages. In contrast to that National Trends show a higher reliance on flexibility from dispatchable generation.

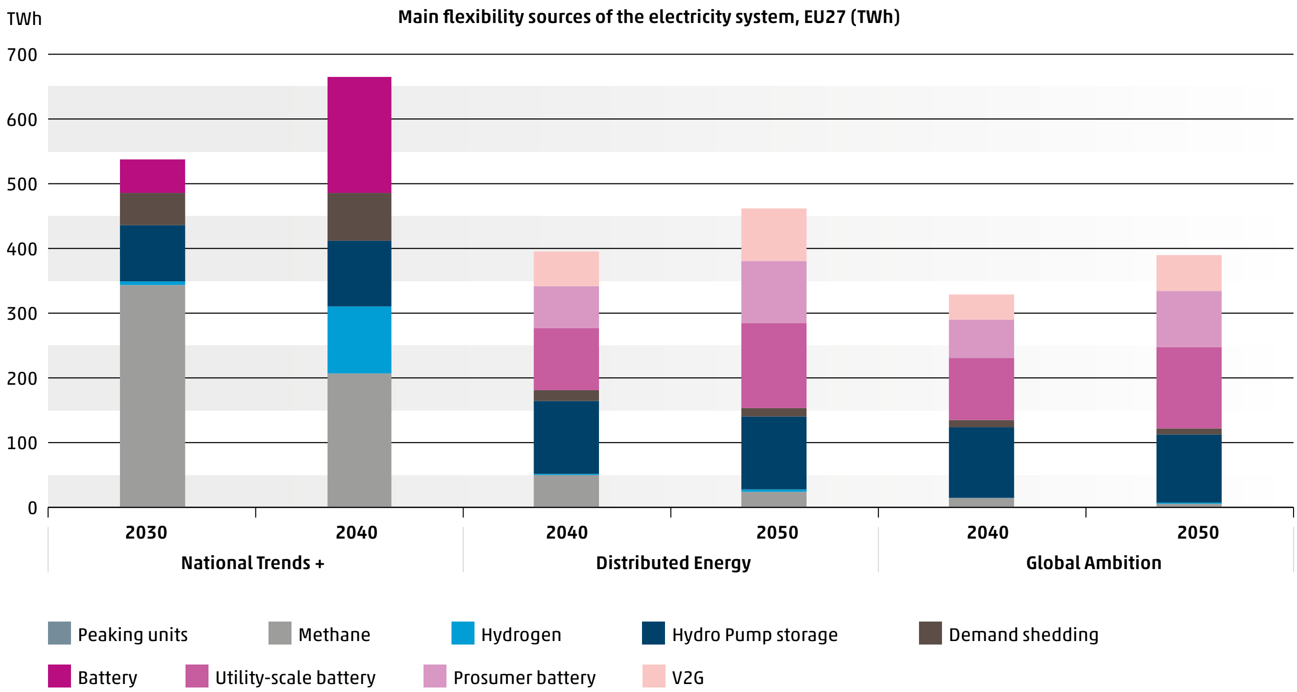



**Figure 29:** Main flexibility sources for adequacy of the electricity system for EU27[33]

## Focus on system operation under various climatic situations

The influence of climatic conditions on the electricity system will significantly increase as a result of the electrification of space-heating and the evolution of wind and solar. In order to illustrate the impact of the climate on the electricity system, the following graphs show the hourly balance in 2-week periods of the climatic year 2009[34] under different circumstances.

33 Peaking units are resulting from the new adequacy step. In NT flexibility of V2G is modelled within the demand.

34 Climatic year of highest residual demand based on Distributed Energy RES capacity and demand profile.

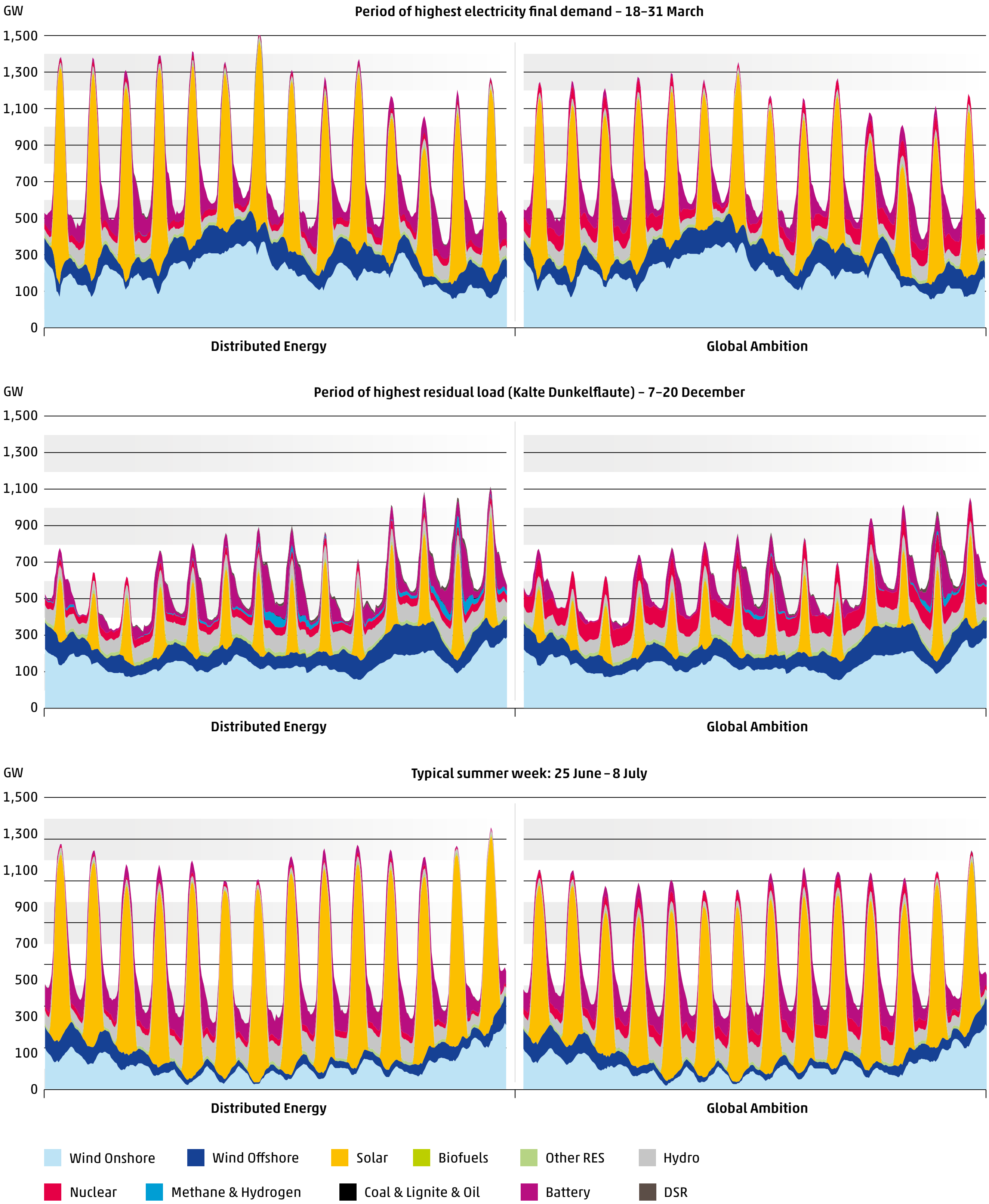



**Figure 30:** Hourly generation profile of power generation[35] (Distributed Energy, left – Global Ambition, right)

35 Excluding RES dedicated to Electrolysers.

### 7.4.4 Gas supply

**All renewable and decarbonisation technologies are needed to meet the EU energy and climate objectives.**

The decarbonisation of the gas supply can be done in many ways. Gas can either be produced from renewable energy such as biomass producing biomethane or wind and solar energy producing hydrogen via P2G. Furthermore, decarbonised hydrogen can be produced with natural gas with different technologies such as steam methane reforming (SMR)/autothermal reforming (ATR) associated with carbon capture and storage technologies[36].

Both deviation scenarios consider all types of technologies to a greater or lesser extent following their storyline. Each technology comes with its level of decarbonisation that is considered in the computation of the GHG emissions of each scenario to keep track of their carbon budget expenses. For instance, biomethane can be considered as carbon neutral or carbon negative if associated with CCS[37].

**The EU methane and hydrogen production can decarbonise by 2050 in both TYNDP 2024 deviation scenarios.**

With the development of renewable hydrogen, biomethane and decarbonisation technologies, the EU can decarbonise nearly 80 % of its gas production by 2030 in National Trends. The EU indigenous production is largely decarbonised in 2040 in both National Trends and the deviation scenarios with remaining 105 TWh of remaining unabated Natural gas and up to 24TWh grey Hydrogen.

Global Ambition shows the highest development of indigenous gas production (about 3,166 TWh produced in 2050) with a higher role for biomethane and hydrogen. In Distributed Energy, the indigenous production of methane and hydrogen increases relatively less with roughly 2,715 TWh produced in 2050.

In the production mix, the specific role of synthetic methane is also crucial, which develops in all scenarios by 2040, and in line with its storyline reaching its peak in the Distributed Energy scenario by 2050 with about 285 TWh.

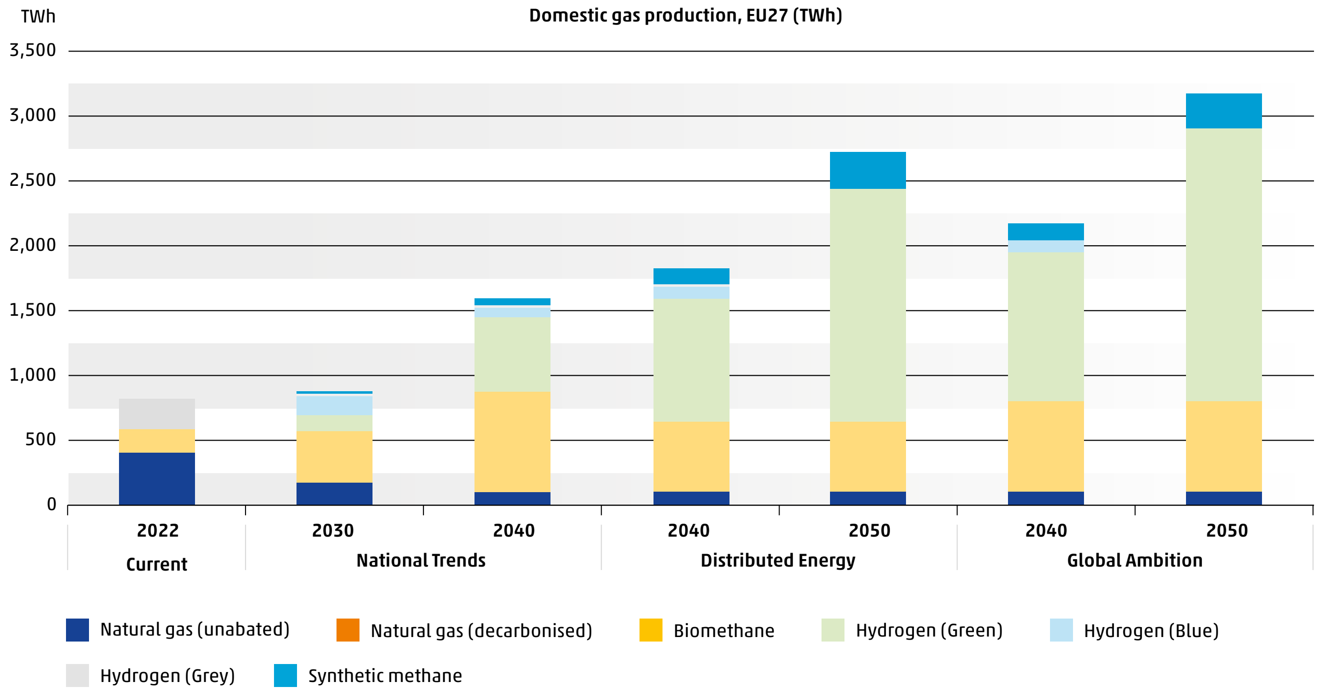



**Figure 31:** EU27 annual gas production per scenario

36 For SMR/ATR an overall efficiency factor of 77 % is used. For CCS processes a capture rate of 90 % is considered. This capture rate represents the various methane reforming technologies and takes into to account the part of the $CO_2$ that cannot be captured in the process and that is therefore released in the atmosphere.

37 Also known as bio-energy carbon capture and sequestration (BECCS).

## 7.4.5 Methane supply

Figure 32 provides an overview of the methane supply in all three TYNDP 2024 scenarios. All scenarios consider similar decrease of the conventional indigenous natural gas production, reaching zero in 2050. By 2040, compared to the National Trends + 2030 level, there is a 31 % reduction in methane production, while the DE and GA scenarios aim for more ambitious reductions, with 47 % in DE and 40 % in GA.

The production of indigenous renewable methane, including biomethane and synthetic methane, varies across the scenarios in alignment with their respective storylines.

National Trends+ shows an increase of biomethane production over time and the production of synthetic methane through electrolysis is rather limited. The overall production of renewable gases is enough to compensate the decline in conventional natural gas production.

**Biomethane: an essential source of renewable methane.**

Biomethane plays a major role in the decarbonisation of the methane supply, and it is the main source of decarbonisation of the methane supply in both deviation scenarios. Synthetic methane is the key to complement the supply needs and reach carbon neutrality by 2050.

**Import levels are reduced to zero by 2050 in both scenarios.**

In the Distributed Energy scenario, there is a lower level of indigenous production of renewable and decarbonised methane, amounting 920 TWh in 2050. Synthetic methane production is slightly higher compared to the Global Ambition scenario, reaching around 285 TWh in 2050. Biomethane plays a crucial but less prominent role in the Distributed Energy scenario, accounting for approximately 635 TWh by 2050[38]. In 2040, the level of imports in Distributed Energy is the lowest of all three scenarios and does not consider any natural gas in 2050.

As a scenario focusing on the integration of the EU into the global energy transition, Global Ambition combines both high decarbonisation levels and access to global and diversified markets for renewable and decarbonised methane (1,078 TWh in 2050). Furthermore, thanks to energy efficiency measures, methane imports decrease to 1,119 TWh by 2040. Natural gas imports are reduced to zero by 2050.

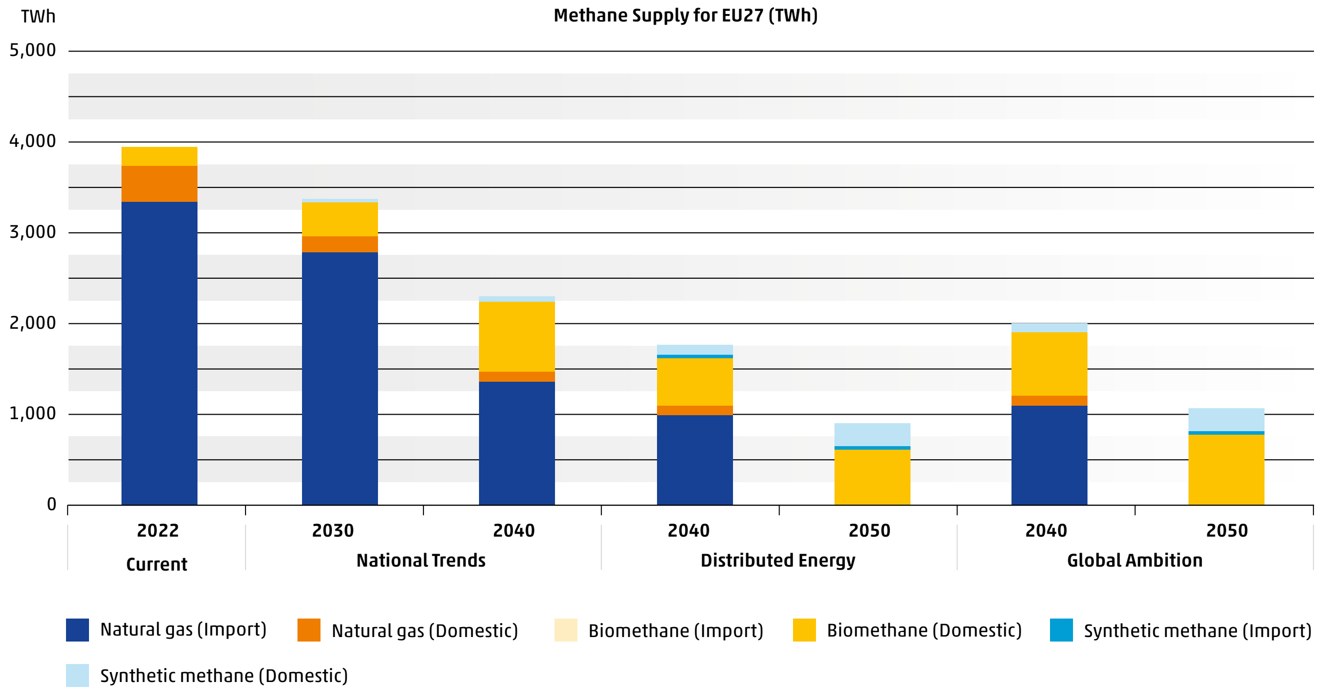



**Figure 32:** Methane supply for EU27

38 See TYNDP 2024 Scenarios Methodology Report for the potential of EU27 biomethane production.

## 7.4.6 Hydrogen supply

### A game changer

Today the EU-27 hydrogen supply is a domestic production of about 250 TWh[39], mainly used as a feedstock. About 75 % is produced with SMR/ATR, the remaining volumes are by-products from other industrial processes . However, all scenarios consider the hydrogen market will undergo a complete transformation over the next 30 years and be traded mainly as an energy carrier to become the main gas energy carrier by 2050 with a marginal role for its demand as feedstock. The main drivers of this transformation of the hydrogen market are the significant EU and global potentials for producing hydrogen from variable renewable electricity and water, and the development of EU-wide, cross-border, hydrogen infrastructure. Figure 33 provides an overview of the hydrogen supply in the three TYNDP 2024 scenarios.

