

TYNDP 2022

SCENARIOS FINAL STORYLINE REPORT



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1

Introduction to TYNDP 2022 Scenarios

What is this report about?

Regulation (EU) 347/2013 requires that the ENTSO-E and ENTSOG use scenarios for their respective Ten-Year Network Development Plans (TYNDPs) 2022. The development of the scenarios marks the first step in the TYNDP 2022 process. Defining the scenarios in turn begins with the development of the (qualitative) storylines to be explored. In a webinar on 3 July 2020 ENTSOG and ENTSO-E presented their first ideas for the TYNDP 2022 storylines. Several stakeholders provided comments and feedback. On 3 November 2020 ENTSOG and ENTSO-E published a draft storyline report for the scenarios to be included in TYNDP 2022. This draft storyline report proposes the scenario framework for TYNDP 2022, consisting of one national policy scenario and the storyline development of two top-down scenarios.

The draft storyline report was consulted with stakeholders in a public consultation from 3 November to 15 December 2020. During the public consultations ENTSOG and ENTSO-E received some valuable feedback from a wide variety of stakeholders. We used this feedback to adapt the storyline report and provide additional information requested by stakeholders. The result is captured in this final and definitive storyline report.

The storylines captured in this final storyline report are the foundation of the scenario building quantification phase that ENTSOG and ENTSO-E will perform later this year. This modelling will result in full energy scenarios including accompanying datasets which will be consulted in the Summer of 2021.

Why do ENTSOG and ENTSO-E build scenarios together?

Joint scenarios are a key step towards an interlinked approach to energy system analysis. Joint scenarios allow ENTSO-E and ENTSOG to undertake infrastructure analysis from a common and consistent set of assumptions and data. The TYNDP 2018 was the first time ENTSOG and ENTSO-E cooperated on scenario development. For the TYNDP 2020 the scenario building process was further expanded and improved. Since there are strong synergies and co-dependencies between gas and electricity infrastructures, it is increasingly important to understand the impact of European policies that aim to achieve a carbon-neutral European energy system by 2050.

Joint scenarios allow ENTSOG and ENTSO-E to assess future infrastructure needs and projects against the same

future outlooks. The TYNDP 2022 scenarios go beyond the EU-27 to the ENTSO-E & ENTSOG perimeters, which includes members, observers and associated partners. In total over 80 participants, covering more than 35 countries, are directly involved in the process. Gas and electricity TSOs incorporate the technical knowledge and experience to provide both quantitative and European focused scenarios that demonstrate how the energy transition will impact the European electricity and gas systems; along with an assessment of the challenges for the long-term horizon.

The outcome of the joint scenario development process provides decision makers with important information, as they seek to make informed choices that will benefit all European consumers. Combining the efforts from

gas and electricity TSOs offers ENTSOG and ENTSO-E an opportunity to leverage cross-sectorial and country specific knowledge and expertise that would otherwise be missing. Joint working provides access to a broader range of stakeholders who are actively participating in the energy sector. The scenario building process for TYNDP

2022 builds on the work from previous editions and aims to continually improve the overall quality, level of detail and transparency. The purpose is to grant stakeholders access and enable the use of scenario data to understand what is required to deliver a cleaner and better energy system for everyone of Europe.

What is the goal of the TYNDP scenarios and their storylines?

As outlined in Regulation (EU) 347/2013, ENTSOG and ENTSO-E are required to use scenarios as the basis for the official TYNDP (created every two years by ENTSO-E and ENTSOG) and also for the calculation of the Cost-Benefit Analysis (CBA) used as an input to assess EU electricity and gas infrastructure Projects of Common Interest (PCI). ENTSOG and ENTSO-E design their scenarios specifically for this purpose. The scenarios are intended to project the long-term energy supply and demand considering the ongoing energy transition. Furthermore, the scenarios draw extensively on the current political and economic consensus and attempt to follow a logical trajectory to achieve future energy and climate targets.

The scenarios and their storylines are designed to reflect the EU and national policy goals and strategies, including the Energy Efficiency First principle, such that they specifically explore the uncertainties that are relevant to the development of gas and electricity infrastructure. As such, they primarily focus on aspects which determine infrastructure utilisation. The differences between the scenario storylines are therefore predominantly related to possible variations in demand and supply patterns. To this end, all the scenarios developed within the TYNDP 2022 framework remain technology, source and energy-carrier neutral.

What is new in the TYNDP 2022 storyline report?

The previous storyline report for TYNDP 2020 was limited to descriptive (qualitative) information only. Due to a lack of quantitative figures some stakeholder found it challenging to comment on the proposed storylines. Based on this feedback the storyline report for TYNDP 2022 now incorporates quantitative ranges for some of the key storyline parameters. These ranges can be found in chapter 5 and illustrate how the storylines differ from one another. It should be noted however that a full dataset can only be provided after the scenario modelling has been performed.

In the public consultation of the TYNDP 2020 scenario report several stakeholders also perceived a lack of differ-

entiation between the scenarios. Although this concern was addressed in the final scenario report published in June 2020, ENTSOG and ENTSO-E aim to further improve this for the next edition. The joint Working Group Scenario Building (WGSB) extensively analysed the main scenario drivers to be explored in the storylines in order to ensure appropriately differentiated TYNDP 2022 scenarios. More details are provided in chapter 4.

Several adaptations were considered in this final storyline report compared to the draft report released in November 2020. More information on the update compared to the draft can be found in chapter 6.

Where do we stand today in the scenario development process?

The scenario storylines are the first step in the scenario building process. A more detailed description of the complete process can be found in Chapter 7.

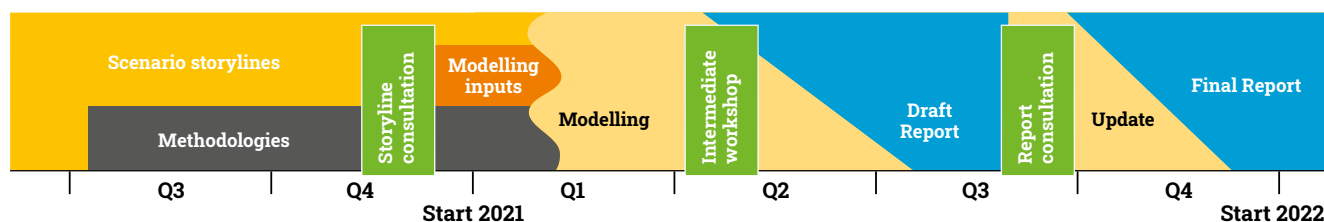


Figure 1: Scenario building process



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Scenario framework and consultation scope

Scenarios will cover different time horizons

The scenario building process for the TYNDP 2022 builds on the work of previous editions. The TYNDP process has shown that scenarios have to combine different expectations along their time horizon: supporting infrastructure project assessment, analyzing investment needs or illustrating the shape of prospective energy systems. In parallel there is an expectation that the short term time horizon reflects existing trends and legislation, while long-term

scenarios should be compliant with the EU policy goals, including the European Green Deal and the Paris Agreement endorsed by the EU and all Member States¹.

Figure 2 illustrates how ENTSO-E and ENTSOG plan to cover the different time horizons in their scenarios for TYNDP 2022. This approach is quite similar to the TYNDP 2020 scenarios.

¹ EU climate action and the European Green Deal, [link](#)

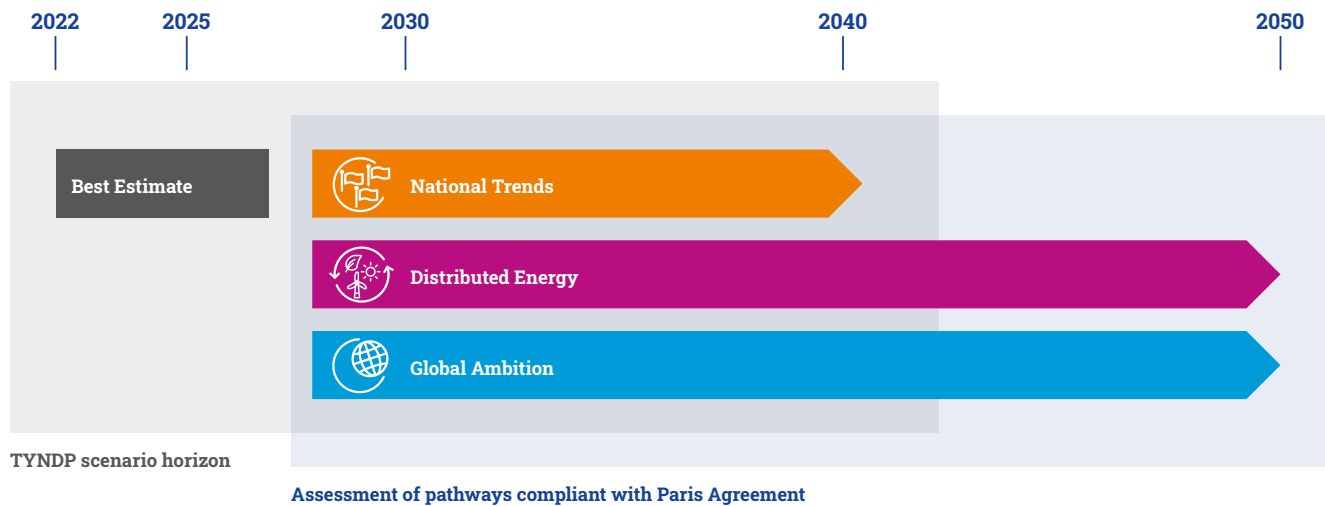


Figure 2: TYNDP Scenario horizon and framework

For both 2022 and 2025 a “Best Estimate” scenario will be developed. For the quantification of this time horizon ENTSO-G and ENTSO-E will use bottom-up data from the TSOs. These figures reflect current national and European regulations as stated end of 2020. Additionally, the replacement of coal by gas based power generation will be simulated as a sensitivity for 2025.

The longer term goals, starting from 2030, will be covered by three different scenarios, reflecting increasing uncertainties towards 2050.

- National Trends will be the scenario in line with national energy and climate policies (NECPs², national long-term strategies³, hydrogen strategies ...) derived from the European targets. The electricity and gas datasets for this scenario will be based on figures collected from the

TSOs translating the latest policy- and market-driven developments as discussed at national level. The quantification of National Trends will focus on electricity and gas up to (at least) 2040. ENTSO-G and ENTSO-E invite the reader to refer to the national documents to have an energy-wide perspective;

- In addition to the National Trends scenario, which is aligned with national policies, ENTSO-G and ENTSO-E will develop two top-down scenarios. These will be built as full energy scenarios (all sectors, all energy carriers) in order to quantify compliance with EU policies and climate ambitions. Both scenarios aim at reaching the 1.5 °C target of the Paris Agreement following the carbon budget approach⁴. They are developed on a country-level until 2040 and on an EU27-level until 2050.

Scope of this final storyline report

The Best Estimate and National Trends scenarios have a strong country-specific narrative that provides insight into the evolving policies and market developments for each area. This is also in line with the legal requirements that the dataset shall reflect European Union and Member State national law in force at the date of analysis (Regulation (EU) 347/2013, Annex V, point 2) and furthermore, conforms with provisions stated in (EC) No 714/2009 and (EC) NO 715/2009, Article 8 point 10.

The assumptions used in the Best Estimate and National Trends scenarios are already being discussed on a national

level. That is why ENTSO-G and ENTSO-E do not have to develop or consult specific scenario storylines for Best Estimate and National Trends themselves. Instead, the ENTSO-G and ENTSO-E will provide details on the data sources per country as part of the draft scenario report due to be published mid-2021. The two top down scenarios on the other hand require specific storylines defined on a European level. The next chapters lay out the top down storylines ENTSO-G and ENTSO-E will use in further scenario development for TYNDP 2022. The feedback received is factored in the Final TYNDP 2022 storylines captured in this report.

² National Energy and Climate Plans, [link](#)

³ National long-term strategies, [link](#)

⁴ More information on carbon budget can be found in chapter 4 (Green Transition driver)



3

Final scenario storylines for TYNDP 2022

The definition of each scenario should enable the gas and electricity infrastructure assessment as part of TYNDP and TEN-E processes. In parallel, Member States define NECPs and national long-term strategies within the Paris Agreement Framework on a regular basis, while the European Commission proposes European focused strategies. The scenario building process is designed to be incremental and iterative and encourages multilateral engagement resulting in several benefits.

The full TYNDP process is achieved in the following ways:

- By providing insights to Member States and decision-makers about the interactions between national strategies;
- By ensuring both alignment of national and European strategies while taking into account country specifics;
- By creating a platform ensuring the consideration of all options with a technology neutral approach.

Following the regulatory obligation, ENTSO-E and ENTSG have launched the scenario building process for the TYNDP 2022 and proactively engaged with a wide range of stakeholders. The proposed storylines intend to incorporate the aforementioned process outcomes based on the experience of previous editions and stakeholder feedback.

Therefore, the key elements defining the scenario selection strategy are:

- To reflect the latest development in national energy and climate policies that are in line with European greenhouse gas reduction ambitions;
- To acknowledge the need for high ambition in terms of European energy efficiency and renewable energy deployment;
- To acknowledge the uncertainties associated with either pushing such renewable development and energy efficiency to the maximum, or relying on low-carbon technologies and energy imports.

As these elements impact the European energy infrastructure to different degrees, it is necessary to build two top-down scenarios in order to provide an appropriate basis for infrastructure assessment. In addition, many intermediate pathways could materialize based on different combinations of drivers. Nevertheless, it is expected that the two top-down scenarios cover a wide range of possible future evolutions of energy infrastructure.

It is beyond ENTSG's and ENTSO-E's remit to favour one or other of the storylines. However, the similarities and the differences in the way to manage uncertainty will be highlighted.

The following table provides an overview of storyline differentiation on the basis of the high-level drivers.



	 Distributed Energy Higher European autonomy with renewable and decentralised focus	 Global Ambition Global economy with centralised low carbon and RES options
Green Transition	At least –55 % ⁵ reduction in 2030, climate neutral in 2050	
Driving force of the energy transition	Transition initiated on local/national level (prosumers)	Transition initiated on a European/international level
	Aims for EU energy autonomy through maximisation of RES and smart sector integration (P2G/L)	High EU RES development supplemented with low carbon energy and imports
Energy intensity	Reduced energy demand through circularity and better energy consumption behaviour	Energy demand also declines, but priority is given to decarbonisation of energy supply
	Digitalisation driven by prosumer and variable RES management	Digitalisation and automation reinforce competitiveness of EU business
Technologies	Focus of decentralised technologies (PV, batteries, etc) and smart charging	Focus on large scale technologies (offshore wind, large storage)
	Focus on electric heat pumps and district heating	Focus on hybrid heating technology
	Higher share of EV, with e-liquids and biofuels supplementing for heavy transport	Wide range of technologies across mobility sectors (electricity, hydrogen and biofuels)
	Minimal CCS and nuclear	Integration of nuclear and CCS

Table 1: Storylines differentiation based on high-level drivers

⁵ This figure stems from the EC proposal for the Green Deal. If this target would change as voted by the European Parliament the scenario assumptions will be adapted accordingly.

3.1 Distributed Energy (DE), storyline A

This scenario pictures a pathway achieving EU-27 carbon neutrality by 2050 and at least 55 % emission reduction in 2030. The scenario is driven by a willingness of the society to achieve energy autonomy based on widely available indigenous renewable energy sources. It translates into both a way-of-life evolution and strong decentralised drive towards decarbonisation through local initiatives by citizens, communities and businesses, supported by authorities.

On the demand side this means a strong commitment to reduce energy consumption through renovation and insulation of residential and commercial buildings, a decrease in individual mobility and a high circularity in the industrial sector. Technologies such as heat pumps and EVs ensure the high efficiency gains necessary to limit demand, so it is balanced by potential energy production at local, national and European levels.

On the supply side, public acceptance for a very ambitious RES development is achieved. The development of prosumer behaviours become common place as citizens gain a better understanding of the energy system and its impact on climate. Further to this, higher involvement of citizens in local RES projects (e.g. PV, wind turbines, district heating/cooling, geothermal and biomass) is crucial to meet this challenge.

Specific European legislation sets the decarbonisation framework of activities managed at European scale such as aviation, shipping and some industrial sectors. In parallel, hard-to-decarbonize sectors that currently rely on fossil fuel imports switch to bio- and synthetic fuels (derived from electrolysis of renewable electricity) produced in Europe.

From an electricity system perspective, strong increase of heat pumps and EVs results in a deep electrification of final use demand. This demand is met by maximising the use of wind and solar, which results in a power system with little dispatchable thermal generation remaining. The dispatchable capacities that are available are based on solid biomass and power plants fuelled by renewable gas. Demand-side flexibility solutions are required, so that hour-by-hour the electricity system can remain in balance. In residential and tertiary sectors, the use of home batteries and smart charging of EVs can support short term balancing of the electricity grids. Large consumers in agriculture, industry and district heating are able to provide flexibility through demand side response (moving tasks to an earlier or later time period). Sector integration through the production of storable energy in the form of gas and liquids by electrolysis provides seasonal flexibility to the electricity system.

The factors influencing the design of the European energy system are the development of local optimization (circularity, prosumers), the need to connect huge amounts of RES energy and flexibility management from a geographical and temporal perspective. The available European primary energy sources require the coupling between energy carriers and infrastructures to cover the energy demand throughout all sectors.

The achievement of European energy autonomy on the basis of renewable energy relies on a range of prerequisites such as:

- The public acceptance of energy infrastructures and hosting of generation technologies associated with the maximisation of RES development across the whole Europe;
- The understanding and willingness of European citizens to adapt their behaviour in order to minimize energy demand and fully participate to the system adequacy;
- The maturity of technologies (hydrogen fuel cell, batteries, DSR, etc.) ensuring:
 - _the security of the electricity system with limited dispatchable generation
 - _the production of synthetic fuels for hard-to-electrify processes in absence of energy imports

This scenario targets European energy autonomy and as a consequence, sourcing low carbon energy imports from global markets is not prioritised. This focus discards possible (economic and competitiveness) opportunities in favour of a geopolitical priority to be more self-sufficient.

3.2 Global Ambition (GA), storyline B

This scenario pictures a pathway to achieving carbon neutrality by 2050 and at least 55% emission reduction in 2030, driven by a fast and global move towards the Paris Agreement targets. It translates into development of a very wide range of technologies (many being centralised) and the use of global energy trade as a tool to accelerate decarbonisation.

This scenario takes a global CO₂ avoided cost approach to define the evolution of the energy system. It considers the full scope of available technologies and energy sources to reduce CO₂ emissions at the lowest possible cost. It requires a holistic approach of the energy mix where demand and supply are considered together when defining the most efficient actions.

On the demand side, there is a fast development of energy and cost-efficient technologies such as EVs for passenger transport and heat pumps for residential and tertiary heating. In cold areas with existing widespread gas distribution infrastructure, hybrid heat pumps offer optimization potential for lowering the need of deep renovation and providing flexibility to the electricity system. Electricity technologies are complemented by a wide range of solutions like bio LNG, biomethane and fuel cell electric vehicles (FCEV). Europe benefits of biomass conversion into liquid and gas as well as low carbon energy imports. Industrial sectors strengthen their competitive position through automation and digital production. Substitution of natural gas by hydrogen and biomethane reduces adaptation cost. Activities participating to global trade (aviation, shipping and a wide range of industrial sectors) align on global decarbonisation solutions in order to avoid any loss of competitiveness.

European decarbonisation effort is strongly driven by a high European RES development complemented by energy imports and low-carbon solutions. This leads to a great variety of energy carriers used like electricity, hydrogen, biomethane and synthetic biofuels. CCS is an option to support decarbonisation of some industrial processes; and to achieve negative emissions where bio/synthetic fuels are used within the next ten years an international market for hydrogen and biofuels is established, which rapidly expands after 2030.

This offers Europe the opportunity to import competitive green hydrogen and derived fuels, playing a twofold role:

- Providing gaseous and liquid fuels for hard-to-decarbonise sectors while avoiding the conversion loss of European energy production;
- Preserving the link to the global energy market price.

From an electricity system perspective, renewable deployment is optimized at European level in order to seek both cost efficiency and build public acceptance. Global efforts see offshore wind as major technology in northern Europe with the formation of North Sea Energy Hubs while centralised solar is leading in the south of Europe. Nuclear power complements the energy mix to a limited extent, largely led by national energy policies. Moreover, the power sector will also benefit from the development of biomethane in the methane mix which enables negative emissions to compensate for hard-to-decarbonise sectors. Despite the existence of dispatchable generation there is still some need for additional flexibility, to be provided by utility-scale batteries, demand-side management (including hybrid heat pumps) and smart charging of EVs.

There is a progressive evolution of the transition towards a net-zero European energy system. This energy system is characterised by a balanced energy mix of electricity, gas and biofuels sourced by renewable development and imports. A balanced share of energy carriers and split of end user technologies means that the need for conversion of electricity to gas and liquid is limited.

The materialisation of a scenario based on European renewable, that are complemented by low carbon technology use and energy imports, relies on the following key prerequisites:

- The public acceptance and economic competitiveness of nuclear and CCS technologies within Europe;
- The availability of competitive low carbon energy for European imports by 2050.



4

Storyline development methodology and scenario drivers

This section gives stakeholders more information on the methodologies and guiding factors that shape the top-down scenario storylines.

The storylines are a key step to ensure differentiated and consistent scenarios. They aim at contrasted views on future energy demand and supply patterns to test infrastructure needs within the TYNDP process. ENTSOG and ENTSO-E use a top-down methodology to identify and define contrasting political, societal and technology underlying choices – so called “high-level drivers”.