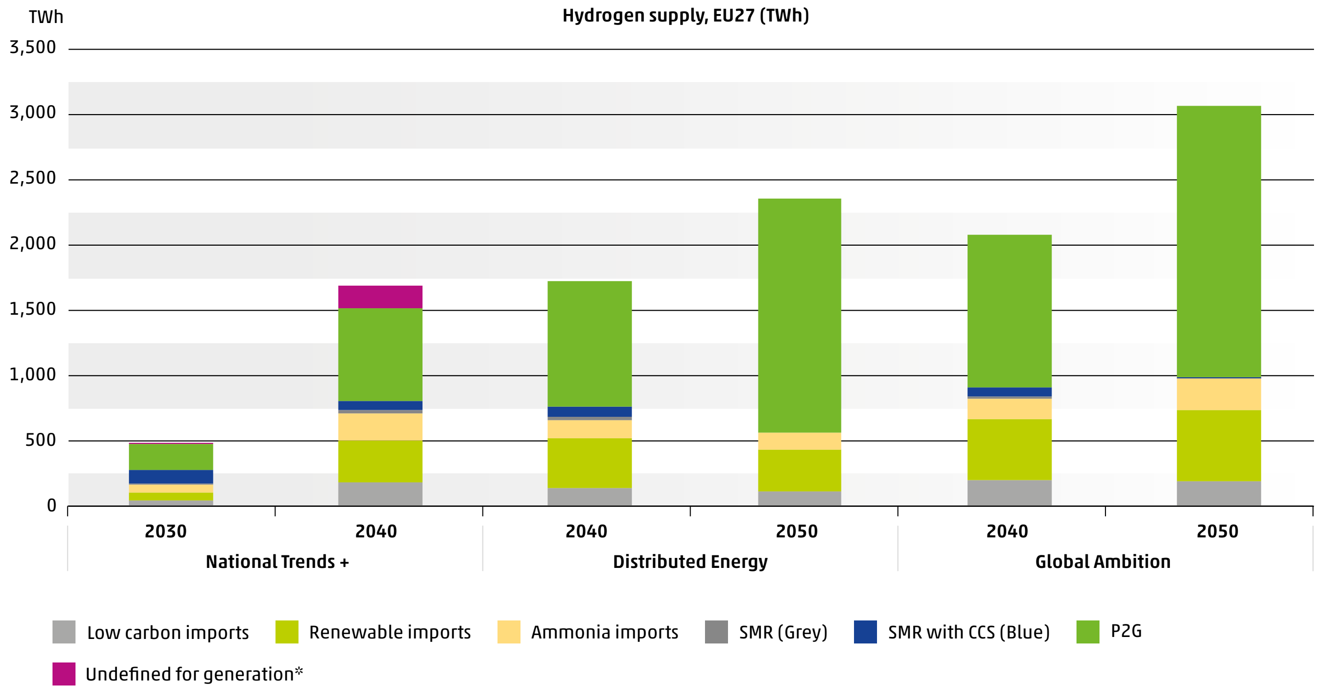



**Figure 33:** Hydrogen supply for EU27

### National Trends considers an uptake of hydrogen production already in 2030.

In 2030 the hydrogen production/consumption already shows a strong uptake compared to today's levels. However, between 2030 and 2040 an even more substantial increase can be seen, indicating that the transformation to hydrogen in many sectors has begun. The hydrogen supply is more than 1,500 TWh in 2040, whereof more than half is imported. In the National Trends+ scenario, the supply of $H_2$ required for power generation is not explicitly modelled, and therefore, it is referred to as 'undefined for generation.' This indicates that the $H_2$ supply for generation could either come from imports or domestic production. As the import potentials could fulfil this demand (10 TWh in 2030 and 174 TWh in 2040) the assumptions for the $H_2$ supply are referred as 'green'.

As NT+ models don't include dedicated electrolyser modeling, Spanish native $H_2$ demand including the production for synthetic fuel is not specifically modelled. The assumption is that all native Spanish $H_2$ demand, including the production of synfuel, is met by dedicated electrolysers. Annex 3 provides overview of the figures submitted by Enagás[40] for transparency on how these native $H_2$ demand, not included in the ENTSOs model, is met by dedicated electrolysers.

### Deviation scenarios: the key role of hydrogen to decarbonise the energy system.

Distributed Energy, as a decentralised scenario with high energy autonomy, considers a high level of domestic production of renewable hydrogen. Since both decarbonisation and higher self-sufficiency are the main drivers of the Distributed Energy Scenario, it requires a significant increase in renewable electricity generation to meet the P2G demand (1,795 TWh in 2050) and its related indirect

39 See here

40 Enagás has been designated provisional HTNO. Enagás has been requested by the Spanish Ministry to send a proposal for the development of the $H_2$ infrastructures in Spain. The final data submitted to the Ministry might differ from the data contained in this Report.

electricity demand. The uptake of hydrogen imports is limited (564 TWh renewable hydrogen in 2050), with an import share of 24 %. In 2050 there is no more production of hydrogen with SMR.

Global Ambition, as a scenario considering larger scale solutions and the EU as an actor of the global energy transition, combines both high decarbonisation levels with access to a global and diversified clean hydrogen market. Hydrogen produced from renewables in the EU play an important role in the supply mix (2,083 TWh) and clean hydrogen imports are key to ensure the supply and demand adequacy of the EU, providing 981 TWh of decarbonised and renewable hydrogen, resulting in an import share of 33 %.

### A strong development of electrolysis.

Electrolysers enable the production of hydrogen and synthetic fuels (synthetic methane and synthetic liquids). Both scenarios show a higher electrolyser capacity reaching close to 400 GW in 2050.

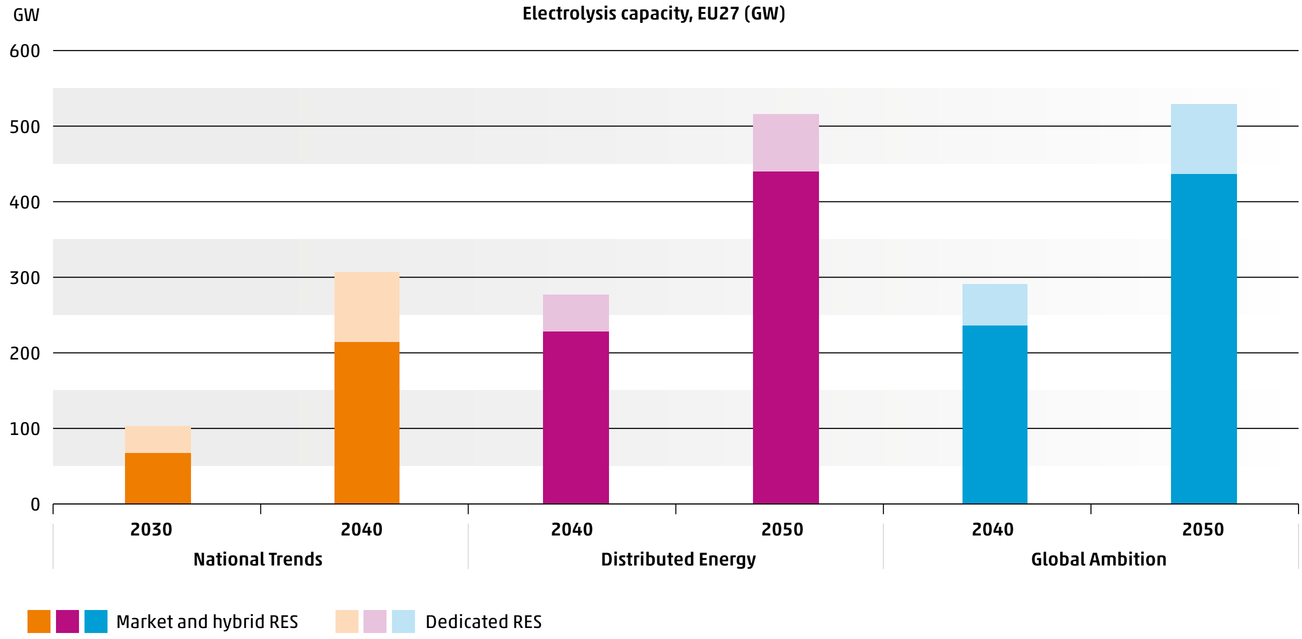



**Figure 34:** Electrolyser capacity for EU27[41]

As a result, from the decarbonisation of the generation mix and the high number of hours at low marginal price, the wholesale electricity market is the main source of electrolysers. In 2050, it accounts for 81 % of electrolyser electricity supply in Distributed Energy and Global Ambition[42]. Electrolyser development also takes advantage of local availability of RES closed to consumption areas, where they can either simultaneously connect to nearby RES and the wholesale market (hybrid RES) or provide a direct connection to the hydrogen grid without expansion of the electricity grid (Dedicated RES)[43].

41 The configurations are explained in the Scenarios Methodology Report.

42 Consideration about a specific market design or requirement laid out in the legal framework (e. g., the criteria's outlined in the Renewable Energy Directive (RED II) are beyond this edition of the TYNDP scenarios report.

43 The market modelling methodology for the TYNDP 2024 introduces a more detailed offshore modelling for electricity and hydrogen. The model is set up to allow for different configurations, including hybrid and dedicated offshore electrolysis, considering input specifications from TSOs. Based on these inputs the model sometimes concludes that dedicated renewables for offshore hydrogen production are the optimal solution, whereas in practice a hybrid configuration may be a more attractive option (as shown in the Pathway study performed by the North Sea Wind Power Hub). The model split in dedicated, and hybrid offshore electrolysis tends to be somewhat biased towards dedicated renewables. For transparency purposes the modelling results are published as is. But the ENTSOs would like to underline that both hybrid and dedicated offshore renewables should be interpreted as a mix of both. See the Scenario Building Guideline for more information.

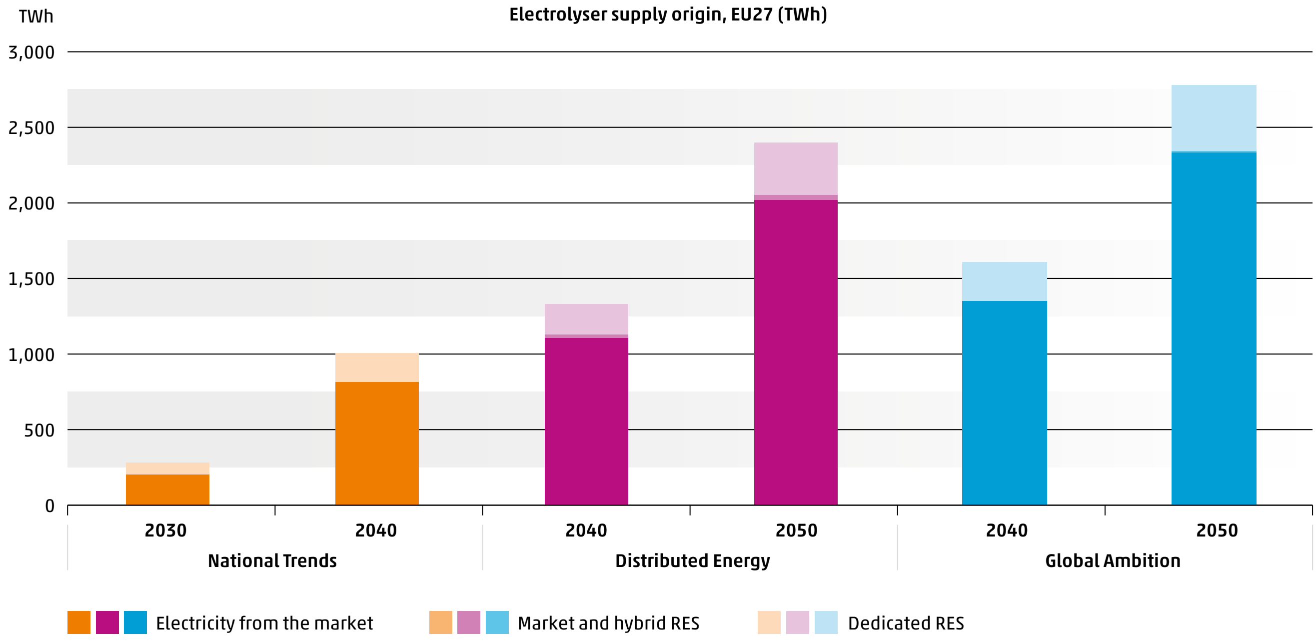



**Figure 35:** Origin of the electrolyser supply for EU27[44]

## All production of grey hydrogen is phased out by 2050.

The deviation scenarios have in common that until 2050, all SMR/ATR without carbon capture and storage will be either decommissioned, retrofitted with CCS or replaced by SMR/ATR with CSS. For countries with a published CCS strategy, it is assumed that all current facilities will be retrofitted with CCS by 2030[45]. In both scenarios low carbon hydrogen plays an important role in the early stage of the transition therefore securing the renewable supply is critical. In the longer term SMR/ATR will be decreased and in 2050 there is no more SMR or ATR left in Distributed Energy. In Global Ambition the supply of low carbon hydrogen will decrease as well. However, a small fraction (5 TWh SMR with CCS) is remaining in 2050.

## The system role of hydrogen goes hand in hand with an increasing need for flexibility.

The current hydrogen market is mainly characterised by baseload demand and dispatchable supply. The future hydrogen system will see much more imbalance in (hourly) supply and demand. The application of hydrogen for heating will introduce temperature dependent demand. Renewable hydrogen supply through electrolysis will also be weather dependent. Furthermore, hydrogen will enable increasing flexibility in the electricity system, through dispatchable power plants to run at peak times.

There is still great uncertainty as to what the optimum portfolio of flexibility resources in the future hydrogen system will look like and how best to distribute these resources geographically across Europe. Certain hydrogen supply sources may provide flexibility to some extent, like SMR/ATR or imports. Studies[46] show however that the majority of flexibility in the hydrogen system needs to come from storage, as is current practice in the methane system. Hydrogen storage in salt caverns is already demonstrated. In the long term, hydrogen storage in depleted gas field may also be feasible, although there are still (technical) challenges to overcome.

The scenario modelling for this TYNDP 2024 is set up to allow flexibility from various sources, like SMR/ATR, e-fuel production, import terminals, demand side response, etc. The flexibility needs of the hydrogen system is illustrated in the figures below[47]. By 2050 the system needs flexibility of an order of magnitude of up to 180 TWh of working gas volume to balance supply and demand. In the current model the main part of this flexibility is delivered by other sources than storage facilities, which for both economical and technical reasons may not be able to deliver flexibility to this extent. As a result, the model seems to underestimate the need for hydrogen storage. If conventional production and imports provide only (very) limited flexibility, the hydrogen storage capacity requirement will be a factor up to 9 higher than shown for the various scenarios. Limitations in connections between countries as well as a more extreme climate years can further increase this factor.