To explain the concept some examples are useful:

1. Electrification is mentioned from time to time as a driver or target per se; however it often results from higher level choices, lead to the adoption of electricity-using technologies (e.g. efficiency of heat pumps). Moreover, the penetration of electric appliances differs within sectors.
2. In transport the use of energy carriers will depend on technology choices that are likely to differ between transport modes (road, rail, aviation and navigation). All in all, technologies and their future market shares are identified as one specific high-level driver as part of the storylines.

High-Level Driver

TECHNOLOGIES

Dimension

PRIVATE TRANSPORT

LOW TEMPERATURE HEAT DEMAND

Characteristics

EV/FCEV/ICE/GAS CARS ETC.

DISTRICT HEATING/(HYBRID) HEAT PUMPS/
GAS CONDENSING BOILERS ETC.

Figure 3: How to specify storyline characteristics (example)

Storylines aim to ensure sufficient differences are made between the scenarios by correctly identifying high-level drivers and quantifying the outcomes. A key success factor to understanding these drivers is by ongoing dialogue with

NGOs, policy makers and industrial companies at EU level. Based on this engagement process ENTSOG and ENTSO-E identified four high level drivers; illustrated in Figure 4.



Figure 4: High-Level Drivers of top-down scenarios

Green Transition



Green Transition reflects the level of GHG reduction targets and is one of the most important political drivers of energy scenarios. The European Union has ratified the Paris Agreement. This implies a commitment to the long-term goal of keeping the increase in global average temperature to well below 2 °C compared to pre-industrial levels and to pursue efforts to limit the increase to 1.5 °C. Since there are different emission mitigation pathways⁶ as described by the Intergovernmental Panel on Climate Change (IPCC), intermediate targets for 2030 and 2050 and a carbon budget up to 2100 have to be defined.

The current EU decarbonisation targets are defined under the 2030 Climate and Energy Framework⁷ (at least 40 % cuts in GHG emissions from 1990 levels). For 2050, there are only non-binding decarbonisation targets (80 to 95 % cuts in GHG emission from 1990 levels). These overall EU

targets are accompanied by NECP, which each Member State had to submit to the European Commission by the end of 2019 under the Regulation on the governance of the energy union and climate action⁸.

However, the European Commission has announced its European Green Deal on 11 December 2019⁹ and since then published several policy strategies, among others its Energy System Integration Strategy¹⁰ (ESI) and EU Hydrogen Strategy¹¹ 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 climate neutrality by 2050; this was accompanied by a supporting impact assessment¹². Moreover, on the 6th of October 2020, the European Parliament voted for climate neutrality goal by 2050 in EU legislation. And at the same time they request a more ambitious 2030 target, calling emissions to be reduced by 60 % in 2030 compared to 1990¹³. The draft TYNDP 2022 Storyline Report is based on the assumption that a new EU Climate Law driven by the Green Deal will consider at least – 55 % GHG emissions reduction in 2030 compared to 1990.

6 IPCC Special Report 1.5, Chapter 2, Figure SPM.3b, IPCC, 2018

7 2030 Climate and Energy Framework, EC, [link](#)

8 Regulation on the governance of the energy union and climate action, EC, [link](#)

9 European Green Deal, EC, [link](#)

10 Energy System Integration Strategy, [link](#)

11 EU Hydrogen Strategy, [link](#)

12 State of the Union 2020, [link](#)

13 EU Parliament votes for 60 % carbon emissions cut by 2030, [link](#)

Moreover, ENTSOG and ENTSO-E acknowledge that setting GHG emissions targets for 2030 and 2050 is not sufficient for keeping temperature rise below 1.5 °C. As a result, the scenarios will consider a carbon budget including emissions and removals from agriculture and from Land Use, Land Use Change and Forestry (LULUCF). Based on the exchange with CAN Europe for the TYNDP 2020 Scenarios,

ENTSOG and ENTSO-E consider a carbon budget for the EU-27 from 2018–2100 of 42.2 GtCO₂eq per capita and 33.8 GtCO₂eq by equity. The scenario building exercise will result in a decarbonisation pathway till 2050 and ENTSOG and ENTSO-E will transparently present the cumulative emissions of their scenarios in comparison with the carbon budget assumed for the EU27.

Side Note¹⁴: Carbon Budget

Carbon budgets refer to the net total of CO₂ that can be emitted in a given time period taking into account the total CO₂ that is removed in the same period. Hence, carbon budgets include emissions and removals from LULUCF.

The IPCC Special Report on warming of 1.5 °C (SR1.5-2018) shows why 1.5 °C is a critical threshold and assesses 1.5 °C compatible carbon budgets. These carbon budgets in SR1.5 are higher than those in the IPCC's Fifth Assessment Report (AR5-2014), mainly because of an effort of rebasing. The "Summary for Policy Makers of SR1.5" provides four 1.5 °C compatible carbon budgets (for global CO₂ emissions), with differences due to:

- likelihood of staying within the temperature threshold: 50 % or 66 % (which is an expression of the number of scenarios that allow a certain carbon budget);
- means of temperature measurement: based on computer modelling only (global mean surface air temperature) or computer modelling combined with real-time observations (GMST).

The carbon budgets in the IPCC reports refer to the available budgets for CO₂-emissions, while they take into account a certain limited reduction pathway for non-CO₂ emissions. Assuming stringent emission reductions of non-CO₂ gases, in line with the deep reductions of CO₂ emissions needed for 1.5 °C compatible budgets, could help in converting CO₂-budgets into greenhouse gas budgets that would according to SR1.5 Coordinating Lead Author Joeri Rogelj be approximately 25 % higher.

Based on above mentioned parameters and assumptions the global carbon budget is 712 GtCO₂ from 2018 onwards till the end of the century. There are multiple ways to divide the global carbon budget across countries. The main approaches take population and/or equity into account.

Driving force of the Energy Transition

GREEN TRANSITION	DRIVING FORCE OF ENERGY TRANSITION
ENERGY INTENSITY	TECHNOLOGIES

Beyond climate targets, the European energy system will be increasingly shaped by societal decisions and initiatives acting as a **driving force of the energy transition**. Today, the EU imports account for almost 60 % of its primary energy demand, but the import needs differ highly from fuel to fuel and country to country. These large imports entering Europe through a limited number of points together with large scale thermal power generation units have shaped a rather centralised European energy system.

There is rapid decline of the indigenous gas production within the EU, amongst others noteworthy factors are the future shut down of the Groningen field and the exit of the United Kingdom from the EU-28. At least in the short to medium term, the EU-27 will need to import a higher share of its currently forecasted growth in gas demand. It is worth stating that the uptake of renewables¹⁵ has not led to lower import shares over the past 20 years¹⁶. At the same time, continued dependence on energy imports is perceived as a risk by some stakeholders due to uncertainties in the geopolitical context. In addition, the need to switch to low carbon or renewable imports triggers the question of their long-term availability. Such availability can be negatively impacted by a slow energy transition of producing countries or a situation of high global demand where Europe would be a price-taker. These stakeholders favour the maximisation of the EU RES potential facilitated by local initiatives and a greater participation of prosumers in the operation of the

¹⁴ Based on exchange with CAN Europe

¹⁵ Share of renewables in gross inland consumption, EC, [link](#)

¹⁶ EU imports in 2018, EC, [link](#)

energy system as described in the Clean Energy Package. Following that path would move the structure of the energy system away from its current centralised structure.

Regarding hydrogen, the ESI and EU Hydrogen Strategy illustrate the duality of the driving forces. The ESI emphasizes the benefits of “linking up the different energy carriers and through localized production, self-production and smart use of distributed energy supply. System integration can also contribute to greater consumer empowerment, improved resilience and security of supply”. The EU Hydrogen Strategy also foresees “cooperation opportunities with neighbouring countries and regions of the EU” and the establishment of a “global hydrogen market”. The strategies of EU Member States present a wide range of perspectives, with some NECPs and National long-term strategies aiming at a

strong reduction of energy imports while some hydrogen strategies emphasize the need for global cooperation for a future hydrogen economy. On a global scale, similar trends can be seen in Japan and Korea as importing countries and Morocco, Australia or Norway as possible hydrogen exporting countries¹⁷.

The level of decentralisation and autonomy can strongly impact the structure of the European energy system and therefore the need of infrastructure. At present there are a range of possible futures reflecting the uncertainties around societal aspiration, global evolution and technological requirement. The purpose of different scenario storylines is to understand the impact from traveling differing paths that lead to a common net-zero future.

Energy Intensity



Energy Intensity is a result of innovation and consumer behaviour and can be a major factor in the transition of the energy system. New appliances and technological innovation reduce specific energy demand (e.g. heat pumps) or facilitate the participation of consumer in the energy system (e.g. digitalisation and smart metering). On the other side, new technologies can lead to additional energy demand (e.g. e-scooters replacing walk or public

transport). Moreover, increasing energy efficiency can also lead to an increased rate of consumption (Jevon Paradox). Heat pumps for example provide reduced energy demand through more efficient heating. But at the same this technology also provides the option for cooling, increasing energy demand in summer. Finally, consumers can reduce their consumption by modal shifts, for example using the bike instead of the car for shorter distances or by more shared economy through public transport and vehicle sharing. This also applies to agriculture and industrial sectors, were a drive towards circularity could lower energy demand, but an increase economic activity could at least in part offset the efficiency gains. Assumptions need to be made for each sector and energy application.

The following table describes two examples:

Sector	Residential	Transport
Sub-sector	Heating	Passenger Travelling
Issue	Heat pumps in new houses	Increasing share of home-office
Issue description	Heat pumps have a higher efficiency, also called coefficient of performance. Moreover, in new houses with a necessary ventilation system, heat pumps can be used for cooling using a reversing valve.	Recent trends show a higher share of home-office (also due to the Corona pandemic).
Question	Although heat pumps will reduce the annual heat demand in buildings, will they create new electricity demand for cooling (e.g. in northern-European countries)? How will this impact the energy system?	How will home-office influence commuting and transport demand? Will this reduce the number of individual cars? Will ownership still be the main trend, or will car sharing take over? How will this influence the flexibility by V2g for the electricity system?

17 INTERNATIONAL HYDROGEN STRATEGIES, Ludwig Bölkow Systemtechnik and World Energy Council, 2020

Technologies

GREEN TRANSITION	DRIVING FORCE OF ENERGY TRANSITION
ENERGY INTENSITY	TECHNOLOGIES

Technological progress is a driver for the energy system evolution. It can act both as an enabler of other drivers (e.g. more powerful wind turbine helping to further harvest EU RES potential) and as a trigger (e.g. electrolysis paving the way to a low carbon hydrogen economy). Further assumptions are needed to define the market shares for different technologies/appliances. Assumed market shares should reflect maturity and replacement rate of the relevant technologies. Assumptions need to reflect national policies/strategies and future consumer trends. Moreover, in certain cases it is necessary to make the assumptions that are specific to certain countries, sub-sectors or even individual processes.

Storyline Matrix

ENTSOG and ENTSO-E apply the aforementioned methodology to create a storyline matrix. The storyline matrix provides an overview of each parameter taken into account and reflects the technological or societal behaviour drivers being considered. It illustrates from a qualitative perspective how they differ from one storyline to the next (and not compared to present situation). This storyline matrix is published as an annex ([link](#)).

All the parameter choices in the storyline matrix will go through a detailed quantification in the next stage of the scenario building process. This quantification will also account for European and national policies as well as other studies. It is important to note that a full dataset cannot yet be quantified within this draft storyline report. The full scenario data set is a result of the scenario modelling and it will be provided as part of the Scenario Report to be published mid-2021. The next chapter will provide insights on the quantitative ranges for key parameters that have a significant impact on the energy system. The purpose of quantitative ranges is to illustrate how the storylines differ from one another. These quantitative ranges fulfil the goal set by ENTSO-E and ENTSOG to increase the level of numerical transparency as early as possible for valuable feedback during the consultation process.



5

Quantification of key parameter ranges

The TYNDP 2020 Scenario building process, first developed qualitative storylines followed by a second step that created quantitative scenarios. TYNDP 2020 was the first year that ENTSOG and ENSTO-E created a whole energy system tool, called the Ambition Tool and developed new methodologies for collecting energy and technology trajectory information. The availability of new tools and methodologies means that for TYNDP2022 we can provide meaningful quantification of key parameters at storyline level.

As a result, the combination of parameters defining each storyline (see Storyline Matrix in annex) is now complemented with quantitative ranges or priority orders for key parameters. The exact level of development of each technology will finally depend on the supply-demand balance of each scenario and therefore cannot be defined ex-ante at storyline level. A high and low trajectory have therefore been defined for key parameters. They play a benchmark role as upper and lower boundaries rather than

a targeted level to be reached. Top down scenarios are open to a wider range of technology inputs, based on economic and storyline assumptions. It is expected that the resulting scenarios will have a diverse range of technologies that enable a net-zero pathway, rather than leaning on one particular technology or energy carrier.

For reference, the graphs in this chapter highlight the ranges of key parameters as published in the Draft Storyline report in November 2020 and the updated ranges based on consultation feedback and TSO consideration of country specifics. For comparison purpose, the charts also include the level of those parameters as resulting from the Final TYNDP 2020 Scenario Report published in June 2020. The updated ranges will serve as the basis for the building of the Distributed Energy and Global Ambition scenarios. For consistency, all graphs have been updated to consider the EU27 perimeter.

5.1 Demand

Energy demand is defined by many factors such as the range of energy services to be provided, the behaviour of energy consumers and the available technology choices. It translates for each energy carrier and application into an energy demand level and a temporal profile across the year.

Some technologies will have a strong influence on energy demand as they result in usage transfer (e.g. e-mobility, from oil to electricity), energy savings (e.g. heat pumps,

Coefficient of Performance gains) or the need for new energy carriers (e.g. hydrogen). They also may become an increasing source of flexibility for the energy system (e.g. demand-side management, smart charging, hybrid heat-pump, district heating, electrolysis...).

In order to bring visibility to the storyline and scenario design, some quantitative ranges have been defined for certain heating and mobility technologies.

Overall electrification rate

By 2050 the electrification shares in residential and tertiary will surpass 50 %. In industry it will be at least 40 %. For mobility (including aviation and shipping) will see a direct electrification rate of at least 25 %. In the agriculture sector the direct electrification will reach around 20 %. A higher

electrification is considered in every sector being higher in Distributed Energy scenario according to the storylines. In all cases values may change a bit after the modelling. Electrification rates will differ from one country to another.

Number and type of individual heat pumps

Heat pumps cover a wide range of technologies depending on the ambient heat source, the heating fluid and the energy source used to operate the heat pump. As a result, each technology incorporates a specific electricity or gas demand profile. For the purpose of quantifying the storylines, specific ranges are defined for:

- Electric heat pumps (covering Air/Air, Air/Water and Water or ground/Water)
- Hybrid heat pumps (combination of a size-optimized Air/Water electric heat pump and a gas boiler)

Residential and tertiary sectors will see similar developments of heat pumps while the evolution may differ for district heating.

When defining the electricity demand profiles as inputs for the scenario modelling, a specific profile will be used for each heat pump category. For the hybrid heat pumps the switch from purely electricity mode to hybrid (gas) mode will occur at an outside temperature of 3 – 5 °C.

Scenario DE

In this scenario, the installation of individual all-electric heat pumps is predominant due to the strong efficiency gain required to reach European energy autonomy. This technology participates to the high electrification of demand in parallel with the maximisation of electricity generation through solar and wind.

Scenario GA

In this scenario, the availability of methane and hydrogen imports supports the use of gas in the building sector. Hybrid heat pumps are a meaningful alternative to all-electric heat pumps in certain countries. They combine the energy saving of the electric heat pumps on a wide temperature range while avoiding the necessity of deep renovation or oversizing electricity infrastructure. They benefit from the flexibility of the gas system to cover extremely cold temperature or stress situation.

Proposed ranges

The range for all-electric heat pumps is based on external studies consistent with carbon neutrality (EC LTS 1.5 Life/Tech scenarios¹⁸ and Eurelectric 95 % Scenario¹⁹). The range for hybrid heat pumps is based on the conversion of existing gas boilers taking into account the benefit of the technology under cold and humid climate where all-electric heat pumps

may create some challenge for the electricity system at very cold temperature. A regional approach will be developed in order to take into consideration such country specifics such as climate and the spread of gas distribution networks. As a result the heat pump share at country level may be lower or higher than the range defined below at European level.

– Concerning the electric heat pumps in 2050:

_Maximum: 54 % market share slightly above the average of heat pumps in residential (44 %) and tertiary (53 %) heating according to the Eurelectric 95 % Scenario plus a 10 % headroom

_Minimum: 43 % market share as resulting from a more ambitious vision from stakeholders and TSOs on the role of this technology compared to the Draft Storyline report

– Concerning the hybrid heat pumps in 2050:

_Maximum: 18 % market share resulting from a conversion assumption of 40 % of existing gas boilers²⁰ to hybrid heat pumps

_Minimum: 9 % market share resulting from a conversion assumption of 25 % of existing gas boilers to hybrid heat pumps

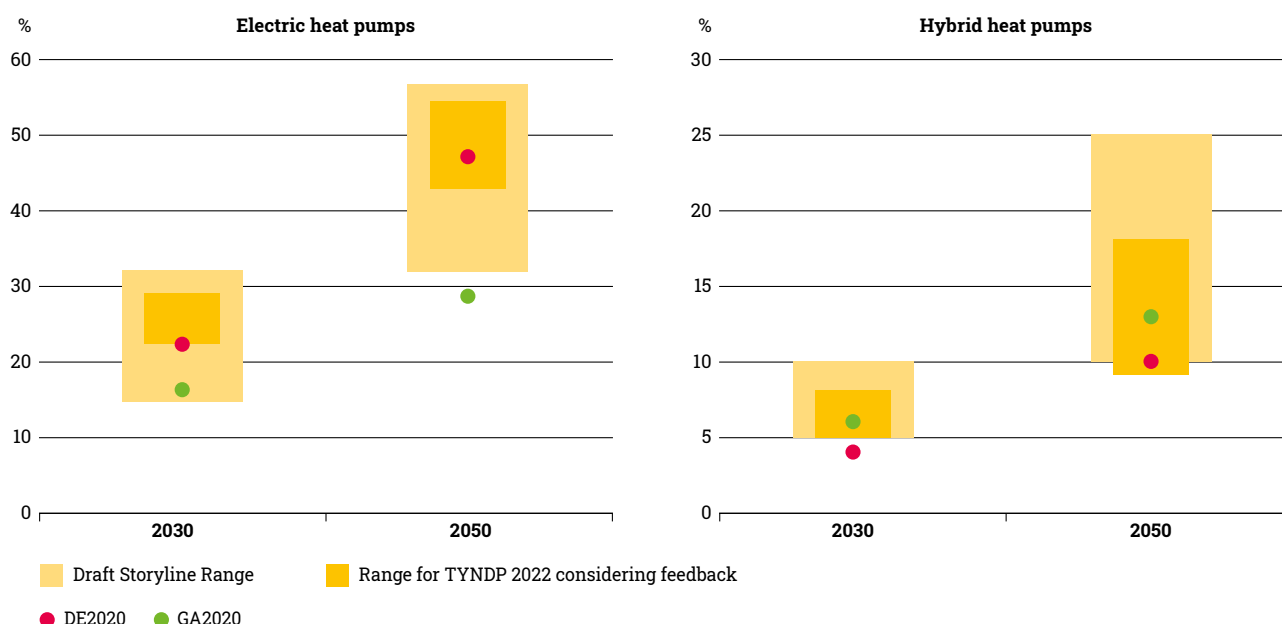


Figure 5: Market share of (hybrid) heat pumps in the built environment

In the graph we included an updated range to be used in the TYNDP 2022 scenarios. Concerning electric heat pumps, we consider a split between air source and ground source of around 80 %/20 % respectively (for all target years, both for GA and DE).

18 In-depth analysis in support of the Commission Communication COM(2018) 773 "A Clean Planet for all", [link](#)

19 Scenario 3 from Eurelectric Decarbonisation Pathways achieving a 95 % GHG emission reduction, [link](#)

20 Assuming a present 43 % market share

Share of district heating

District heating covers a wide range of situation in terms of demand (residential, tertiary or industrial space heating and cooling) and energy sources (excess heat, ambient heat, solar, biomass...). These differences are strongly linked to geography (urban, sub-urban or countryside areas).

For the purpose of quantifying the storylines a range is provided for the overall market share of district heating in low temperature heating demand.

The fuel mix for district heating will be detailed at a later stage of the scenario building process. It will reflect the ongoing cooperation between the district heating sector in particular through Euroheat & Power, ENTSO-E and ENTSG. The scenarios are enhanced by accounting for different district heating systems and the role flexibility of these systems can offer within the overall energy system.

Scenario DE

Local initiatives and circularity are key drivers of the scenario. District heating and cooling embodies both trends. They are part of spatial planning by local authorities and can combine a wide range of local energy sources (geothermal, solar or biomass). They offer a link to consumers for recovered heat from a wide range of sectors (industry, waste, data centres...).

They enable energy saving through the use of large-scale efficient heat pumps. These benefits are combined with the ability to back-up heat pumps with other heat sources and thermal storage. The resulting flexibility is of particular importance in a scenario with very low dispatchable power generation.