44 Hybrid renewables are connected to both the electricity grid as well as to an electrolyser.

45 The countries with a CCS strategy is; Belgium, Hungary, Bulgaria, Denmark, Estonia, France, Germany, Croatia, Italy and Netherlands. Source: IOGP

46 See here

47 More information on the methodology and model limitations can be found in the methodology report.

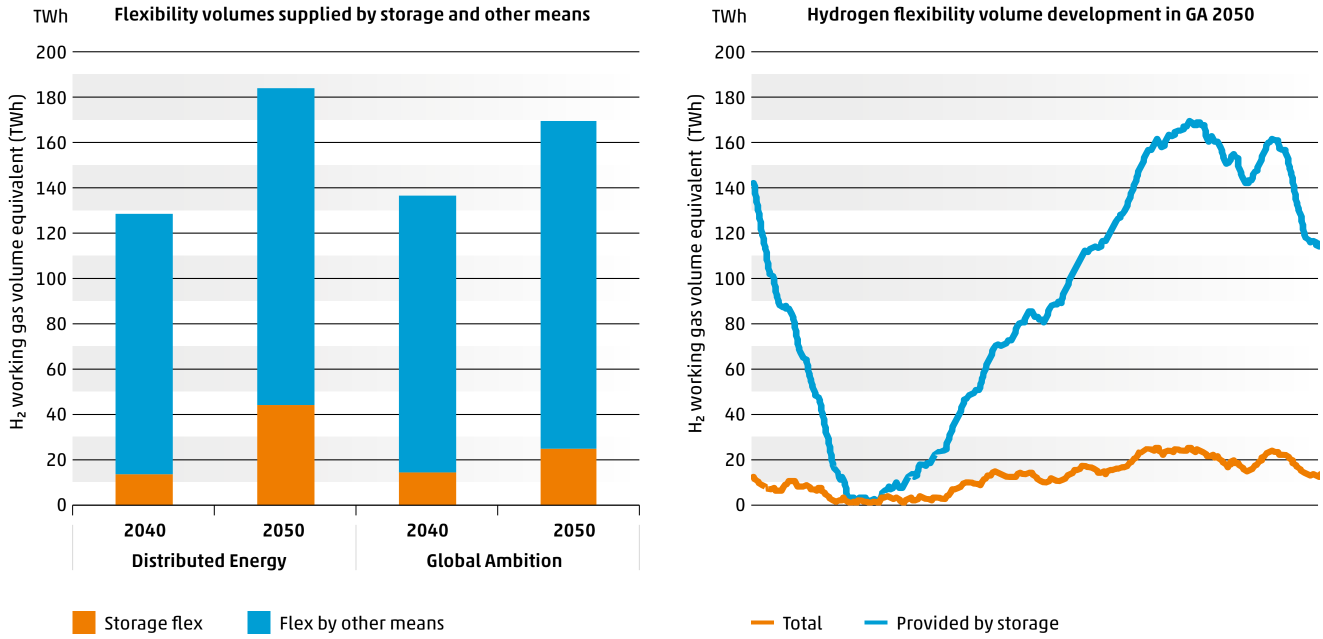



**Figure 36:** Hydrogen Flexibility

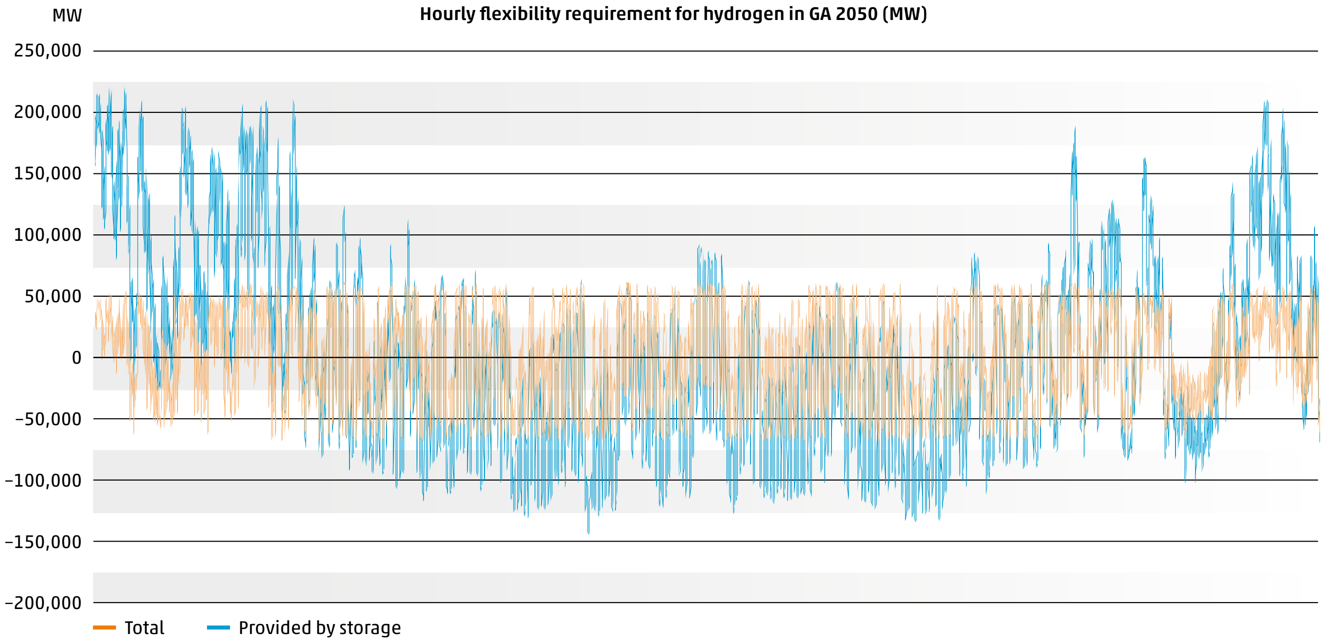



**Figure 37:** Hourly flexibility requirement for hydrogen in GA 2050 (MW)

### 7.4.7 E-Liquid Supply

Similar to synthetic methane (see 7.4.5 Methane supply) the demand and supply of e-diesel and e-kerosene is modelled endogenously. The demand can be supplied either by importing the e-liquid directly or by synthesising it domestically from biogenic $CO_2$ and $H_2$. The total production of synthetic methane, e-diesel or e-kerosene is thus limited by the available amount of captured biogenic $CO_2$.

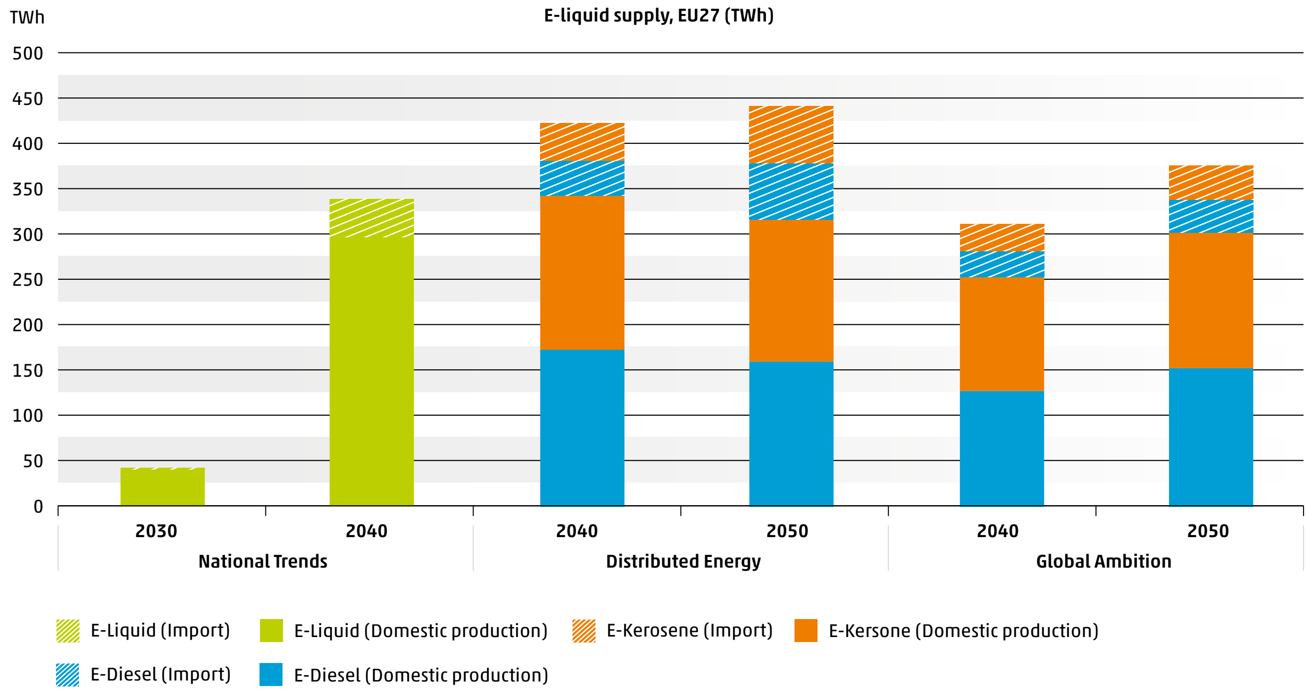



**Figure 38:** E-Liquid Supply

Figure 38 shows the total amount of e-liquids supplied by imports and from domestic production. In all three scenarios the majority is synthesised within Europe rather than imported. In order to produce those e-liquids domestically, significant amounts of $H_2$ have to be supplied: For all e-fuels (including synthetic methane) between 500 and 643 TWh of $H_2$ in 2040 and between 767 and 813 TWh in 2050 (see Figure 54: Hydrogen demand by sector, EU 27, TWh) are used. Besides hydrogen a carbon source is needed in the synthetises as shown in Figure 39. These amounts of $CO_2$ captured and used are additional to the amounts of $CO_2$ captured and stored described in Section 8.2.1 Role of non-energy sectors.

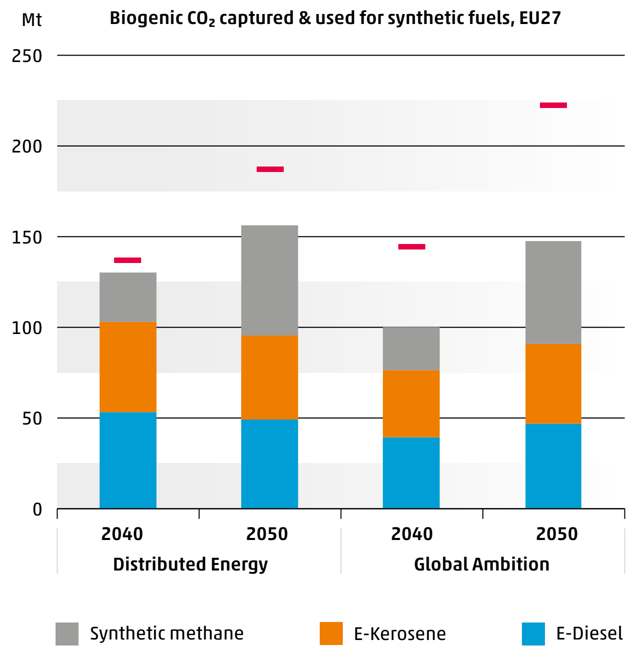



**Figure 39:** Biogenic $CO_2$ captured and used for synthetic fuels

## 7.5 Imports

**With the development of RES capacities and further reductions of energy demand, overall imports are decreasing significantly.**

In all three scenarios, the combination of the energy efficiency measures combined with further integration of the different energy systems significantly reduces the energy demand. Furthermore, both Distributed Energy and Global Ambition scenarios see the significant development of indigenous renewable capacities for electricity and gas, reducing the need for imports in the future.

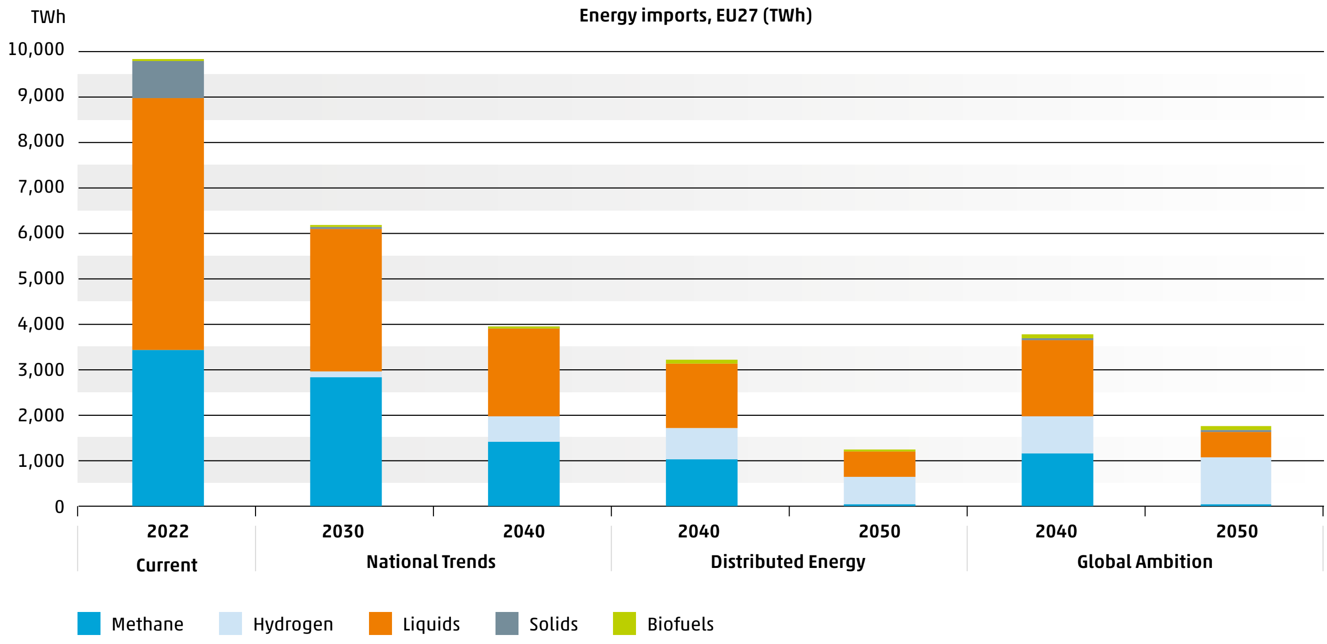



**Figure 40:** Energy imports for EU27 (TWh)

**System integration fosters clean energy production and contributes to energy independency.**

With increasing system integration, the EU energy system increasingly relies on renewable sources to satisfy its energy demand since significant production capacities can be developed in the EU. Therefore, the EU energy demand only marginally relies on coal, oil, and gas which reduces the need for carbon intensive energy imports in the future.

Overall, the scenarios show a significant decline in imports compared to the current level, a trend that is already anticipated for 2030 in the NT+ scenario. In 2050 there will be no need for imports of methane and solids, and only a fraction of today's import level of oil is remaining. The $H_2$ imports are higher in GA than in DE, indicating the storylines differentiation with more energy independence in DE.

# 8 TARGET COMPLIANCE AND BENCHMARK //

This section demonstrates the alignment with the Union's 2030 targets for energy and climate and its 2050 climate neutrality objective. Additionally, this section includes benchmark of the TYNDP scenarios with the Commission's Impact Assessment study which was published on 6 February 2024, towards end of TYNDP Scenarios cycle. As required by the regulation, the latest available Commission Scenarios taken into account during the development of the scenario building process and for this cycle these are Fit for 55 & REPowerEU scenarios. Therefore, this section includes benchmarking with these scenarios as well the Commission's Impact Assessment study.

## 8.1 Energy efficiency first principle and Renewable Energy Directive Objectives

On 10 March 2023, the European Parliament and the Council reached a provisional agreement on the EU Energy Efficiency Directive ('EED'). Accordingly, the EU energy efficiency target agreed for 11.7 % reduction for 2030 comparing to the 2022 reference scenarios[48]. This target is above the Commission's original Fit for 55 proposal (9 %) but marks lower than REPowerEU proposal (13 %)[49].

This energy efficiency target corresponds a binding target for final energy consumption in 2030, which is 763 Mtoe (**8,873 TWh**) and an indicative primary energy consumption target, which is 992 Mtoe[50].

ENTSOs collected the annual final energy consumption figures from the electricity and gas TSOs to provide overall energy system view and to be able to calculate the compliance with this EED target. These are called NT energy mix surveys, represents the electricity and gas TSOs best estimate of their upcoming NECPs and national views as the data collection process took place before the submission of draft NECPs to the Commission. There will be a new data collection in Q4 2024, for the purpose of 2026 Scenarios; where the data collection will be closer to the NECPs, if they will be published before the end of the year as planned.

The NT energy mix surveys[51] shows up to 8 % (818 TWh) gap to reach the Union's latest energy efficiency target.[52] The adjustment has been done according to the consulted 'Gap Closing Methodology'[53] and the table below illustrates the EU27 level energy carrier breakdown of the original National Trends Scenario ('TYNDP NT') and after adjustment according to the gap closing methodology ('TYNDP NT+').

48 See here

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50 See here

51 See here

52 Comparing to the EC scenarios, the NT scenarios include part of the energy branch (e.g., refineries) as some are included under industry sector therefore overestimating the reported overall final energy consumption.

53 See here

| ENERGY CARRIERS | 2015 | 2016 | 2030 | | | | |
|---|---|---|---|---|---|---|---|
| | EC IA | EC IA | TYNDP NT | TYNDP NT+** | EC IA S3 | EC FF55 | EC REPowerEU |
| ELECTRICITY | 2,450 | 2,479 | 2,952 | 2,952 | 2,793 | 2,787 | 2,741 |
| HYDROGEN*** | 0 | 0 | 251 | 251 | 38 | 55 | 242 |
| METHANE | 2,295 | 2,369 | 1,720 | 1,720 | 1,186 | 1,643 | 875 |
| LIQUIDS | 4,340 | 4,506 | 2,816 | 2,051 | 3,250 | 2,973 | 3,037 |
| RENEWABLES | 1,085 | 1,266 | 1,299 | 1,299 | 977 | 1,030 | 1,140 |
| SOLID | 279 | 236 | 210 | 133 | 151 | 114 | 155 |
| SYNTHETIC FUELS | 0 | 0 | 39 | 39 | 8 | 43 | 41 |
| DISTRICT HEATING | 525 | 534 | 373 | 373 | 474 | 0 | 0 |
| FEC | 10,974 | 11,389 | 9,690 | 8,818 | 8,877 | 8,644 | 8,231 |

**Table 1:** Final Energy Consumption*, EU27 (TWh)

* Final energy consumption including international aviation and excludes ambient heat, non-energy use, energy branch and international shipping.[54]
Except TYNDP includes part of energy branch as some are reported under industry.

** Adjusted according to the consulted 'gap filling methodology'. Solid is only coal, liquids represent only oil and renewables includes; biofuels, biogas, geothermal, excess heat, biomethane, waste and other renewables

*** Includes $H_2$ for ammonia production in TYNDP scenarios

While the public consultation on the gap closing methodology finds the methodology appropriate, it required to adjust the 2040 figures where it is necessary. Therefore, the gap closing methodology is extended to the National Trends 2040 scenarios by taking the minimum figure of oil or coal between 2030 adjusted figure and 2040 submitted figure. This represents 0.5 % of the 2040 final energy consumption, translates in reduction of 45 TWh oil and 1 TWh coal according to the methodology.