Scenario GA

In this scenario, gas and electricity distribution networks connected to renewable production and transmission systems continue to be the main solution for building heating and cooling. As a consequence the market share of district heating will similar to the present situation.

Proposed range in 2050

The EC LTS and Policy²¹ scenarios and the Heat Roadmap Europe²² study were taken as references for district heating market shares:

- Maximum: 32 % as resulting from the cross-sectorial work with the district heating sector
- Minimum: 15 % in line with the EC LTS 1.5 Tech/Life scenarios not anticipating a significant evolution from the technology.

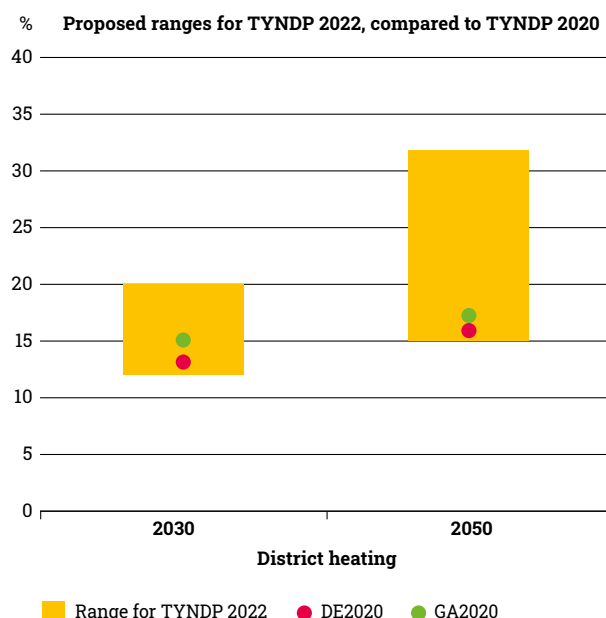


Figure 6: Market share of district heating in the built environment

Share of hydrogen fuel cells for heating

For hydrogen fuel cells there is no pre-defined range in the storyline. The market share of this technology is rather limited in both (around 1 % in 2050). As such, there isn't a strong differentiation between Global Ambition and Distributed

Energy regarding the penetration of this technology in the residential & commercial sector, resulting in market shares which are rather low.

21 Policy scenarios from the "Stepping up Europe's 2030 climate ambition" impact assessment, [link](#)

22 Heat Roadmap Europe 4 Quantifying the Impact of Low-Carbon Heating and Cooling Roadmaps, [link](#)

Shares for passenger EV and FCEV

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 CO₂ 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 Electrical Vehicles (EVs).

Fuel Cell Electrical Vehicles (FCEVs) will remain limited compared to EVs in the passenger cars segment. However, for other transport categories, such as heavy good this technology presents itself as a better alternative.

Scenario DE

The use of electric motors delivers high efficiency gains, compared to ICE, helping Europe to reach energy autonomy, complimented by the strong development of solar and power. Secondly EVs offer flexibility to the electricity system through smart charging, which becomes increasingly important in a scenario where dispatchable power generation is in rapid decline.

The strong development of common transport modes, such as, train in this scenario will mitigate the challenge of autonomy for long distance travel.

Scenario GA

In this scenario, there is a wider range of clean mobility technologies with fuel cells as a meaningful option for long distance travel, high usage rate and power requirement. EVs offer the most efficient solution for short to medium distance mobility. In parallel the availability of hydrogen supply and transport infrastructure leads to technology

development of fuel cell mobility driven by specific segments where driving range, engine power or use intensity matters. Personal mobility benefits from these development and private FCEVs take some market shares especially for long distance travel.

Proposed ranges in 2050

Based on third party studies, ranges for both technologies were defined:

- Maximum:
 - _EV: 89 % market share in line with the EC REG Policy scenario having the highest market share for battery and plug-in hybrid passenger cars
 - _FCEV: 16 % market share in line with the EC REG Policy scenario having the highest market share for fuel cell passenger cars
- Minimum:
 - _EV: 74 % market share in line with the EC CPRICE scenario having the lowest market share for battery and plug-in hybrid passenger cars
 - _FCEV: 6 % just above the EC Baseline scenario

From TYNDP 2020, it is worth noting that EV fleet trajectory used a linear progression resulting in too high a market share for EVs in 2030 when considering supply chain effects and replacement rates. For this edition a lower range has been defined for 2030 consistent with existing projection compared the most optimistic sales figures up to 2030 (Eurelectric 95 % Scenario).

In the graph we included and updated range to be used in the TYNDP 2022 scenarios.

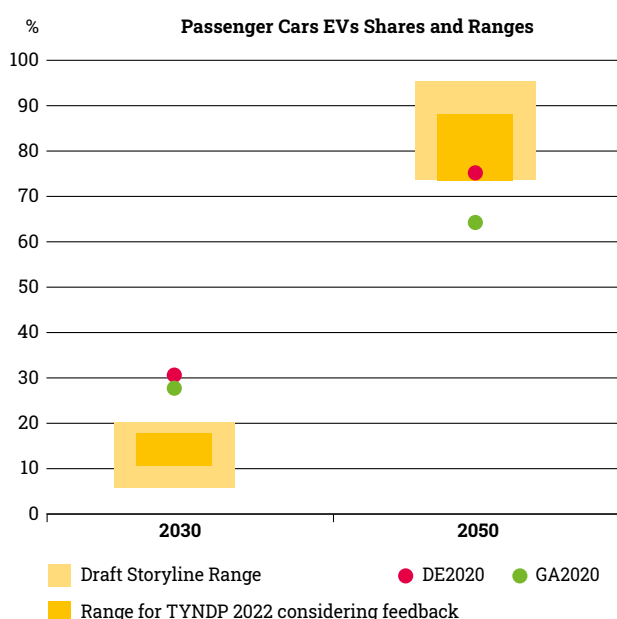


Figure 7: Market share of EVs in passenger car fleet

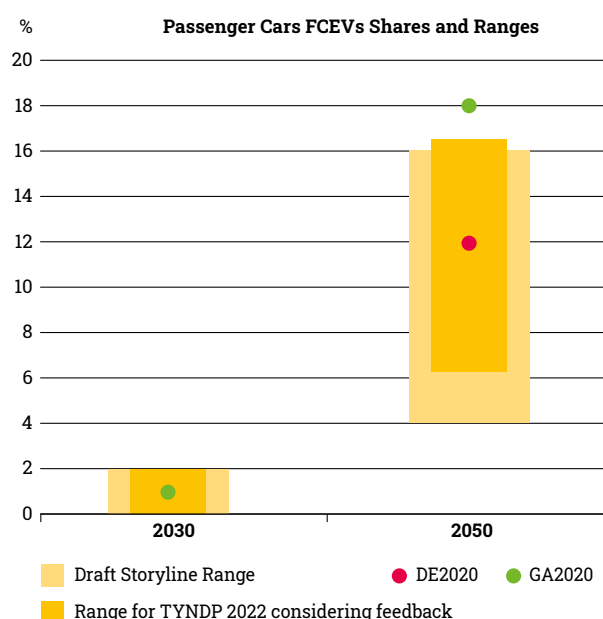


Figure 8: Market share of FCEVs in passenger car fleet

Shares for heavy good vehicles EV and FCEV

For heavy goods there are no ranges proposed in the draft storyline report. Following stakeholder feedback we have included some additional information for this mobility segment. For heavy goods transport the FCEVs present as a better alternative than EVs especially in Global Ambition scenario. The ranges for each technology are shown in the following graphs.

Distributed Energy will be in the high range for EVs and in the lower range for FCEVs. The opposite will be the case for Global Ambition.

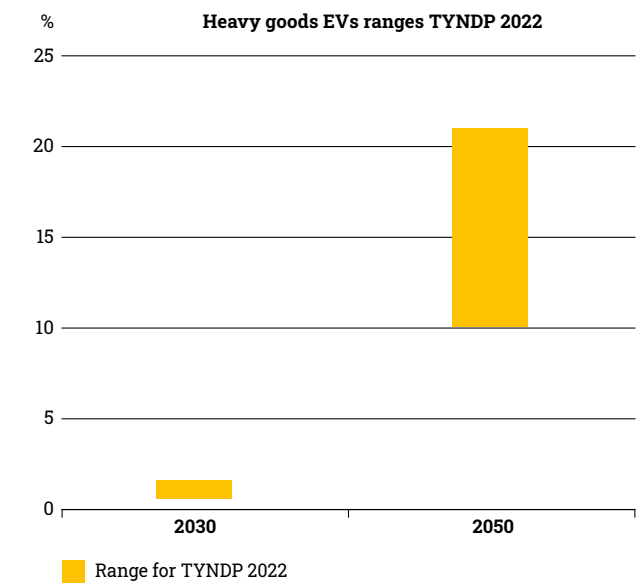


Figure 9: Market share of EVs in heavy goods vehicles

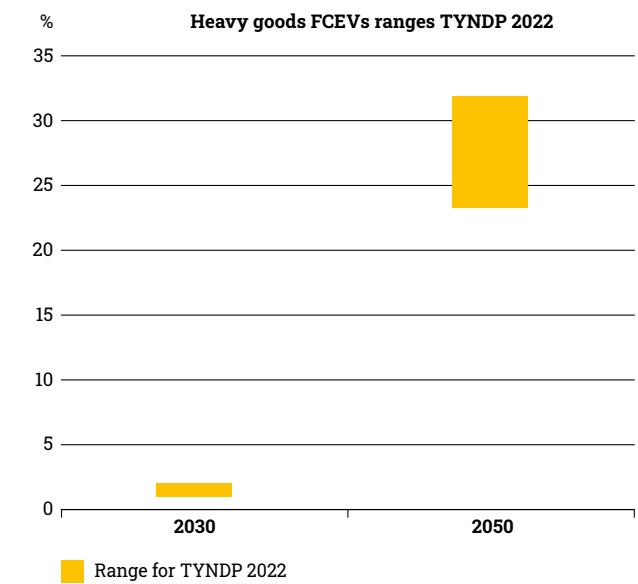


Figure 10: Market share of FCEVs in heavy goods vehicles

Energy Intensity

During the storylines consultation several stakeholders suggested that the draft storylines showed too much variation in terms of energy intensity (efficiency, circularity, etc.). Following this feedback, ENTSOG and ENTSO-E have adapted the storyline description so that they only show a limited difference for this scenario driver. Distributed Energy going only a little bit further than Global Ambition.

In the EC Impact Assessment, we observe a difference in final demand of approximately 6% between the scenarios. We aim to remain close to this assumption.

5.2 Supply

The range and the extent of available energy sources in Europe are drivers that will shape the evolution of the energy system. The proposed storylines intend to cover

contrasted pathways resorting to different technologies, renewable sources and imports.

Wind onshore, wind offshore and solar PV

Wind (onshore and offshore) and solar PV technologies are key components of the future decarbonised energy mix and therefore play a pivotal role in the development of the scenario storylines.

From a modelling perspective, the deployment of these technologies will result from an investment loop using the below updated ranges as boundary conditions and annualized cost assumptions. The results will strongly depend on electricity demand level (including electricity for P2X). Apart from these cost assumptions, the geographical investment decisions are further driven by technology and country specific Climate Data. For instance, where offshore wind is not an option due to a lack of coast line or policy measure, the model will naturally not invest in this option. This boundary is reflected in either conditions given by TSOs or the climate data.

Scenario DE

Targeting European energy autonomy based on renewable energy sources requires maximizing wind and solar development. Increasingly triggered by local initiatives solar PV and onshore wind will see the highest development compared to their potential. As a result RES development will be close to the upper range and potentially higher than the level reached in the TYNDP 2020 DE scenario, mainly due to lower imports and nuclear capacity. The resulting variability of the energy mix will require significant flexibility at network and demand level.

Scenario GA

Widening the supply range to low carbon electricity generation and energy imports will provide some room to optimize renewable development at a European scale seeking both cost efficiency and public acceptance. As a result, offshore wind and large scale solar farms will be respectively predominant in the north (e.g. North Sea Energy Hubs) and in the south of Europe. At the same time the capacity level of those technologies could be lower in absolute terms than in Distributed Energy as relatively higher energy imports results in lower deployment of wind, solar and electrolysis capacity to produce synthetic fuels in Europe.

Proposed ranges in 2050

The following graphs cover both technical potential of solar and wind as well as the installed capacities as stated in the main third party scenarios (EC, IRENA, IEA, Eurelectric and e-Highway) approaching carbon neutrality. Onshore and offshore wind ranges are defined as separate categories to improve visibility on storylines.

- Maximum technical potential
 - _ Solar: 4,600 GW²³ as resulting from a conservative scaling of the Solar Power Europe scenario to EU27
 - _ Wind: 8,362 GW from JRC Technical Report: Wind potentials for EU and neighbouring countries
- Highest level in external studies for 2050
 - _ Solar: 2,000 GW (43% of technical potential) from Energy Watch Group²⁴ and PAC scenarios)
 - _ Onshore wind: 1,095 GW as 10% above the EC CPRICE scenario in order to give flexibility to the investment loop defining the electricity generation capacity
 - _ Offshore wind: 340 GW based on Wind Europe "Our energy our future" scenario scaled down to EU27
- Lowest level in external studies for 2050

For each technology, the limit derives from the study achieving carbon neutrality in 2050 with a low level of the technology and applying an additional 10% reduction in order to give flexibility to the investment loop defining the electricity generation capacity:

 - _ Solar: 930 GW as 10% below the EC REG scenario
 - _ Onshore wind: 840 GW as 10% below the EC REG scenario
 - _ Offshore wind: 270 GW as 10% below the EC Strategy on offshore renewable energy

²³ Due to this figure being far outside the range of the other sources we encountered, it was not considered in the range for our storylines.

²⁴ As mentioned in the JRC PV Status report 2019

Highest levels for 2030 are set on the EC ALLBNK scenario (380 GW for solar, 374 GW for onshore wind and 79 GW for offshore wind) when lowest levels for 2030 are set based on historical trends (300 GW for solar, 280 GW for onshore wind and 55 GW for offshore wind).

Figure 11 displays the ranges for installed capacities of solar PV and wind (onshore and offshore) from third party studies and the TYNDP2020 scenarios GA and DE. The

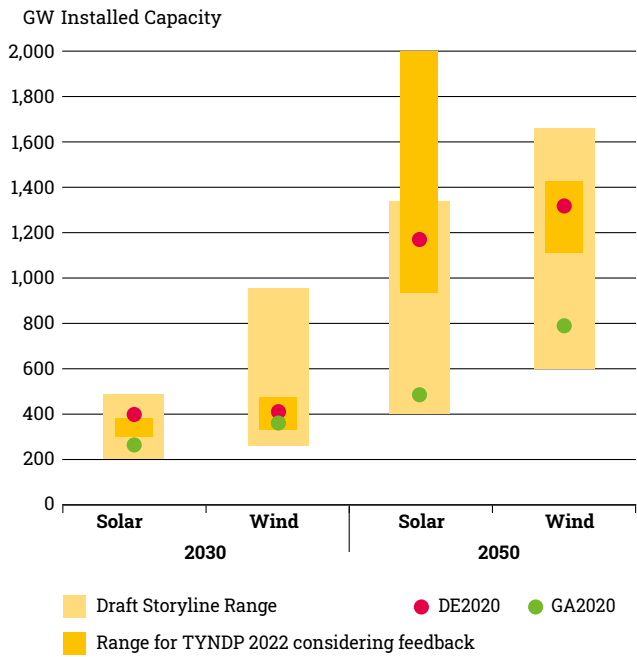


Figure 11: Installed capacities for solar PV and wind generation for EU27 (comparison between initial range from the Draft Storyline Report and the updated range considering consultation feedback)

ranges presented are from various external scenario studies and are substantially lower than the technical potentials for solar and wind, which finally define the boundaries for the modelling process. The range for 2030 has been narrowed to reflect stakeholder feedback the on a 2030 time horizon the uncertainty was overestimated in the initial ranges.

Figure 12 provides a breakdown of wind trajectory in onshore and offshore technologies.

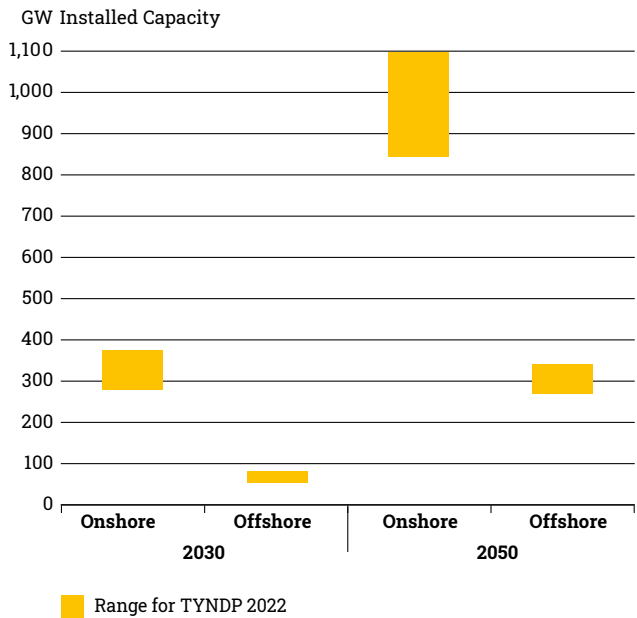


Figure 12: Trajectories of onshore and offshore wind technologies for EU27

Nuclear

Nuclear energy is a low-carbon energy source having the ability to contribute towards meeting EU CO₂ emissions targets. Nuclear development is decided by governmental policies at a nation level. It ranges from countries having decided an accelerated phase out of existing units, to countries planning the construction of new reactors. In any case the level of nuclear capacity is likely to influence the European electricity system, as such the top-down scenarios should capture different evolutions according to their storylines.

Scenario DE

The objective of a fully renewable energy mix results in the absence of construction of new reactors and the phase out of existing ones according to national policies.

Scenario GA

Some European countries take the decision to extend the life of existing units and to build new reactors. The objective is to complement RES development with some low-carbon production with some dispatch capability.

Proposed ranges in 2050

Trajectories are based on TSOs data complemented with assumptions on project development and unit lifetime:

- Maximum: 99 GW with a 55-year lifetime assumption for existing, under construction and plan units when not provided by TSOs. This trajectory shows a capacity decrease down to 2030 then a slow increase up to present level in 2050.
- Minimum: 19 GW with a 45-year lifetime assumptions for existing units and those under construction.

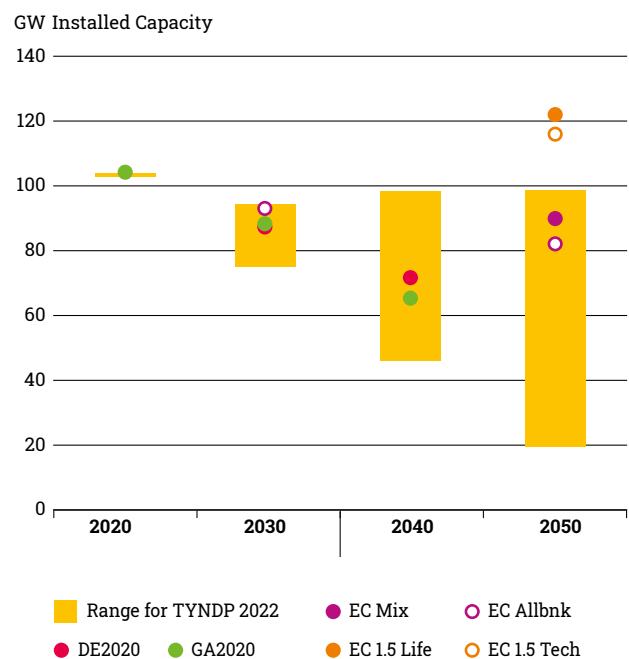


Figure 13: Trajectories for nuclear generation capacity for EU27

At quantification stage of the top-down scenarios, the nuclear capacity of each country will be defined as an input of the modelling taking into account the aforementioned trajectories, public consultation results and the latest national policy developments.

Energy Imports

Nowadays Europe imports a wide range of energy carriers complementing indigenous production. With higher efficiency and electrification compared to present situation, the need of imports will decrease in the long-term. At the same time some countries over the world consider the possibility to export low carbon and renewable energy.

While top-down scenarios will in the end capture the full energy mix, the storylines focus primarily on methane and hydrogen (including derived forms such as ammonia).

Scenario DE

The reduction in gas demand resulting from deep electrification together with the significant uptake of local renewable gas production, imports experiment a high decrease in comparison to today's level. Gas imports are assumed to

be lower than 35 % of present level which was the TYNDP 2020 DE threshold already substantially lower than the EC LTS 1.5 Tech/Life scenarios.

Scenario GA

With a more diverse supply mix, gas demand is higher than in DE scenario. With lower uptake of electrolysis within Europe the path to achieve large scale decarbonisation entails a more import-oriented vision. In any case total energy imports stay within the upper range set by EC LTS 1.5 Tech scenario representing a 70 % decrease compared to present level.