As TYNDP scenarios are required for infrastructure assessment, the study does not go beyond the calculation of the gap & adjusting it with rather a pragmatic approach for the target calculation. This approach does not provide any detailed analysis neither the MS nor the sub-sectorial level as it is not a purpose of the scenarios. It should be noted that as the gap closing methodology does not require adaptation on the electricity and gas figures, the modeling simulation results are not affected with this adaptation.

54 See here

Figure 41 provides an overview on the evolution of the Final Energy Consumption over 2050. It should be noted that for the TYNDP DE & GA scenarios, synfuels and biomethane are distributed under methane and liquid demands, solid includes biomass whereas renewables only represent biofuels.

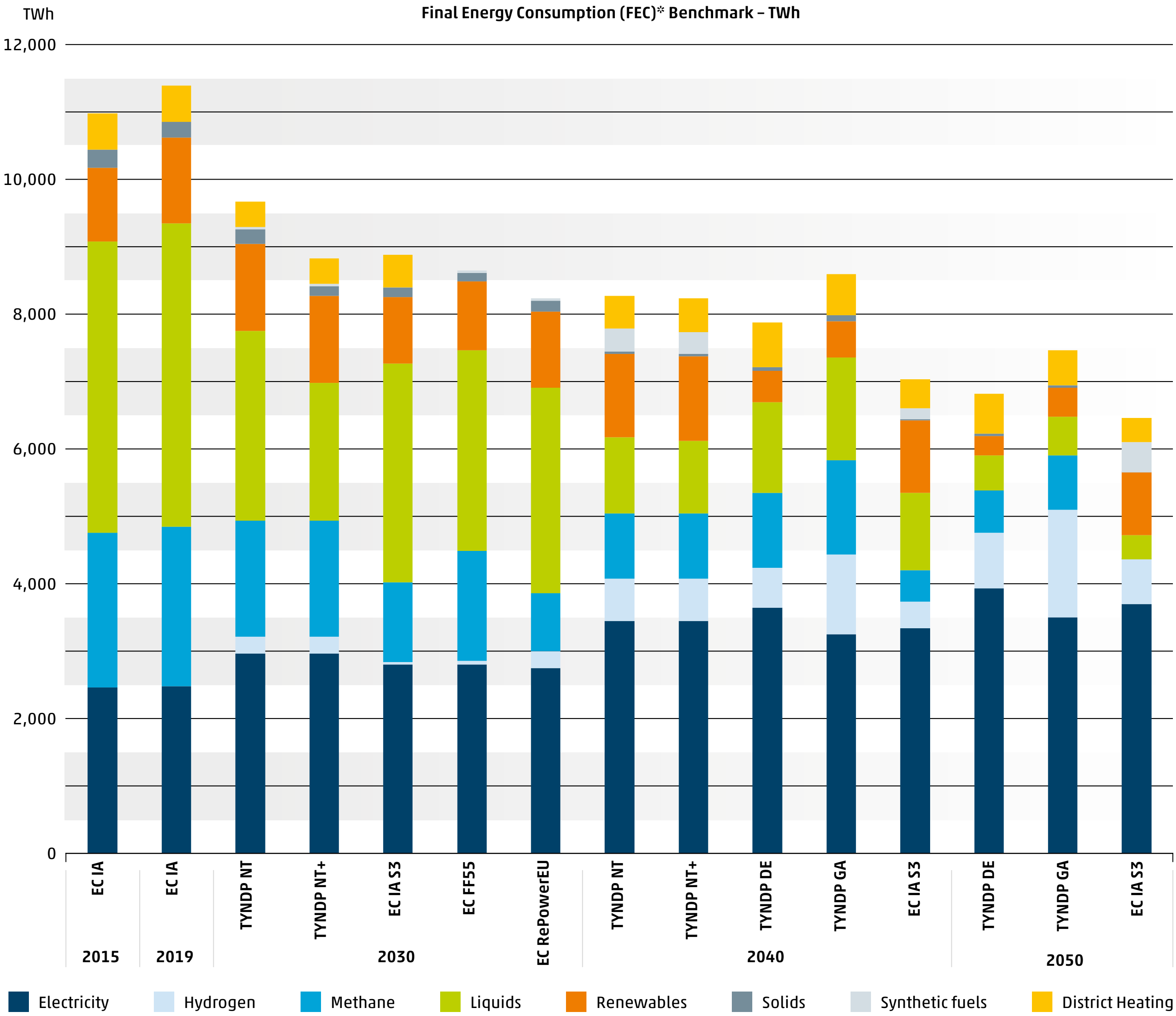


**Figure 41:** Final Energy Consumption Benchmark, EU27 (TWh)

* FEC for the EC studies excludes energy branch, international shipping, ambient heat, non-energy use and includes international aviation. TYNDP analysis follows the same approach, additionally part of energy branch is included (as some are reported under industry).

TYNDP NT+ figures are adjusted according to the consulted 'gap filling methodology'. Solid is only coal, liquids represent only oil and renewables includes biofuels, biogas, geothermal, excess heat, biomethane, waste and other renewables.

Hydrogen includes ammonia production for TYNDP scenarios.

DE & GA scenarios synfuels and biomethane are distributed under methane and liquid demands, Solid includes coal and renewables only includes some biofuels and biomass.

### 8.1.1 RES Share

The overall target for the share of renewable energy was agreed at **42.5 %** by 2030, with an indicative top-up of 2.5 %.

According to the modeling results of electricity and gas supply mix together with the remaining careers from the NT+ energy mix surveys, the overall RES share is 41.7 % in 2030 prior to the gap closing methodology. The RES-share after the gap closing methodology reaches 45.4 % in 2030.

**Overall, the scenarios illustrate high increase of deployment of wind and solar which increases the RES-E and RES-H share which has great influence on the overall RES Share calculation.**

| | 2030 – NT+ | 2030 – NT |
|---|---|---|
| **OVERALL RES SHARE (GFCOE ADJUSTED) [%]** | **45.4 %** | **41.7 %** |
| **NUMERATOR** | **4,135,408** | **4,135,408** |
| Energy from renewable resources (including RFNBOs, excluding electricity, $H_2$ and biofuels) – GWh | 1,522,544 | 1,522,544 |
| Ambient Heat – GWh | 87,704 | 87,704 |
| Renewable electricity, exc. RE electricity used for the energy branch except heat production* – GWh | 2,353,070 | 2,353,070 |
| Renewable $H_2$, exc. RE $H_2$ used for energy branch, non-energy use and international shipping – GWh | 172,090 | 172,090 |
| **DENOMINATOR** | **9,165,433** | **9,987,433** |
| **Gross Final Consumption of Energy (GFCoE) – GWh** | **9,165,433** | **9,165,433** |
| Final Energy Consumption (FEC) – GWh | 8,872,841 | 9,987,841 |
| Ambient Heat – GWh | 87,704 | 87,704 |
| Distribution losses for electricity – GWh | 151,671 | 151,671 |
| The consumption of electricity and heat by the energy branch for electricity and heat production – GWh* | 53,130 | 53,130 |
| Transmission and distribution losses for derived heat** – GWh | 88 | 88 |
| **GFCOE ADJUSTED*** (AVIATION CAP), GWH** | **9,107,555** | **9,924,364** |

**Table 2:** RES Share Target Calculation (GWh)

* **The consumption of electricity and heat by the energy branch for electricity and heat production is assumed 48 % of electricity and heat comsumption by the energy branch. (The share calculated acc to EC FF55)**

** **The transmission and distribution losses for derived heat is taken 0.57 % of FEC (The share calculated acc to EC FF55)**

*** **GFCoE adjusted/GFCoE share is taken from EC FF55 scenario**

## 8.1.2 GHG reduction objectives

All scenarios comply with the European climate and energy objectives, in particular the greenhouse gas reduction targets. On 11 December 2019 the European Commission has announced the European Green Deal[55] and since then published several policy strategies, among others the Energy System Integration strategy[56] (ESI) and EU Hydrogen strategy[57] for the European Union. On 17 September 2020 the European Commission reconfirmed its proposal of reducing GHG emission by at least –55 % by 2030 and reach climate neutrality by 2050. This was accompanied by a supporting Impact Assessment[58]. Since then, a climate target on 90 % reduction has been recommended by the EU Commission[59] and is based on the newest Impact Assessment[60].

**TYNDP scenarios meet the 2030 targets and reach carbon neutrality by 2050.**

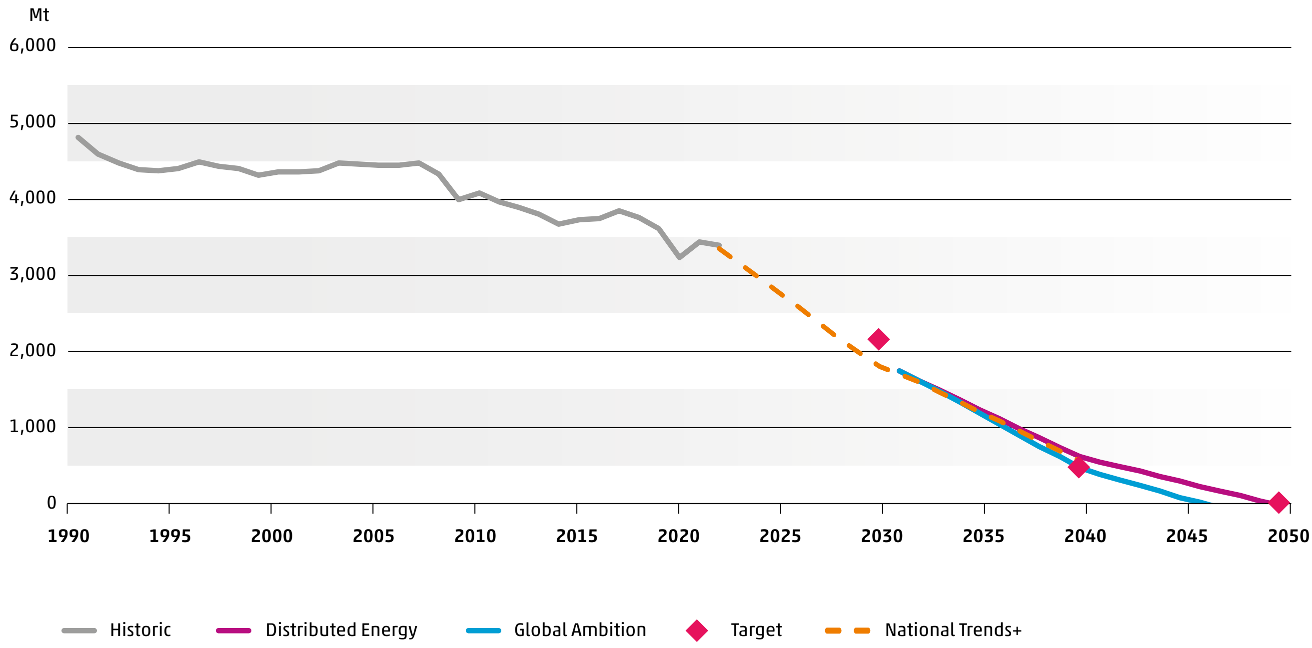


**Figure 42:** GHG emissions outlook, EU27 (Mt)

All scenarios built on NT+ scenarios which foresee a reduction of GHG emissions of at least 55 % by 2030 compared to the 1990 level. NT+ reaches a reduction of 88 % in 2040 which slightly above the target at 90 %. Both Distributed Energy and Global Ambition reach carbon neutrality by 2050[61].

**The EU needs to become carbon negative in 2050.**

The development of large-scale decarbonisation technologies can contribute to accelerate the decarbonisation of the European economy and reaching carbon negativity after 2045–2050 to be on the trajectory to meet the EU climate objectives. Reaching carbon negativity in the second half of the century is necessary to recover from the overshoot of the carbon budget defined to comply with the COP 21 objective of limiting the amount of GHG by the end of the century to limit the global temperature increase to +1.5°C.

55 See here

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61 Carbon neutrality (or net zero) means having a balance between emitting carbon and absorbing carbon from the atmosphere in carbon sinks. Removing carbon oxide from the atmosphere and then storing it is known as carbon sequestration, for example through land use, land use change and forestry (LULUCF).

## 8.2 GHG emissions

**A carbon tracker to compare the scenarios with the EUs climate objectives.**

In the scenarios the EU emission reduction targets[62] for 2030, 2040 and 2050 are analysed and the climate budget set up from 2030 to 2050 in line with the EC impact assessment report[63].

**Energy efficiency first: reducing the energy demand is the most efficient way to reduce GHG emissions.**

All scenarios consider the development of energy efficiency measures like renovation of buildings and transition to more efficient technologies. A significant decrease in primary energy demand combined with increasing shares of renewables and decarbonised energy in the EU supply mix is a necessary condition of meeting the EU climate and energy objectives.

**Renewable and decarbonisation capacities need significant increase.**

Whereas electricity generation has already undergone some level of transition, the EU needs a significant increase in renewable and decarbonised capacities including for hydrogen and methane to decarbonise the whole energy system. Just for wind and solar generation, this represents an increase from 400 TWh produced in 2019 to 2,500 or 3,000 TWh in 2050 in Global Ambition and Distributed Energy respectively.

### 8.2.1 Role of non-energy sectors

**All sectors need to decarbonise.**

The fully integrated scenarios confirm that reaching a net zero economy by 2050 requires the contribution of non-energy related sectors, such as the decarbonisation of agriculture land and production, and requires further afforestation. It should be noted, that for non-$CO_2$ emissions (methane, $N_2O$, F-gases) and LULUCF for the ongoing development until 2050, the TYNDP 2024 scenarios rely on data provided in the Impact Assessment[64] from the European Commission. The starting point in 2021 is taking from European Environment Agency[65]. For missing years with in between interpolation is used.

Associated assumptions are the same for both Distributed Energy and Global Ambition. Non-$CO_2$ emissions reduce in both scenarios from 662 Mt in 2022 to 304 Mt in 2050. This is also illustrated in Figure 43. Methane emissions cover the largest part of the non-$CO_2$ emissions. This is mostly enteric fermentation from cattle and anaerobic waste. It also covers methane leakage from gas production, processing and transportation, but this only accounts for a small share (~5 %)[66].

62 EU Climate targets: See here

63 Impact assessment from European Commission: See here

64 Impact assessment from European Commission: See here

65 European Environment Agency: See here

66 See here

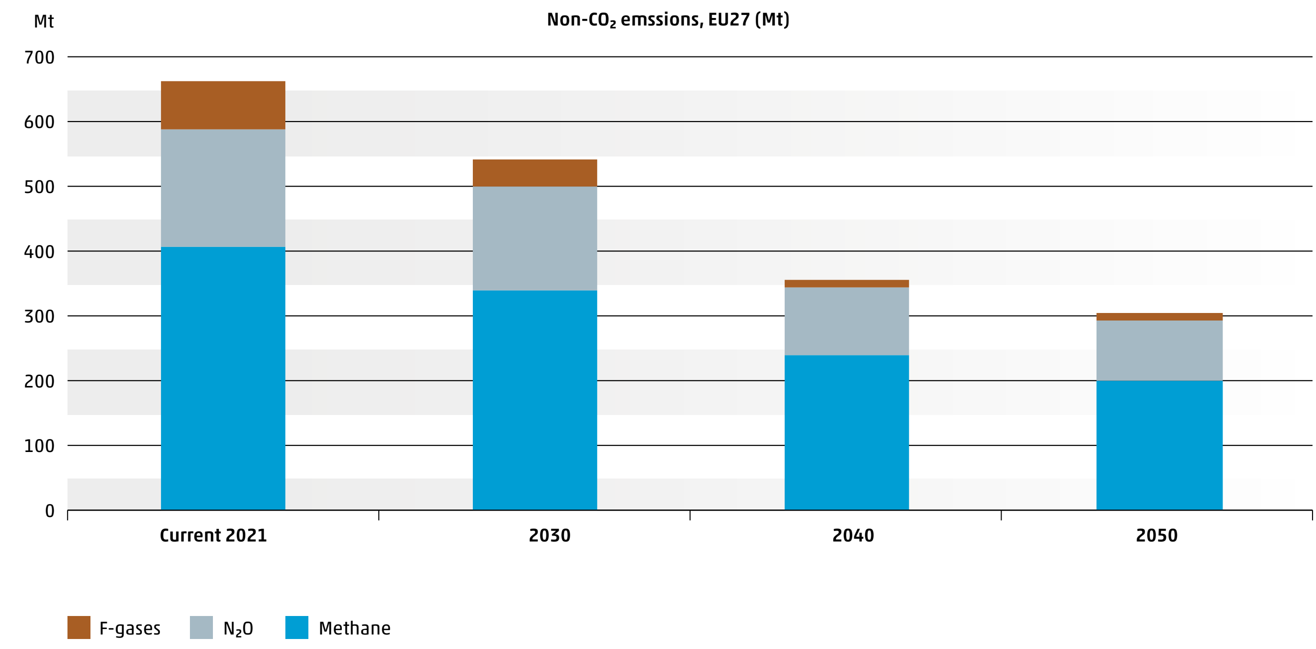


**Figure 43:** Non-$CO_2$ emission, EU27 (Mt)

Negative emissions from LULUCF increase from 201 Mt in 2022 to 333 Mt in 2050, as shown in Figure 44. The sources for the net emissions from LULUCF are for the period from 2022 to 2030 based on the expected net emission from LULUCF given by European Environment Agency[67]. For the years 2040 and 2050 is used the prediction from the EUs Impact Assessment using the prediction in the S3 scenario. For the years between 2030 and 2040, and 2040 and 2050 an interpolation is used.

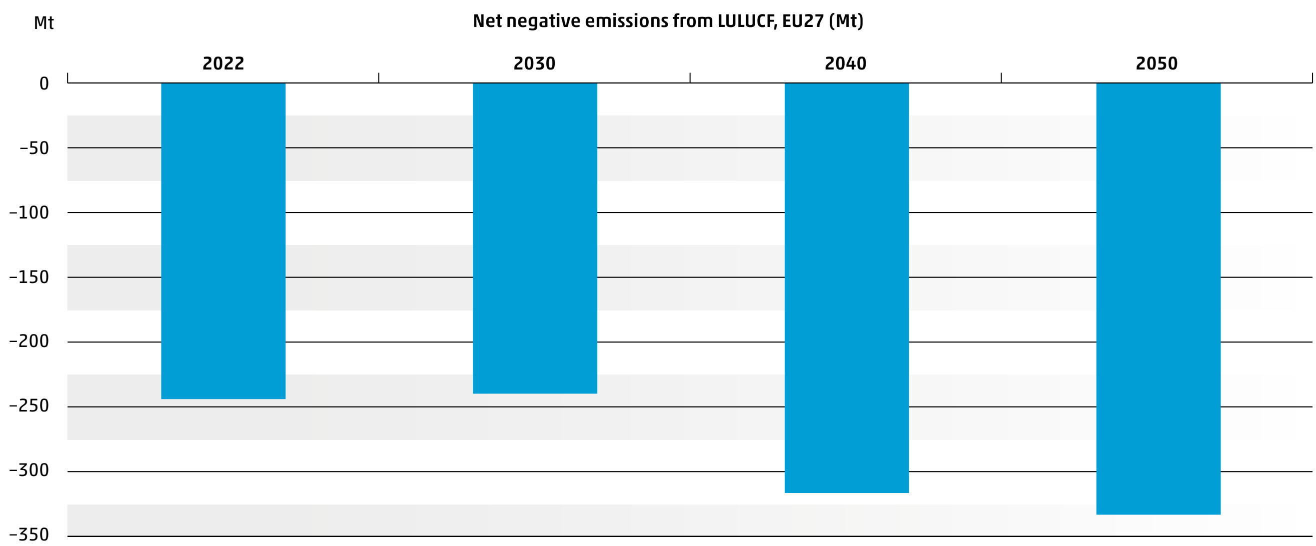


**Figure 44:** Net negative emissions from LULUCF, EU27 (Mt)

The TYNDP 2020 and TYNDP 2022 scenario building exercises have already shown that to decarbonise all sectors as well as all fuel types, additional measures such as CCU/S are needed, also in combination with bioenergy. The TYNDP 2024 scenario assumptions for CCS are summarised in Figure 45. A quantification of available biogenic $CO_2$ is made in the process as well. However, this amount is only used to set a maximum value for production of electro fuels in the modelling and are not directly linked to the used values for CCU/S presented below.

The Global Ambition scenario shows an increased application of CCS, with up to 400 Mt per year by 2050 which is in line with the Industrial Carbon Management Strategy for the

67 European Environment Agency (Quoted 4 April 2024): See here

EU[68]. These CCS assumptions are based on the projects listed on the homepage of IOGP for the coming 8 years. For the rest of the period (2033 to 2050) estimates found in the Impact Assessment from the European Commission (Scenario S3) is used. The CCS use is however capped at 400 Mt because in 2046, not to exceed the fossil emissions. Some CCS will be used in the remaining years as DAC not connected to industry emissions. In between is used interpolation. The NT+ scenario follows the same path for CCS as the Global Ambition scenario.

The Distributed Energy scenario is differentiated from Global Ambition by limiting the use of CCS. Therefore, Distributed Energy foresees a limited use of CCS (up to 150 Mt in 2050).

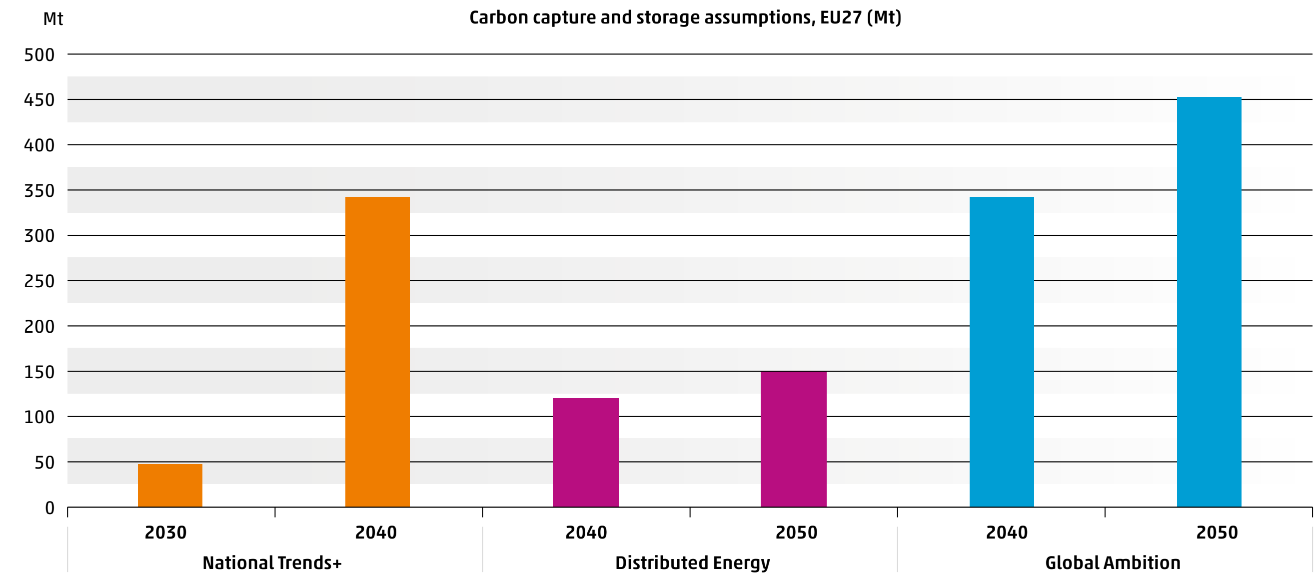


**Figure 45:** Carbon capture and storage assumptions, EU27 (Mt)

## 8.2.2 Carbon budget assessment

The carbon budget calculation starts in 2030. Before 2030 it is assumed that both deviation scenarios are following the path of the NT+ scenario and complies with the EU climate target and reaches a 55 % reduction in 2030.

In the period after 2030 and until 2050, the TYNDP 2024 scenarios are compared to the carbon budget suggested by the European Scientific Advisory Board on Climate Change (ESABCC). The ESABCC find a feasible carbon budget for the EU for 2030 to 2050 to be in the range of 13–16 $GtCO_2eq$ but recommends a range of 11–14 $GtCO_2eq$ which is also presented in the EC's latest Impact Assessment.

A carbon budget secures that the EU contributes with a fair share of reductions to solve the crisis. This indicative 2030–2050 GHG budget should be fully compatible with the Paris Agreement long term temperature goals of well below 2°C. However, the EU only contributes around 7 % to global emissions which means that contributions from the rest of the world in regard to carbon reductions is crucial to solve the crisis.

In calculating the carbon budget for the scenarios, intra-EU maritime transport and intra-EU aviation are included, aligning with ESABCC calculations. Additionally, international extra-EU maritime transport is included 100 % in the scenarios, though only 50 % of the related emissions are included in the EU climate budget. The reason for this approach is chosen, as carbon emissions from international extra-EU maritime cannot be subtracted due to high use of e-liquids not specified for any sectors. However, this may add some $CO_2$ emissions to the scenarios not accounted for in the budget given by the ESABCC.

**Technologies to achieve negative emissions are essential to meet the COP 21 objectives.**

68 See here

In Global Ambition the net cumulative emissions peaks around 2046 with around 14 Gt $CO_2$eq of net cumulative emissions. Renewable energy combined with CCS and LULUCF contributes to bending the curve and will lower the carbon budget to around 12.5 GT $CO_2$eq in 2050. Thus, the carbon budget for Global Ambition will end up in the lower range recommended by ESABCC. The carbon budget for GA is presented in Figure 46.

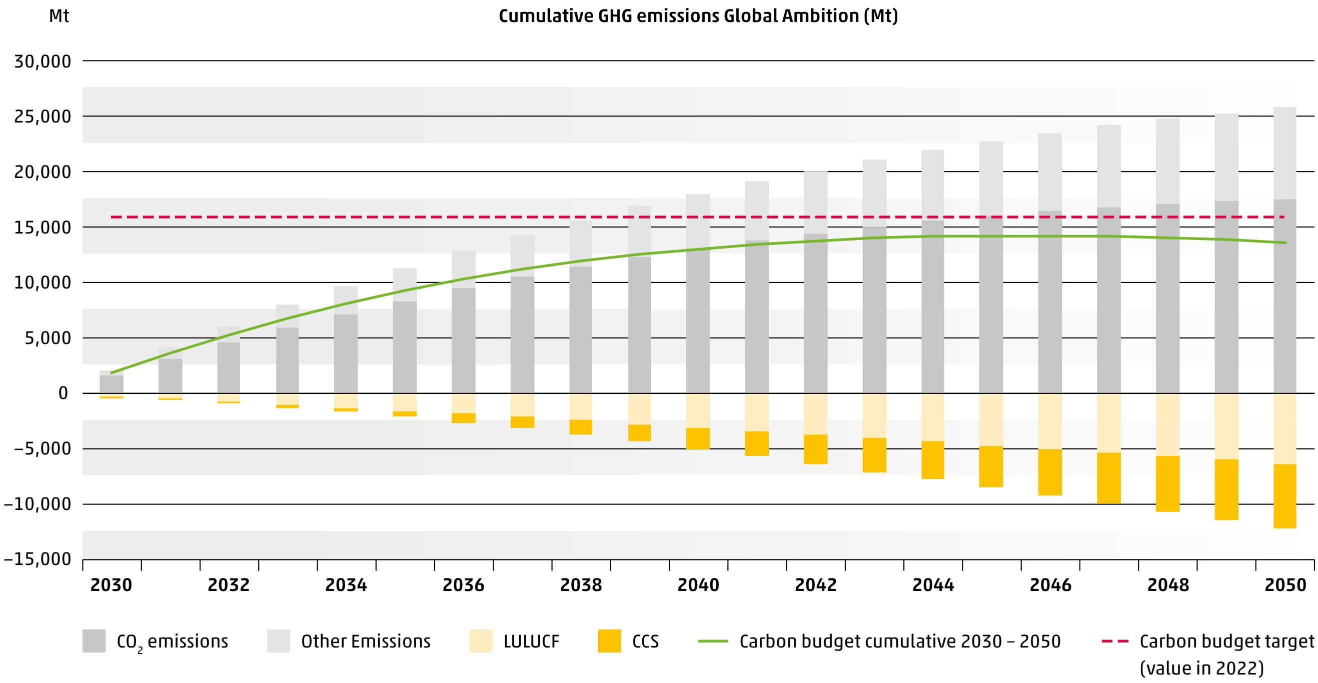


**Figure 46:** Cumulative emissions in the Global Ambition scenario

Distributed Energy shows higher cumulative emissions than GA and the net cumulative emission continue to rise until 2049. However, in 2050 it reaches net negative emissions. In 2050 the cumulative emissions are 15.917 Mt $CO_2$eq and thereby stays within the recommended budget. The carbon budget for DE is presented in Figure 47.

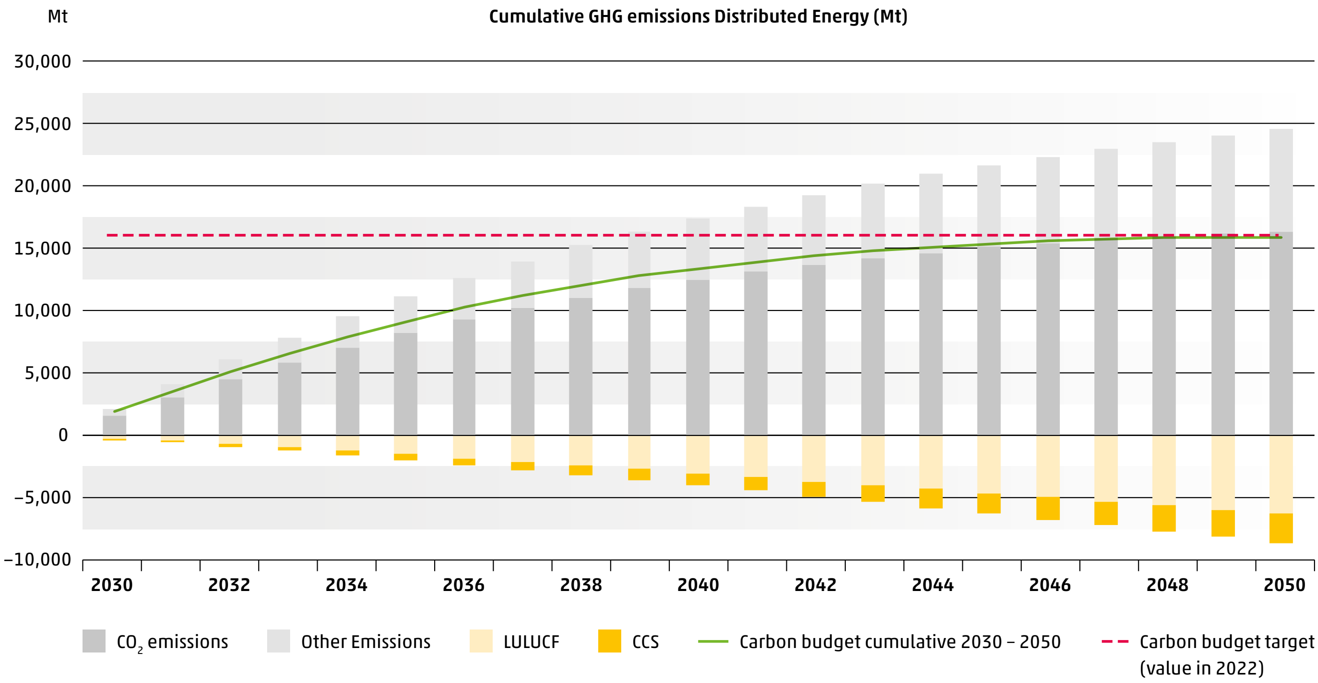


**Figure 47:** Cumulative emissions in the Distributed Energy scenario


## 8.2.3 Carbon footprint of energy

### Electricity generation

Aiming at an earlier decarbonisation, emissions of the electricity sectors already strongly decrease to reach 166 $MtCO_2$ in 2030 which is a decrease of 89 % compared respectively to 1990. In 2040 emissions of the deviation scenarios represent up to 15 $MtCO_2$ for the scenarios.

The decarbonisation of flexible thermal power generation necessary to the reliability of the system is ensured by a switch from natural gas, coal and oil to biomethane, synthetic methane, and renewable and low-carbon hydrogen. Such an approach is more economic than capital intensive investments in CCU/S for power generation due to the decreasing number of running hours. The emissions of electricity generation consider more conservative assumption[69] on the gas blend than the results indicate (see section 7.4.5). The difference on this assumption is normal, as the modelling took place before the final gas blend is calculated.

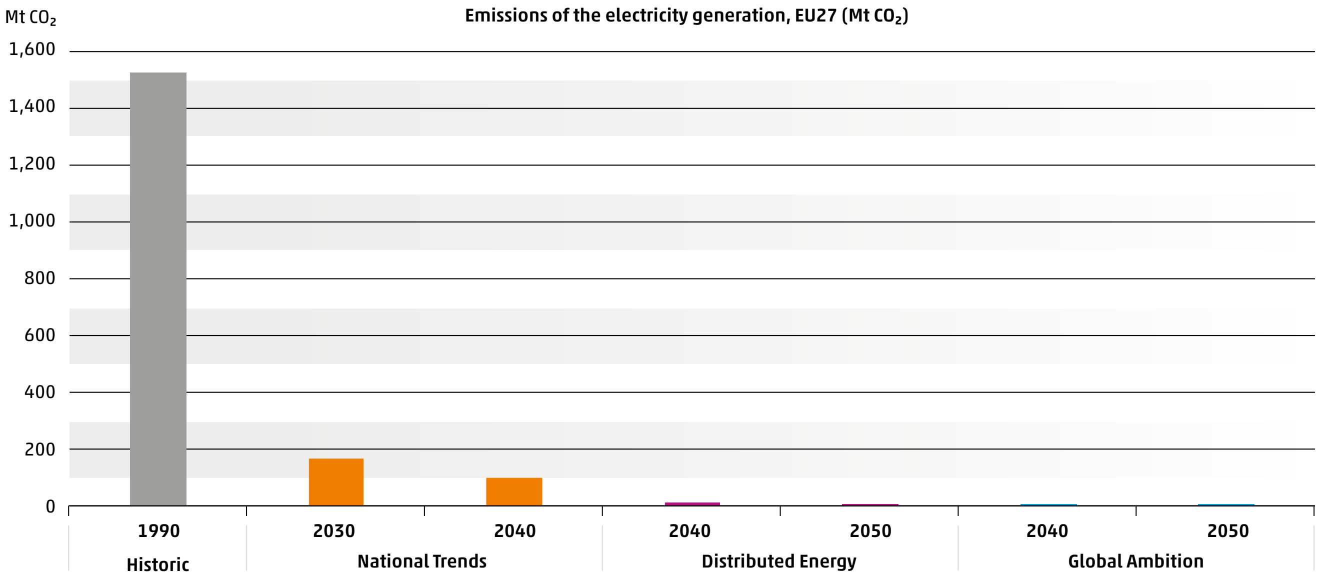


**Figure 48:** Emission of electricity generation for EU27

69 The assumptions on the gas blend are as following: In 2030, 90 % is natural gas. In 2040 76 %, 61 % and 67 % natural gas for National Trends, Distributed Energy and Global Ambition. In 2050, 5 % in Distributed Energy and 21 % in Global Ambition.