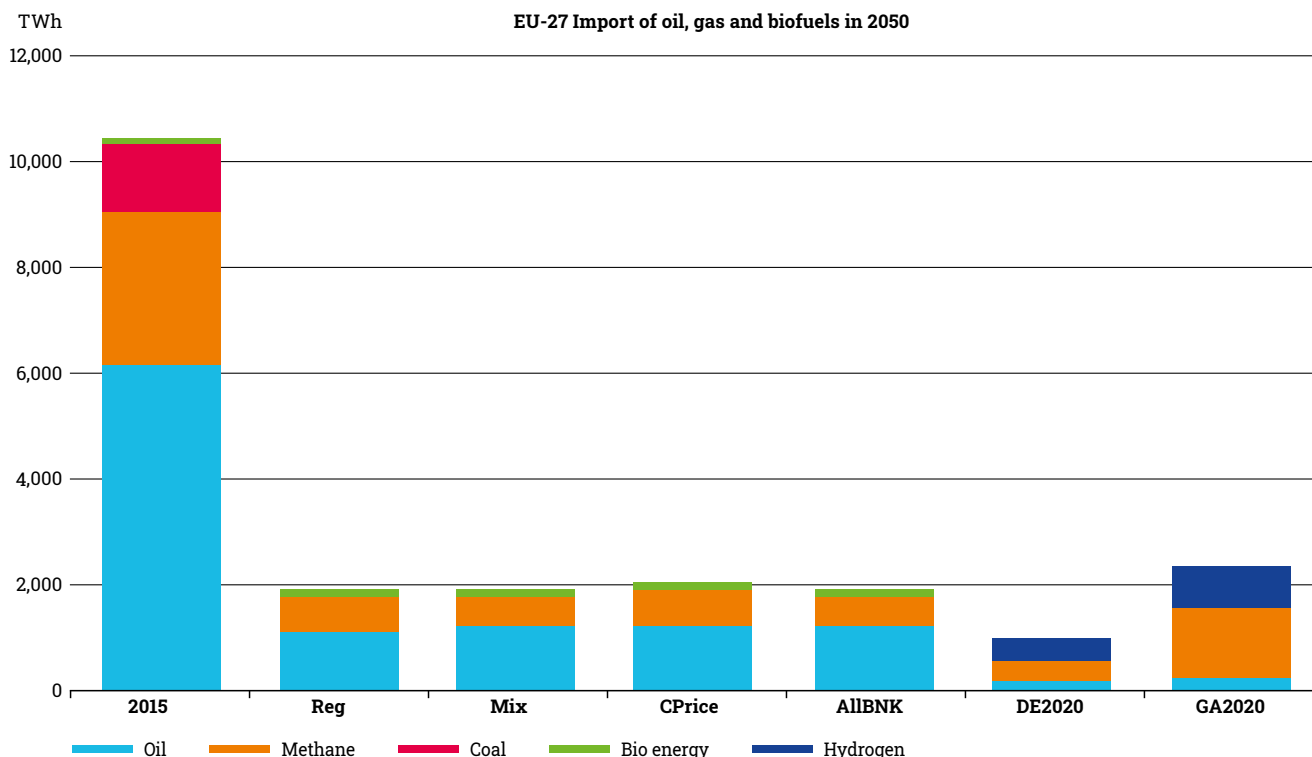


Figure 14: Import of oil, gas and biofuels in 2050

Proposed ranges in 2050

Figure 14 illustrates the EU-27 imports of oil, gas and biofuels for 2050 in the EC scenarios and TYNDP 2020 DE and GA scenarios. At first glance, the total imports in the new EC Policy scenarios (REG, MIX, CPRICE and ALLBNK) are within a narrow range of 1,850–2,000 TWh. The import source in these scenarios does not vary significantly either. Due to higher energy autonomy, the DE 2020 scenario

showed the lowest imports compared to EC and GA 2020 scenarios. Furthermore, the type of imported energy carrier differs, with higher oil and lower renewable gas imports in the EC scenarios. These differences in the imported energy carriers derived from the storyline assumptions. For the 2022 scenarios, we plan to use the TYNDP 2020 scenarios import shares as an upper limit.

Hydrogen supply

Hydrogen is increasingly becoming part of the national energy and climate strategies of countries across the world²⁵. The European Commission has launched an ambitious strategy on hydrogen. This energy carrier enlarges the range of solutions to decarbonize some difficult to electrify sectors. At this stage it is hard to provide a range for the overall hydrogen demand as it is an emerging energy carrier which development depends on a wide range of parameters still to be defined.

Scenario DE

In this scenario, hydrogen is mainly produced by electrolysis with electricity produced by European wind and solar capacity. It can be complemented in a limited amount by steam methane reforming of biomethane as an interim solution or biomass pyrolysis. In any cases the European

renewable energy potential limits the volume of hydrogen that can be produced. As a result, the available volume will be channelled towards the sectors the most challenging to electrify.

Beyond its market share in final energy, hydrogen can play an important role as a source of flexibility since it is a storable energy in the form liquid and gaseous fuels.

Scenario GA

In this scenario, hydrogen comes from a wider range of renewable and low-carbon sources being European as well as imports. As a result, it will be used in a wider range of sectors better mitigating the challenge of deep electrification.

²⁵ Hydrogen is mentioned in most of the Member States NECPs and is subject to dedicated strategies by at least France ([link](#)), Germany ([link](#)), the Netherlands ([link](#)) and Portugal ([link](#)). Beyond EU a wide range of countries have published national hydrogen strategies such as Norway ([link](#)), Japan ([link](#)), South Korea ([link](#)), China, Australia ([link](#)) and California

5.3 Flexibility options

Beyond dispatchable power generation and hydro pumped storage, there are many options to support the energy system flexibility needed to deliver the energy transition. Such options include the use of sector coupling (batteries, P2X) and demand side response. These flexibility options can further be subcategorised:

- Batteries used for short term energy storage (e.g. daily balancing):
 - _behind the meter batteries (mostly residential) driven by mixed signals (energy market and local drivers);
 - _utility-scale batteries driven by the energy market;
 - _utility-scale batteries for system services provision;
- Demand-side response:
 - _the use of flexibility from electric vehicles smart charging (including FCEVs);
 - _the use of hybrid heat pump (cf. § 5.1);
 - _in the tertiary sector (e.g. supermarket switching its fridges off for a short amount of time);
 - _in the industrial sector (e.g. back-up energy or production adaptation).

- Electrolysers which can adapt hydrogen production to electricity market signals provided that there is downstream flexibility (e.g. ability of an industrial consumer to switch off hydrogen demand or to store it locally or a hydrogen network connecting various sources and storages). Depending on the situation electrolysis can offer flexibility option for all timeframes up to and including seasonal energy balancing.

Flexibility is slightly different to other key parameters in that the development of each flexibility technology is dependent from a wide range of other parameters still to be quantified. In the end it is an output of the electricity market models used to help quantify each of the scenarios. For this reason the present document will focus on the modelling approach of each technology and the priority order consistent with each storylines.

Batteries

The number of residential batteries²⁶ will depend on the penetration of rooftop PV in each country and on a coefficient reflecting storyline drivers. It is expected to be higher in DE due to the offtake of decentralized RES and prosumer behaviour.

Utility-scale battery capacity will subject to the optimisation of the overall electricity system. A benchmark will be made against current studies and will be used to set the percentage relation between market based Solar PV capacity and batteries.

Demand Side Response (DSR)

The boundary conditions of smart charging development will be set based on the number of EVs in a country and the related charging infrastructure. The number of EVs will be determined during the quantification of the scenarios together with the infrastructure levels. Once these parameters have been set, it will be then possible to determine a level of flexibility capacity available to the market.

The level of DSR inside the market will reflect the trajectory collection from TSOs, regression analysis and external studies. The regression analysis will be used to set a starting point followed by comparison with external studies and complimented by TSO/DSO input to determine the final values.

26 Also including tertiary batteries of similar features

Electrolysers

The electrolyser capacity will first depend on the hydrogen demand required to support the decarbonisation of the energy mix. With increasing amounts of variable renewable generation and electrical demand, electrolysers can serve as an additional flexibility source to the electricity system by converting excess electricity into storable energy. In the long term the actual capacity will depend on both purposes and the underlying economic and technical boundary conditions. There are three main configurations for electrolysers:

- 1) Supplied by dedicated renewables and whereby the electrolyser follows the production from the renewable sources.
- 2) Electrolysers connected to both electricity and gas markets (their capacity and location result from the modelling of the electricity system).
- 3) Electrolysers that are on site at end user facilities, and are supplied by the electricity markets (modelled as an electricity load).

Some mixed configurations may develop such as on-site electrolysers with the ability to inject hydrogen in gas network when not directly consumed, or supplied by both on site RES and electricity market.

The combination of the above approaches will determine the electrolyser capacity and the flexibility offered to the system.

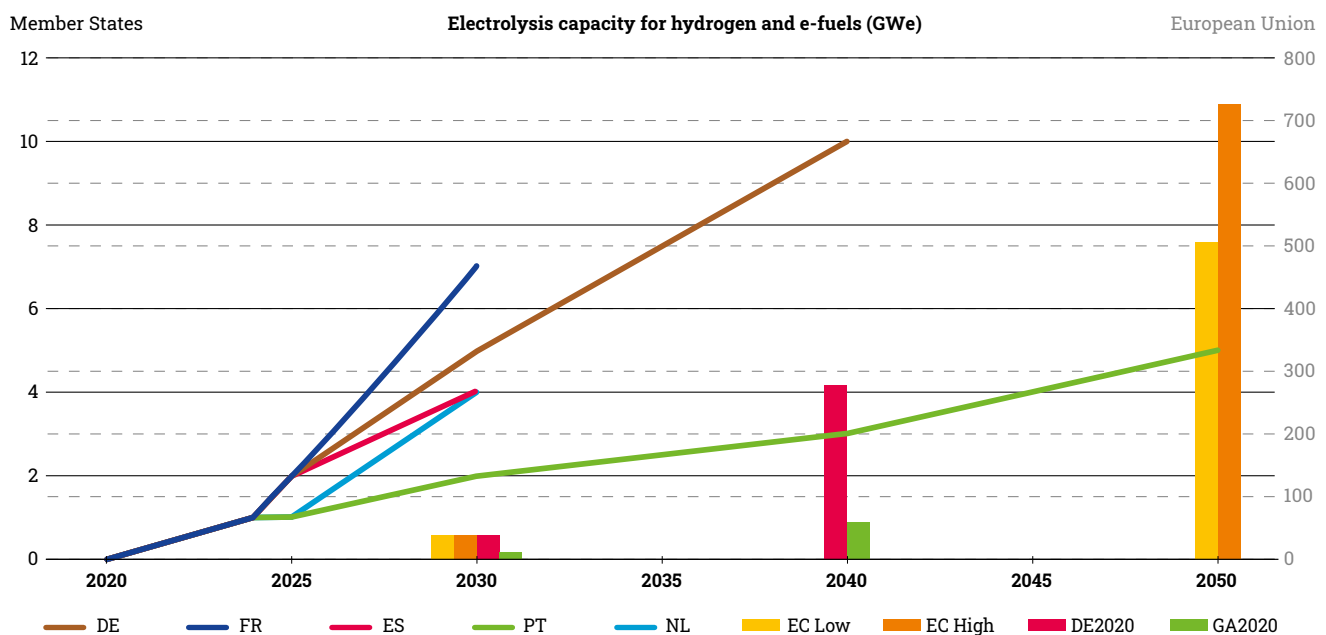


Figure 15: Electrolysis capacity for hydrogen and e-fuels

Priority of the flexibility technologies based on storyline narrative

Scenario DE

In this scenario dispatchable power generation becomes increasingly scarce on annual level. In parallel, there is a very high market share of EVs, the development of prosumer behaviours and the need to replace energy imports by synthetic fuels through electrolysis. As a result, each of the three flexible technologies should reach a significant level. Only utility-scale battery could see a slower development.