It must be noticed that such decrease occurs in parallel to a fast-growing power generation supporting both direct electrification and electrolysis-based fuels. As an illustration carbon intensity is significantly reduced between 2030 and 2040 moving from 46–3 $tCO_2$/MWh for Distributed Energy, the most electrified scenario. In 2050, carbon intensity of electricity is negligible with less than 0,5 $gCO_2$/kWh for both Distributed Energy and Global Ambition.

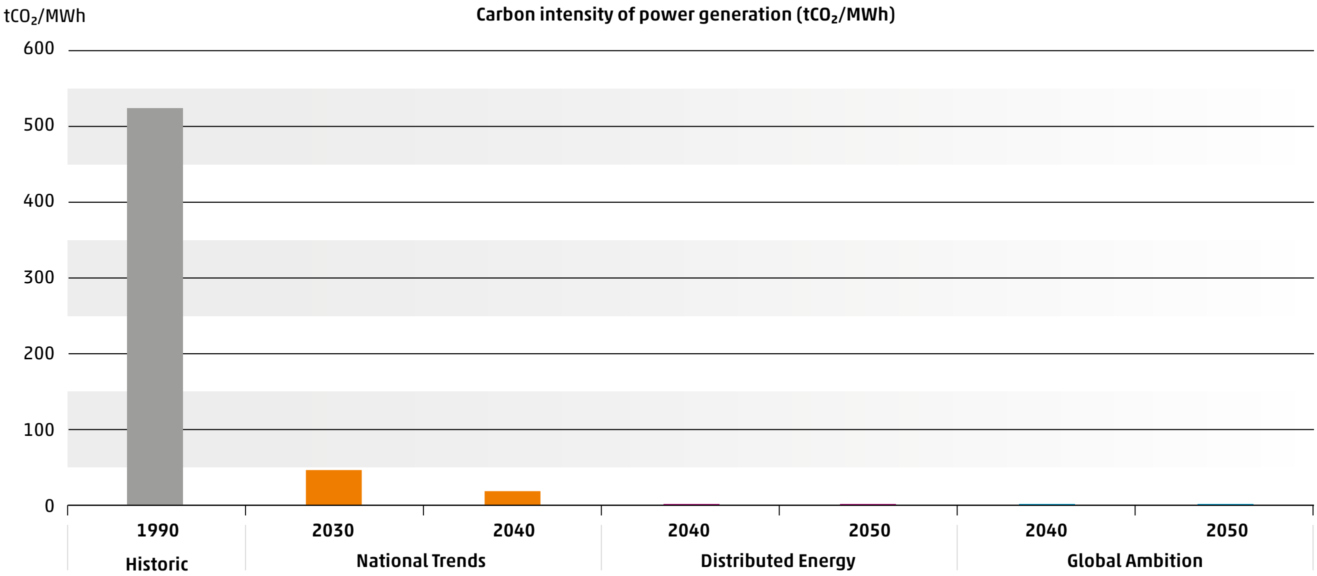


**Figure 49:** Carbon intensity of power generation for EU27

## Hydrogen Generation

Electrolysers are supplied both by dedicated RES and the electricity market. When the first source ensures a carbon free production of synthetic fuels, electrolysis from the market may still be based on carbon emitting sources. As the electricity and hydrogen system is price-driven, the model avoids running electrolyser if it triggers fossil power generation. Nevertheless, some must-run constraints up to 2030, minimum operation of CHP, hydrogen supply and demand requirement may result in electrolyser operating on few hours with a low carbon content. Such a situation may be considered as being favourable to the reach of carbon neutrality if the alternative would be more carbon intensive.

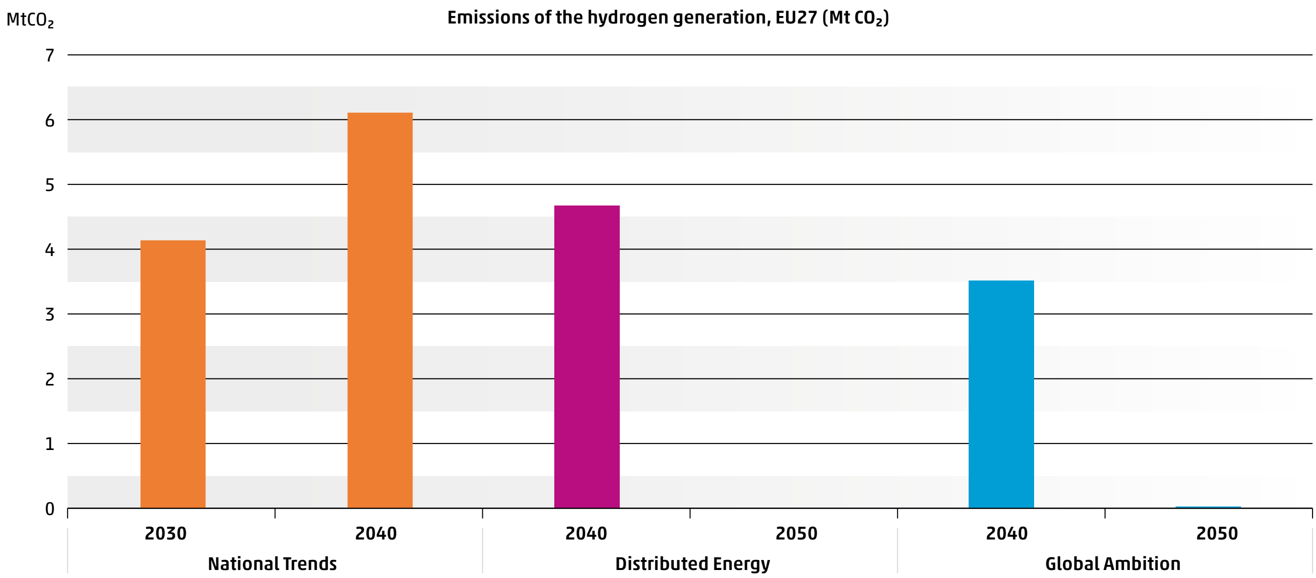


**Figure 50:** Emission of the hydrogen generation, EU27

## 8.3 Benchmark

### 8.3.1 Final energy demand

The following graph compares the Final Energy demand by fuel for the different scenarios.

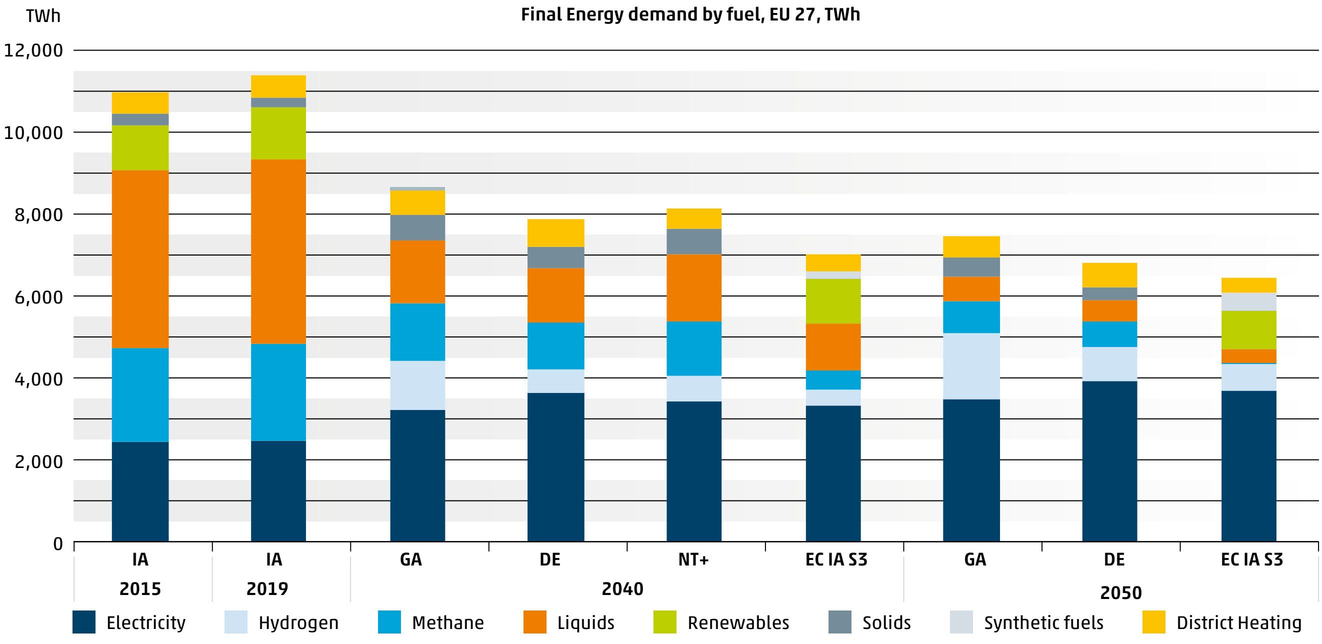


**Figure 51:** Benchmark Final Energy demand by fuel, EU27 (TWh)

- Final energy demand excludes non energy use, energy branch[70] and international shipping. Others include geothermal, industrial excess heat, power to gas excess heat and solar. Liquids includes only oil for 2015, 2019 and S3. Solids include coal for 2015, 2019 and S3, for DE, GA and NT+ solids include biomass as well.
- Ambient heat from district heating heat pumps is excluded for National Trends +
- Source for 2015 and 2019 is Impact Assessment study

### 8.3.2 Direct electricity demand

The following graph compares the electricity demand by sector for the different scenarios.

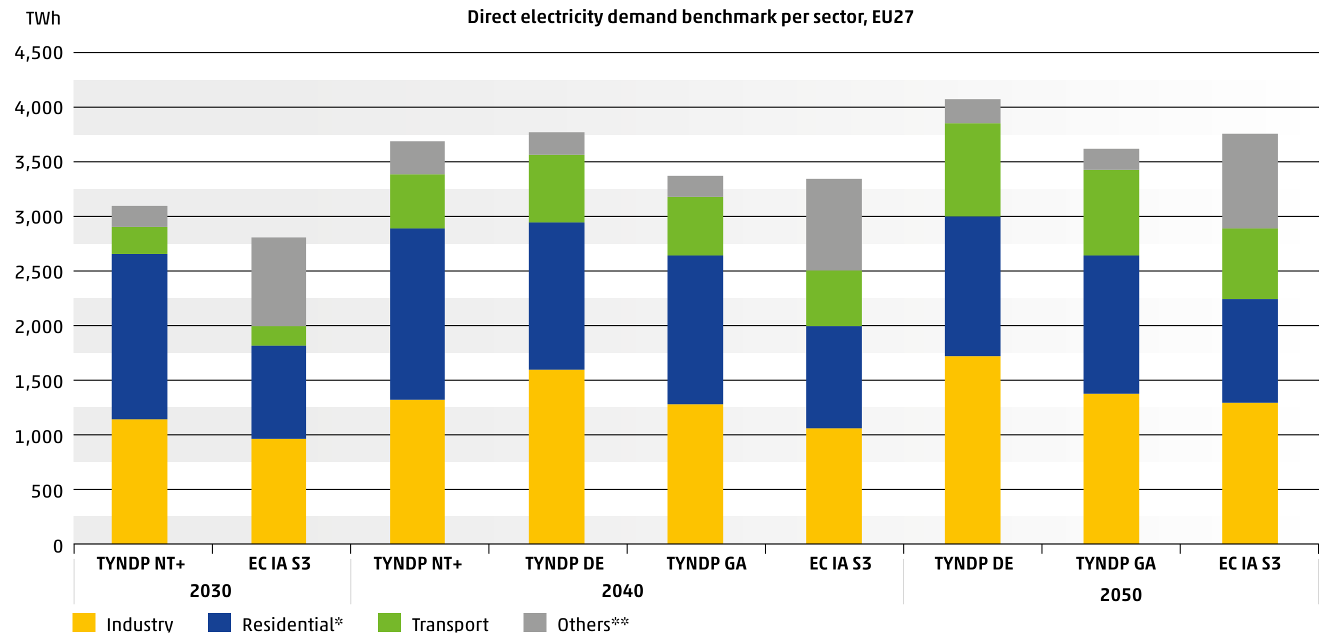


**Figure 52:** Final Electricity demand benchmark per sector, EU27 (TWh)

*Residential includes Residential and Tertiary sectors for TYNDP **Others for TYNDP includes agriculture and energy branch

70 Comparing with EC studies, for TYNDP part of energy branch is included in the industry sector.

### 8.3.3 Total methane demand

The following graph compares the methane demand by sector for the different scenarios.

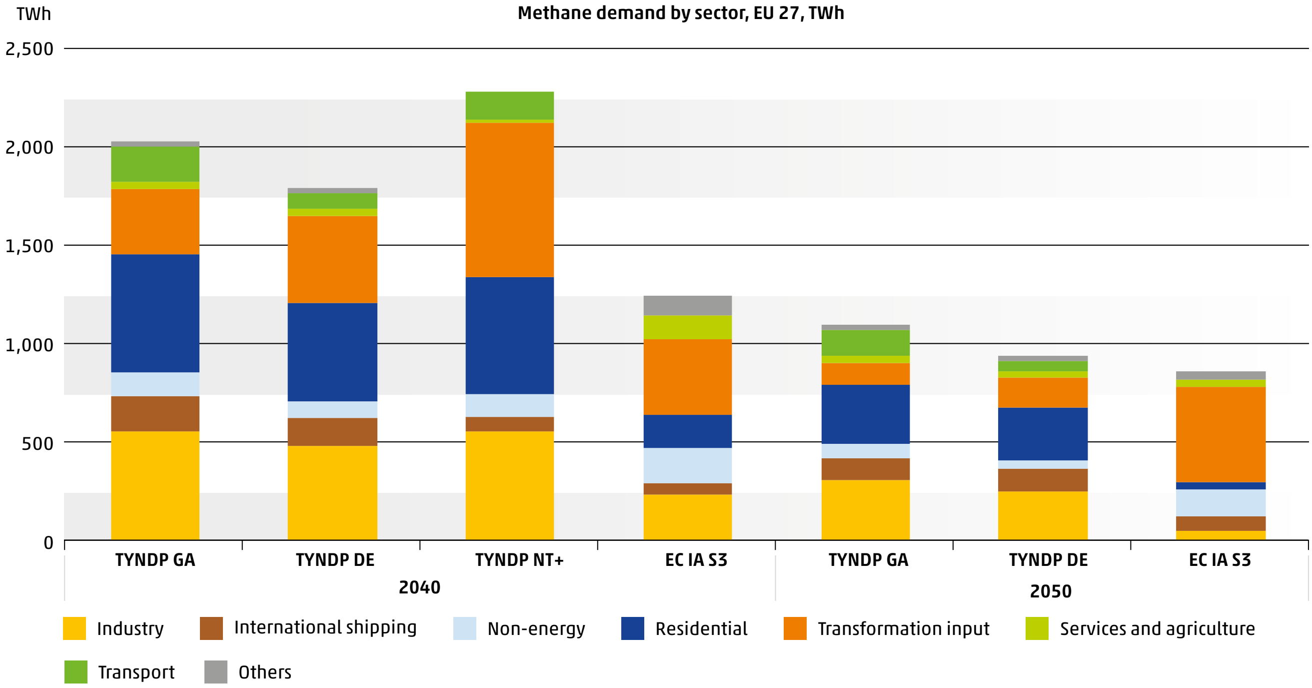


**Figure 53:** Benchmark Methane demand by sector, EU27 (TWh)

**Industry sector excludes non-energy use (reported as a separate category). For DE and GA, the industry sector includes refineries. For NT+, DE and GA Residential includes Residential and Tertiary sectors. Transport sector includes international aviation and excludes international shipping. For NT+, DE and GA the "Transformation input" includes electricity generation, heat production and SMR. For DE and GA, the "Other" category includes the construction sector, the army, the hydrological sector.**

### 8.3.4 Total hydrogen demand

The following graph compares the hydrogen demand by sector for the different scenarios.

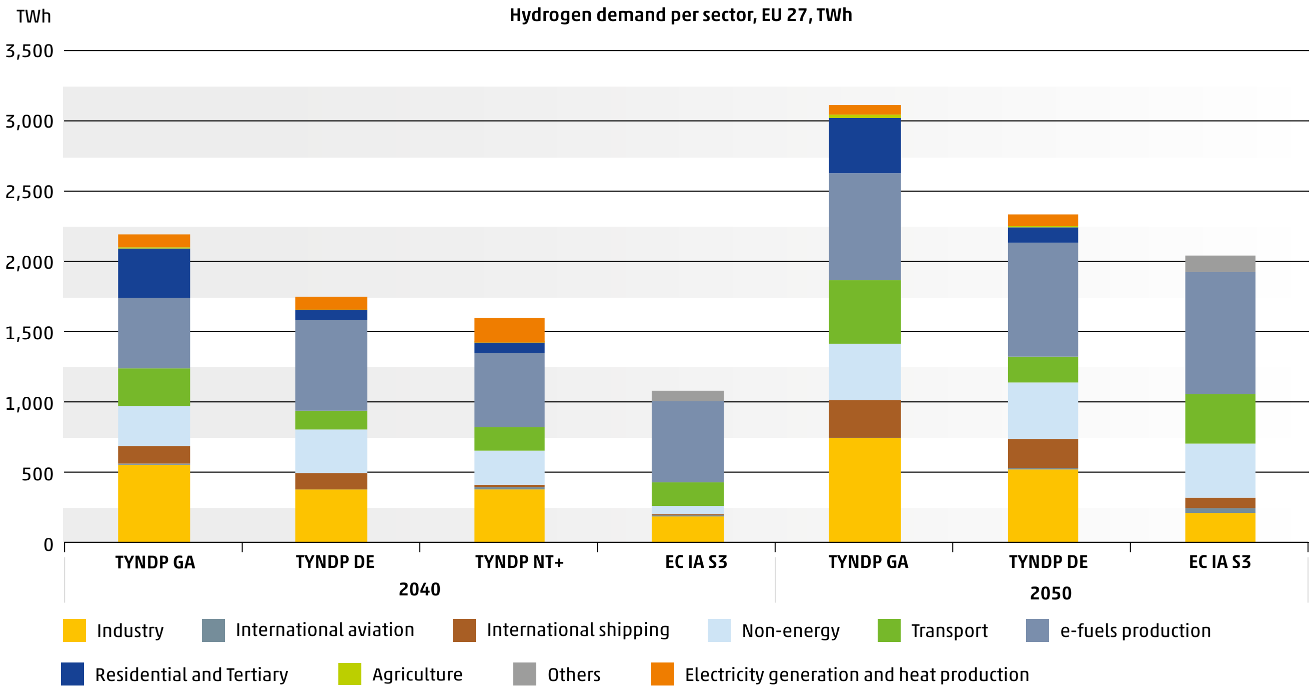


**Figure 54:** Benchmark Hydrogen demand by sector, EU27 (TWh)

**Industry sector excludes non-energy use (reported as a separate category). For DE and GA, the industry sector includes refineries. Transport excludes international aviation and international shipping (reported as separate categories). For DE and GA, the "Other" category includes the construction sector, the army, the hydrological sector.**

## Electricity generation

In 2050, the deviation scenarios consider a strong increase of both final electricity demand and electrolysis. By that time horizon, there will be hardly any fossil-based power generation to supply that demand. It means a redesign of the power generation mix with scenario dependent options being among wind and solar technologies or nuclear.

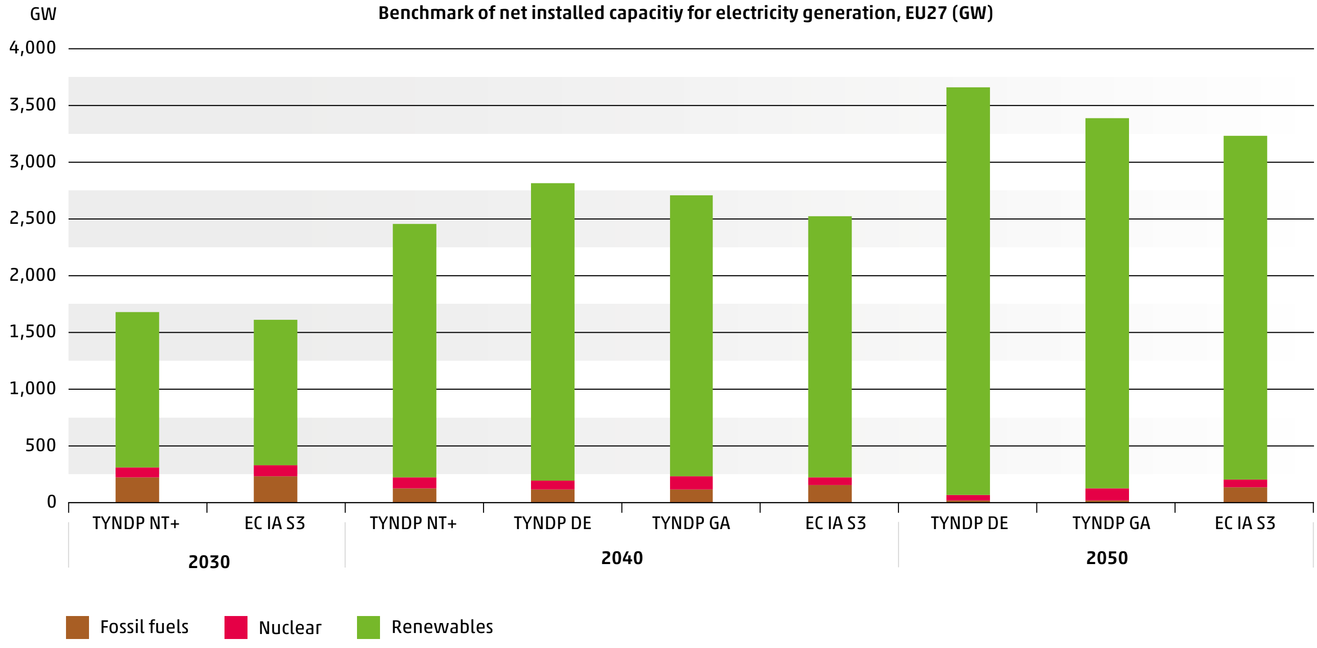


**Figure 55:** Benchmark of net installed capacity, EU27 (GW)[71]

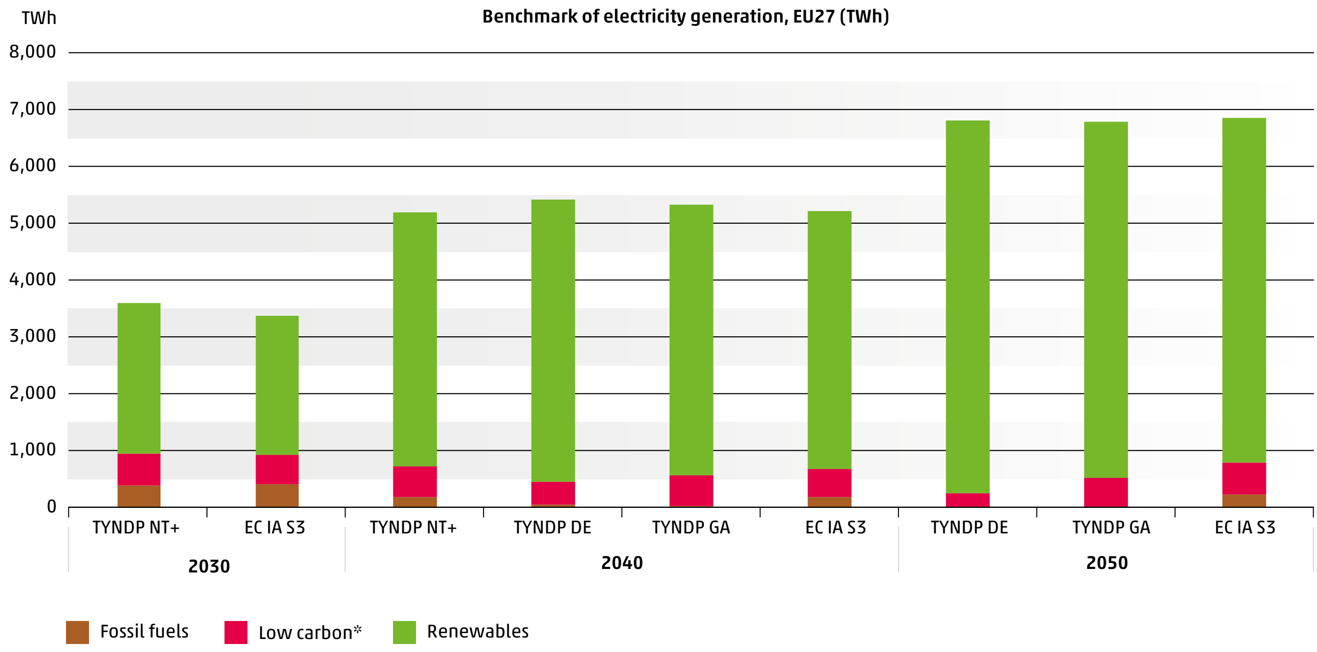


**Figure 56:** Benchmark of electricity generation, EU27 (TWh)

* Low carbon includes nuclear and decarbonised $H_2$

71 For TYNDP scenarios, installed capacities of hydrogen and methane are assigned to Renewables respectively Fossil fuels by the share of renewable respectively non-renewable fuel usage.

### 8.3.5 Methane supply

**Going to a 100 % decarbonisation of the methane supply in 2050.**

Both Distributed Energy and Global Ambition shows a reduction in the overall methane supply from 2040 to 2050. Both scenarios are substantially higher in supply of methane in 2040 and 2050 than the EC Impact Assessment. The data from the Impact Assessment is considered biomethane, biogas and natural gas common as gaseous fuels. Therefore, it is not possible to benchmark on the specific gas types

In Distributed Energy and Global Ambition, natural gas is completely phased out by 2050. In both scenarios the majority of the methane supply is biomethane produced in the EU. The rest is supplied by synthetic methane also mainly produced in the EU.

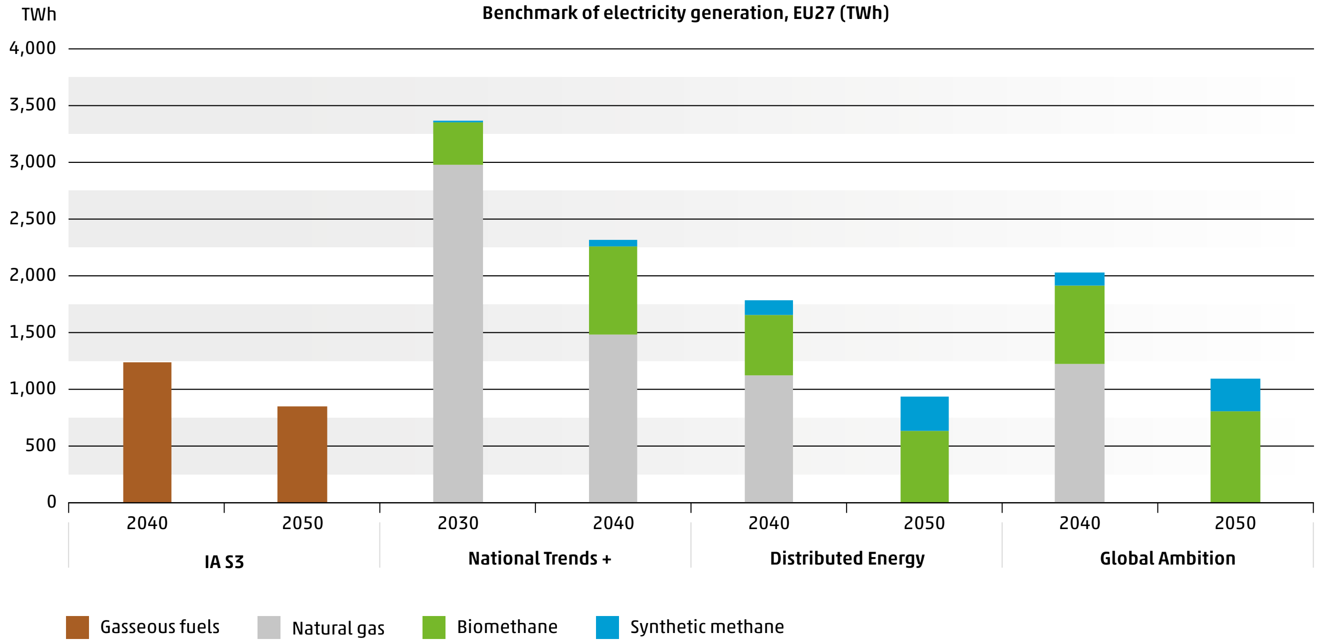


**Figure 57:** Methane supply benchmark, EU27 (TWh)

### 8.3.6 Hydrogen supply

**Hydrogen supply transformation: from carbon emitting feedstock to fully decarbonised energy carrier.**

All three scenarios consider hydrogen supply levels higher comparable to the EC Impact Assessment. By 2050, both TYNDP 2024 scenarios consider exclusively renewable or decarbonised hydrogen supply. Methane conversion into low carbon hydrogen through SMR/ATR combined with CCS has a minor role in Global Ambition and has fully disappeared in Distributed Energy. It leaves the possibility to use decarbonisation technologies with renewable methane to produce carbon negative hydrogen.

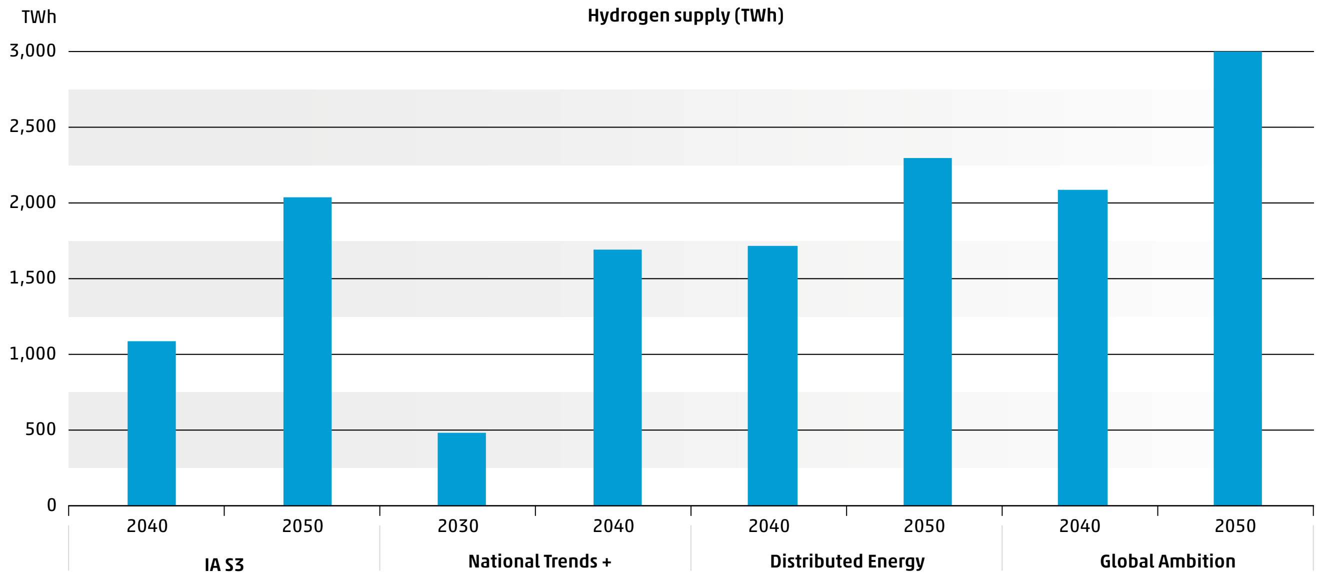


**Figure 58:** Hydrogen supply benchmark, EU27 (TWh)

### 8.3.7 Biomass supply

As discussed in chapter 7.4.2, the TYNDP 2024 scenarios foresee the use of biomass for several applications, e.g., in power generation or in biomethane production. In order to ensure that the scenarios do not overestimate the biomass potential available to these applications, ENTSOG and ENTSO-E benchmark the biomass supply against other studies.

Figure 59 provides a comparison of the TYNDP 2024 biomass supply assumptions against the EC Impact Assessment S3 scenario. The NT+ scenario shows a growing trend and the level in 2040 corresponds to the level in the EU IA in 2040. Both TYNPD 2024 deviation scenarios are below the level observed in the EC Impact Assessment scenarios S3 which have around 2.500 TWh in 2040 and around 2.200 TWh in 2050. DE has the lowest level around 1.500 TWh for both years and GA has around 2.000 TWh for both years.

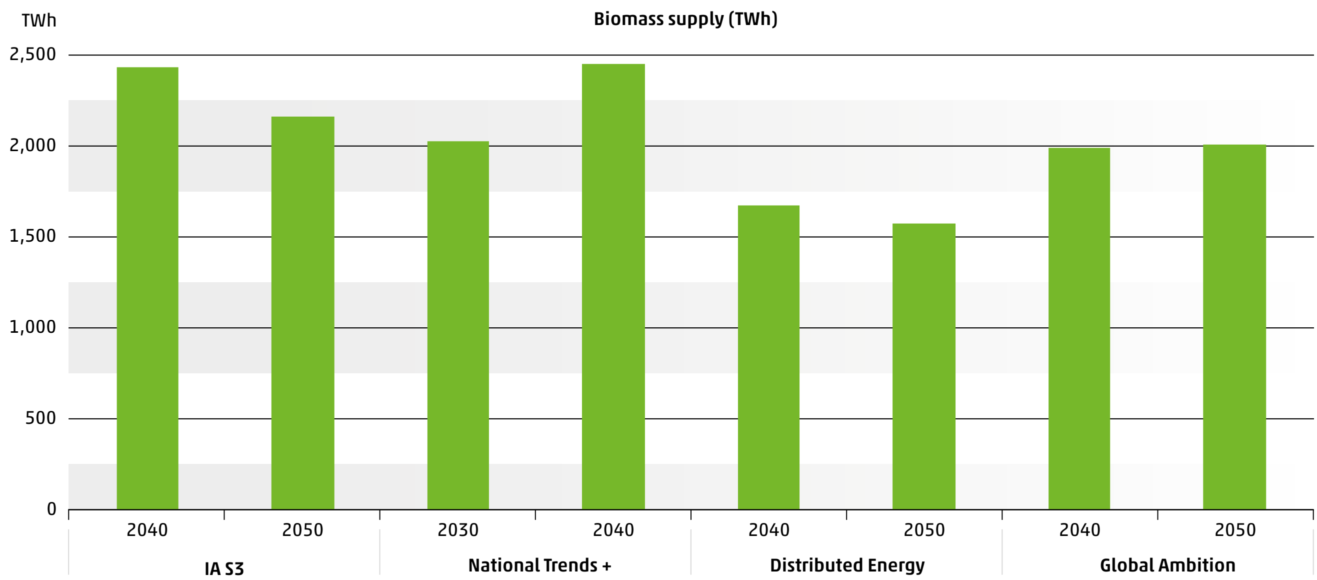


**Figure 59:** Biomass supply benchmark for EU27

### 8.3.8 Energy imports

Figure 60 compares the TYNDP 2024 assumptions on energy imports in 2040 and 2050 with draft scenario S3 in the EC Impact Assessment. The Values for NT+ is shown as well for 2030 and 2040.

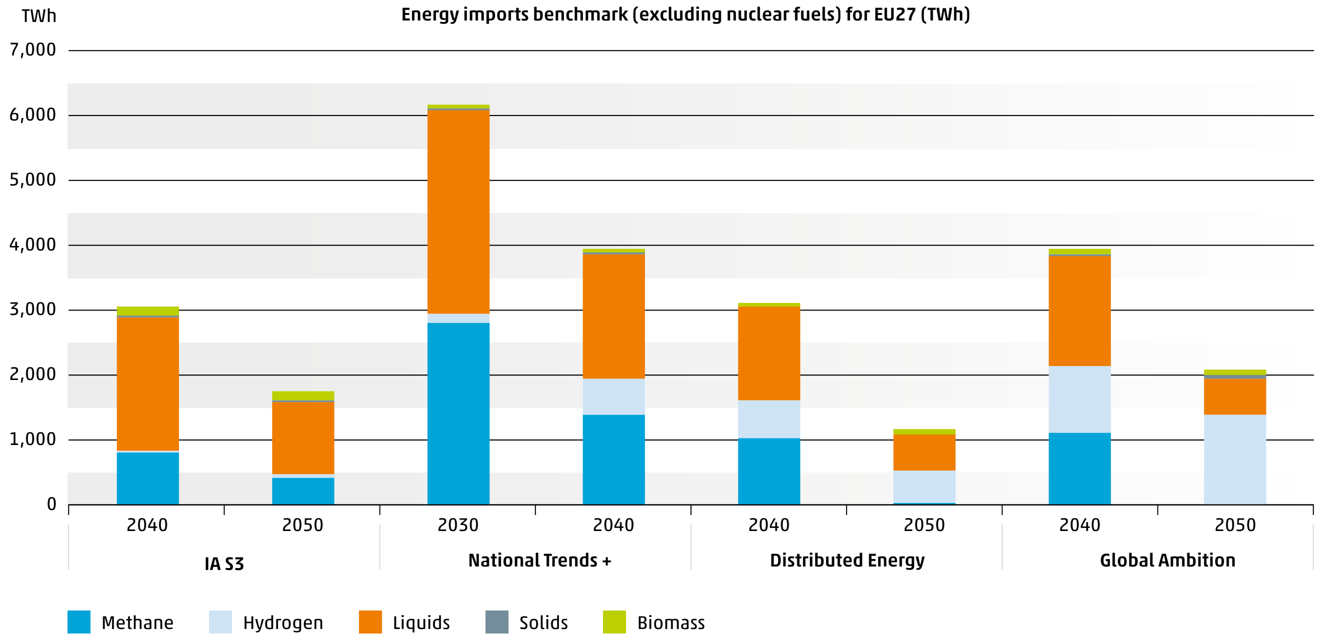


**Figure 60:** Energy imports benchmark (excluding nuclear fuels) for EU27

As Distributed Energy focuses on higher European energy autonomy, this scenario foresees the lowest levels of energy import. By 2050 the total energy imports are reduced to around 1,200 TWh. This is well below the energy imports in the EC Impact Assessment scenarios S3 were 1,761 TWh is imported. Total energy import in Global Ambition is around 2,000 TWh and thereby foresees the highest imports of the three. Besides differences in the total energy imports, the type of imported energy carriers differs significantly. Compared to the EC scenarios, Global Ambition and Distributed Energy foresees less import of oil, almost no import of gas, but a substantially higher imports of hydrogen. Where in the EC impact scenarios almost no hydrogen is imported (15 TWh in 2040 and 41 TWh in 2050) hydrogen imports are a significantly and important energy source in the two deviation scenarios. DE has around 600 TWh imports in 2040 and 546 in 2050, whereas GA foresees around 1,000 TWh in 2040 and 1,372 TWh in 2050.

# 9 NEXT STEPS //

## The next steps are the following:

- The updated scenarios report feed into the TYNDP 2024 development process. The electricity and gas draft TYNDPs are expected to be published in Q4 2024 for public consultation.
- Within three months of receipt of the draft joint scenarios report together with the input received in the consultation process and a report on how it was taken into account, the Agency shall submit its opinion on compliance of the scenarios with the framework guidelines referred to in paragraph 1, first subparagraph, including possible recommendations for amendments, to the ENTSO for Electricity, ENTSO for gas, Member States and the Commission.
- Within three months of receipt of the opinion referred to in paragraph 5, the Commission taking into account the opinions of the Agency and Member States shall approve the draft joint scenarios report or request the ENTSO for Electricity and the ENTSO for Gas to amend it.
- Within two weeks of the approval of the joint scenarios report in accordance with paragraph 6, the ENTSO for Electricity and the ENTSO for Gas shall publish it on their websites.
- Both TYNDPs will support the 7th PCI selection process.

## In the meantime, ENTSO-E and ENTSOG will work together to develop TYNDP 2026 Scenarios.


SWISSGAS

# ANNEX 1 //

## Stakeholder Consultation Input

TYNDP 2024 Scenarios Input Data – Public Consultation Summary Report (PDF, 320 KB)

Annex 1: TYNDP 2024 Scenarios Input Data – Public Consultation All answers received (Excel, 192 KB)

SRG feedback on the preliminary 2024 TYNDP Scenarios results (PDF, 924 KB)

# ANNEX 2 //

## Spanish NT Hydrogen Supply Figures provided by Enagás

### DRES

| | 2030 | | | 2040 | | |
|---|---|---|---|---|---|---|
| | DEDICATED WIND | DEDICATED SOLAR | TOTAL | DEDICATED WIND | DEDICATED SOLAR | TOTAL |
| MIX | 40 % | 60 % | | 40% | 60% | |
| HOURS | 2,400 hours | 1,800 hours | **2,040 hours** | 2,400 hours | 1,800 hours | **2,040 hours** |
| POWER | 14.56 GW | 21.83 GW | **36.4 GW** | 37.23 GW | 55.85 GW | **93.1 GW** |
| ELECTRICITY SUPPLY | 35 TWh | 39 TWh | **74 TWh** | 89 TWh | 100 TWh | **189 TWh** |

### Off-grid electrolysers

| | 2030 | | 2040 | |
|---|---|---|---|---|
| IN | 3,500 hours | 14.8 GW | 3,500 hours | 38.0 GW |
| OUT | 5,000 hours | 10.4 GW | 5,000 hours | 26.6 GW |

### Batteries and $H_2$ Production

| | 2030 | 2040 |
|---|---|---|
| BATTERIES | 7.6 GWh | 19.6 GWh |
| $H_2$ | 52 TWh (1.56 Mt) | 133 TWh (3.99 Mt) |

# ANNEX 3 //

## SRG feedback to the TYNDP 2024 scenario cycle

| CATEGORY | RECOMMENDATIONS FROM SRG | RESPONSE FROM ENTSO-E AND ENTSOG |
| --- | --- | --- |
| COMPARABILITY WITH EUROPEAN COMMISSION'S SCENARIOS AND OUTPUT MODEL | Provide key energy indicators for EU27 as in the EC's impact assessment | Several chapters of the scenarios report and the methodology report have been extended to adress the request by SRG. |
| COMPARABILITY WITH EUROPEAN COMMISSION'S SCENARIOS AND OUTPUT MODEL | Ensure metrics like final energy consumption, gross available energy, primary energy consumption, GHG emissions for EU27 are available in the scenario results. | Several chapters of the scenarios report and the methodology report have been extended to adress the request by SRG. |
| ACCESSIBILITY | SRG recommends developing ways to provide key information publicly in an integrated manner. For each scenario to assist in evaluation of infrastructural choices, alongside energy infrastructure, EC 2040 energy and climate objectives, assumed emission pathways, and +1.5 °C compatibility can be presented in compact fashion. | Several chapters of the scenarios report and the methodology report have been extended to adress the request by SRG. |
| MODELLING APPROACH | Even if each country is only one node, the information on the annual and hourly numbers shall be split into distribution and transmission in gas, electricity and hydrogen. | The gas system is not explicitly modelled in the market models of TYNDP2024. For electricity, the transmission/distribution split is to some extent revealed by the eMarket/RETE split. For hydrogen, however, such a split is not available at this stage and would require updates on the model side that would not fit into the timeline. |
| DEMAND – HOUSEHOLDS – DE | The data shall be checked. Even if the demand figures are frozen, errors should be corrected. The ramp-up of heat pumps in the first 10 years in some countries may be unrealistic if 2019 and 2023 are too far off. The impact on the planning would be significant. | Will be checked with Quintel to fix the reference year value. Due to time challenges, the fix on the datasets is not possible for the TYNDP 2024 cycle but planned for the TYNDP 2026 scenario cycle. |
| DEMAND – NON-RESIDENTIAL BUILDINGS | The data needs to be checked. Even if the demand figures are frozen errors should be corrected. | Will be checked with Quintel to fix the reference year value. Due to time challenges, the fix on the datasets is not possible for the TYNDP 2024 cycle but planned for the TYNDP 2026 scenario cycle. |
| IMPORT PRICES | Prices for ammonia imports shall be amended to better reflect the additional transport and conversion costs, which are clearly higher than those associated with pipeline transport. | The consulted prices for ammonia includes reconversion and transport cost of amonia. The prices are based on the EWI tool calculation.<br><br>The EWI tool uses public available sources and is transperant in the way it calculate the prices. Other sources has been considered during the process, but the EWI source was found the best due to its tranparency in sources and calculation. |
| SENSITIVITY WITH $H_2$ COSTS | As the prices setting mechanism for hydrogen is one of the most relevant parameters for the simulation, a sensitivity is needed. The SRG will provide a proposal for the price setting. | As it is discussed in the recent SRG meetings, the suggestion will be a basis rather for the TYNDP 2026 cycle. More information on the proposal and the timeline is required (to be align with ERAA 2024). |

| CATEGORY | RECOMMENDATIONS FROM SRG | RESPONSE FROM ENTSO-E AND ENTSOG |
|---|---|---|
| **COMMODITY PRICES** | **We propose that the TYNDP 2024 uses the commodity price projections provided by the European Commission.** | For TYNDP 2024, the recommended source was IEA, 2022 as it was only publicly available source that could provide prices for all commodities & $CO_2$. Whereas, for the EC prices, the associated $CO_2$ prices are not available. Therefore, as explained in our consultation summary response, we used IEA prices for the NT+ 2030 & 2040 scenarios, which has been finalised. We recommend using the IEA to ensure consistency between scenarios and also commodities & $CO_2$ prices. |
| **DEMAND RESPONSE** | **If demand response is used in the simulation in a relevant amount, the parameters should be delivered to the SRG. A sensitivity should be calculated as in demand response the end user decided whether it delivers, and not the TSO. And the demand response plant has to be in an operations state to ramp up and down which has to be taken into account (because of multiple factors, such as: holidays, strikes, crisis like Covid, etc.).** | Demand response is modelled as a regular electricity generator that can be activated at a given price and within a given volume range, assuming they are fully flexible. This information exists in the PEMMDB files per country. The activation of these units depends on price only (and therefore it is in the best interest of the user to activate it at high electricity prices) and it is difficult to integrate into the 2024 models any other consideration that would shift the response from users to the TSOs. |
| **BATTERIES AND EV'S** | **We recommend the modelling driving battery expansion is double checked, as it seems unlikely that the two scenarios would have the same resulting battery capacity in all timesteps.** | Will be taken into account for the TYNDP 2026 scenario cycle. |
| **DISTRICT HEATING** | **Mention already any possible limitations of heat profiles, in case not shown. Check the heat planning and supply calculation, what the reason for the high amount of waste heat is, how the heat is produced, and whether technology and temperature of the heating grid fit together.** | Will be taken into account for the TYNDP 2026 scenario cycle. |

# LIST OF FIGURES //

# LIST OF TABLES //

# GLOSSARY //

**Biomethane:** Gaseous renewable energy source derived from agricultural biomass (dedicated crops, by-products and agricultural waste and animal waste), agro-industrial (waste from the food processing chain) and the Organic Fraction Municipal Solid Waste (OFMSW).

**BEV:** Battery electric vehicle

**Carbon budget:** This is the amount of carbon dioxide the world can emit while still having a likely chance of limiting average global temperature rise to 1.5°C above pre-industrial levels, an internationally agreed-upon target.

**CBA:** Cost Benefit Analysis carried out to define to what extent a project is worthwhile from a social perspective.

**CCS:** Carbon Capture and Storage. Process of sequestrating $CO_2$ and storing it in such a way that it won't enter the atmosphere.

**CHP:** Combined heat and power

**Direct electrification:** Electricity demand for direct use in the final demand sectors (residential, tertiary, industry etc). Electricity which is converted to other energy carriers through power to gas or power to liquids is referred to as indirect electrification.

**DSR:** Demand Side Response. Consumers have an active role in the balancing of energy supply and demand by changing their energy consumption according to the energy price and availability. For example, by softening demand peaks in case of congestions, or by increasing energy use during surplus supply.

**EC:** European Commission

**EED:** EU Energy Efficiency Directive

**ERAA:** The ERAA is a pan-European monitoring assessment of power system resource adequacy of up to 10 years ahead.

**ETM:** Energy Transition Model

**EV:** Electric vehicle

**FCEV:** Fuel cell electric vehicle

**GHG:** Greenhouse gas

**Hybrid Heat Pump:** heating system that combines an electric heat pump with a gas condensing boiler to optimise energy efficiency.

**IA:** Impact Assessment released by the European Commission on 17 September 2020: Communication COM/2020/562: Stepping up Europe's 2030 climate ambition Investing in a climate-neutral future for the benefit of our people

**ICE:** Internal combustion engine

**IEA:** World Energy Outlook

**IPCC:** Intergovernmental Panel on Climate Change

**LNG:** Liquefied natural gas

**LTS:** Long Term Strategy released by the European Commission on 28 November 2018: A Clean Planet for all. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy.

**LULUCF:** Land Use, Land Use Change and Forestry. Sink of $CO_2$ made possible by the fact that atmospheric $CO_2$ can accumulate as carbon in vegetation and soils in terrestrial ecosystems.

**NECPs:** National Energy and Climate Plans are the new framework within which EU Member States have to plan, in an integrated manner, their climate and energy objectives, targets, policies and measures to the European Commission. Countries will have to develop NECPs on a ten-year rolling basis, with an update halfway through the implementation period. The NECPs covering the first period from 2021 to 2030 will have to ensure that the Union's 2030 targets for greenhouse gas emission reductions, renewable energy, energy efficiency and electricity interconnection are met.

**NGO:** Non-governmental Organisation

**OR:** Other RES. It includes bio-fuels, marine, geothermal, waste, and any other small renewable technologies. The $CO_2$ content of these technologies are zero; they are carbon neutral.

**ONR:** Other non-RES. It includes mainly CHP that is used in district heating & industry. Fuel use can be gas, coal, lignite, and oil. The $CO_2$ content of ONR technologies depending on the technology and have been considered into the $CO_2$ budget.

**P2G:** Power to gas. Technology that uses electricity to produce hydrogen (Power to Hydrogen – $P2H_2$) by splitting water into oxygen and hydrogen (electrolysis). The hydrogen produced can then either be used directly or indirectly to produce other fuels, where it is combined with $CO_2$ to obtain synthetic methane (Power to Methane – $P2CH_4$) or can be converted to other energy carriers like for example synthetic ammonia ($P2NH_3$).

**P2L:** Power to liquids. Combination of hydrogen from electrolysis and Fischer-Tropsch process to obtain synthetic liquid fuels.

**PCI:** Project of Common Interest

**Power-to-Hydrogen/P2Hydrogen:** Hydrogen obtained from $P2H_2$.

**Power-to-Methane/P2Methane:** Renewable methane, could be biomethane or synthetic methane produced by renewable energy sources only.

**RES:** Renewable energy source

**SMR/ATR:** Steam methane reforming (SMR) and Autothermal reforming (ATR) represent each an industrial process to produce hydrogen with natural gas. Can be outfitted with carbon capture technologies

**SRG:** Stakeholder Reference Group. The SRG is meant to provide expert input to the development of scenarios by ENTSO-E and ENTSOG in accordance with the scenario development timeline.

**Synthetic fuel:** Fuel (gas or liquid) that is produced from renewable or low carbon electrical energy.

**TEN-E:** Trans-European Networks for Energy, EU policy focused on linking the energy infrastructure of EU countries

**TSO:** Transmission System Operator

**TYNDP:** Ten-Year Network Development Plan

# IMPRINT //

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