Scenario GA

In this scenario there is still dispatchable power generation (nuclear or fossil equipped with CCS) to support the development of variable renewables. As a result, the need of downstream flexibility is lower.

5.4 More information to be provided in draft scenario report

The purpose of the quantitative ranges in the earlier chapters is to support stakeholder understanding what characterises the storylines and how they differ from one another. During the consultation of the draft storyline report we received a lot of requests for additional information and more figures. ENTSOG and ENTSO-E fully understand the added value of providing more data. We should point out however that establishing storylines is only the first step in the scenario building process. We have to acknowledge that the availability of quantitative data is still rather limited. At storyline level we only set the input parameters that are needed for our modelling to be performed. The number of heat pumps and electric vehicles are examples of such input assumptions. The consequences of such input assumptions on energy demand and supply and associated emissions are not yet known at storyline level. These can only be provided after we have completed the energy market modelling.

We intend to provide the full energy picture of the TYNDP 2022 scenario storylines in the draft scenario report to be released in Summer this year. This draft scenario report will be accompanied with a full dataset which will be made available to stakeholders. This dataset will also include figures which are not yet available at storyline level, like for example:

- Final demand for electricity, gas, liquids and solids
- Installed capacity and generation of all electricity generators (solar, wind, biomass, gas, coal, etc)
- Gas supply, including conventional production, renewable gas and import
- Peak demand figures for both gas and electricity
- Carbon emissions.



6

Stakeholder engagement for the TYNDP 2022 storylines

What did we learn from the last process?

The transparency and stakeholder interaction in the TYNDP 2020 Scenario Report was deeper and more detailed than in any previous process. Stakeholder feedback played a key role in shaping the scenarios from the outset and the results and the publication of full final data sets as well as a detailed Scenario Methodology Report allowed stakeholders deeper insight into the development process and the subsequent results.

External feedback on the 2020 cycle showed that the following elements of the process were well-received:

- The **Scenario Methodology Report** offering a detailed description of the condition the underlying assumptions for the scenarios and modelling process.
- The **publication of datasets** on the TYNDP Scenario website allowing all users to scrutinize individual figures and break down results to a member-state level.

- The two **public consultations** (one on the storylines and one on the scenarios) giving all interested parties two occasions to offer input on the scenario building process.
- The **multiple stakeholder workshops** providing regular updates on the process, detailed presentations of specific issues and offering all users a platform to ask questions and share opinions.

These elements will therefore serve as the basis for further expansion of the stakeholder engagement in the TYNDP 2022 scenario building cycle.

However, the lack of information on the determination of certain key parameters was criticised as untransparent. In particular, the qualitative parameters used in the Storyline Report in June 2019 were considered too vague to provide a sound assessment basis. In addition, stakeholders requested greater transparency regarding publication of consultation results.



Goals for the 2022 process

For the 2022 scenario building cycle ENTSG and ENTSO-E have increased their ambition on stakeholder engagement as a key topic building upon the valuable lessons learned from the TYNDP 2020 Scenario Report. In order to ensure the credibility and integrity of the Scenario Report, the Scenario Building Team aims for further enhancing transparency and stakeholder engagement.

In the development of the TYNDP 2022, the Scenario Building Team set four principle goals for the stakeholder engagement process:

1. Stakeholder engagement from Day One

In the 2022 Scenario Report-cycle, the Scenario Building Team agreed to include stakeholders from the very beginning. This began at the kick-off meeting for the process on 3 July 2020, where stakeholder questions were documented (via an interactive Q & A app used during the event), answered and subsequently published on the 2022 TYNDP

Storyline Report website. At the Draft Storyline Consultation Workshop on 2 December 2020, more than 60 participants were in attendance and 46 questions were received. As with the kick-off meeting, the questions received at this event have been answered by the Scenario Building Team and [published as part of the Final Storyline Report](#).

2. Input on key parameters

During the 2020 scenario building process, ENTSG and ENTSO-E engaged with the NGO CAN Europe to calculate a carbon budget for the two top-down scenarios. This approach gave the carbon budget more credibility and provided ENTSG and ENTSO-E with important insights from external experts that enhanced the final scenarios. After the success of this cooperation in the TYNDP 2020 Scenario Report, ENTSG and ENTSO-E have decided to expand their interaction with external organisation.

In order to provide greater transparency on the origins of key data parameters in the Draft Storyline Report, the scenario building team decided to document and publish all interactions with bilateral meetings conducted with external stakeholders (e.g. research institutions, industry organisations etc.). After publishing an initial list of bilateral meetings as part of the Draft Storyline Report, this list has been updated for the publication of the Final Storyline Report and [made available on the TYNDP Scenarios website](#). This documentation provides greater transparency and shows clearly the wide range of organisations that have contributed to the creation of the report.

3. Consultation on hard data – not just concepts

After criticism of the qualitative “storyline matrix” produced for the 2020 Storyline Report, the scenario building team chose not only to use qualitative questions in their public consultation, but also to include quantitative ranges on key parameters (e.g. development trajectories for important technologies or energy carriers) based on data from reputable external studies. This gave stakeholders the opportunity to directly influence the underlying assumptions for the scenarios.

4. Transparent documentation of feedback and interactions

In order to ensure stakeholders that their consultation responses have been considered as part of the scenario building process, the team decided to publish all consultation feedback received in the storyline consultation from November – December 2020.

The scenario building team often receives feedback from external stakeholders outside of the planned consultation windows. While the team has always made every effort to respond to this feedback and answer any questions, it was decided that this correspondence should also be published as part of the 2022 cycle. This information is available on [the TYNDP Scenarios website](#). This publication enhances transparency and provides further insight into the process.



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Next steps

In this report ENTSG and ENTSO-E propose the scenario storylines for TYNDP 2022. This publication is an important foundation for further scenario building and quantification, which spans until the end of this year. This is further illustrated in the Figure 16.

Next steps in the scenario building process are the following:

- In Spring 2021 ENTSG and ENTSO-E will organise a workshop to present the approach about energy import potentials to all stakeholders. Energy suppliers are invited to present their view to cover the various aspects of this topic.
- Now that the final storylines have been established, ENTSG and ENTSO-E will perform the quantification and modelling needed to build the TYNDP 2022 scenarios. With this modelling the (qualitative) storylines will be translated into fully quantified scenarios. A draft scenario report including datasets is expected to be published mid-2021, as part of the next major public consultation phase.
- ENTSG and ENTSO-E will use all consultation feedback to refine and establish the final quantified scenarios to be used in TYNDP 2022. The final scenario report is expected to be published in early 2022. The final scenarios feed into the TYNDP 2022 development process. The scenario datasets are used within the system needs assessment process and the cost-benefit analysis (CBA) for the PCI selection.

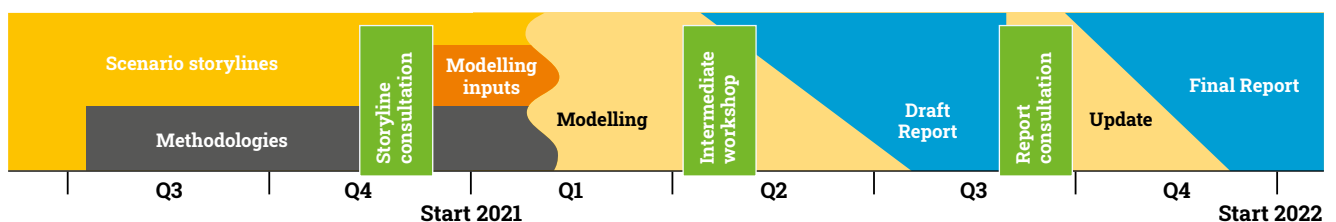


Figure 16: Scenario building process

Annex: Storyline Matrix

High level driver	Dimension	Characteristic	Storyline 1 (DE)	Storyline 2 (GA)
Green transition	by 2030	Compliant with Green Deal (–50 – 55 % GHG emissions)	Yes	Yes
Green transition	by 2050	Reach carbon neutrality	Yes	Yes
Green transition	EU Carbon Budget	Compliant with EU strategies (LTS)	Yes	Yes
Driving force of energy transition	Initiative	Level of Decentralisation (Prosumer vs. Global)	Higher	Lower
Driving force of energy transition	Global Technology and Commodity Trade	Benefits from global synergies (sociatal acceptance and efficiencies)	Lower	Higher
Driving force of energy transition	Autonomy	Share of energy autarky	Higher	Lower
Energy intensity	Residential and Tertiary	Behaviour: surface per person	Lower	Higher
Energy intensity	Residential and Tertiary	Behaviour: share of homeoffice	Higher	Lower
Energy intensity	Residential and Tertiary	Level of energy efficient consumer behaviour (lower room temperature)	Higher	Lower
Energy intensity	Residential and Tertiary	Level of energy efficient consumer behaviour (electric appliances)	Higher	Lower
Energy intensity	Residential and Tertiary	Level of renovation rate	Higher	Lower
Energy intensity	Transport	Level of public/shared transport (occupation per car)	Higher	Lower
Energy intensity	Transport	Number of traveled km per person (including vacation, trade and work)	Lower	Higher
Energy intensity	Transport	Share of autonomous vehicles	Similar	Similar
Energy intensity	Transport	Share of non-motorised transport	Higher	Lower
Energy intensity	Industry	Growth of industry (on shoring, export)	Lower	Higher
Energy intensity	Industry	Raw materials and feedstock (focus on non-energy fuels)	Lower	Higher
Energy intensity	Industry	Data centres	Similar	Similar
Technologies	Low Temperature Heat Demand	District heating (circularity)	Higher	Lower
Technologies	Low Temperature Heat Demand	Small scale gas boilers (households)	Similar	Similar
Technologies	Low Temperature Heat Demand	Small scale hybrid heat pumps (households)	Lower	Higher
Technologies	Low Temperature Heat Demand	Small scale all-electric heat pumps (households)	Higher	Lower
Technologies	Low Temperature Heat Demand	Small scale CHP incl. fuel cells (households)	Higher	Lower
Technologies	Private transport	EV	Higher	Lower
Technologies	Private transport	FCEV	Lower	Higher
Technologies	Heavy goods transport	EV	Higher	Lower
Technologies	Heavy goods transport	FCEV	Lower	Higher

High level driver	Dimension	Characteristic	Storyline 1 (DE)	Storyline 2 (GA)
Technologies	Heavy goods transport	Compressed Methane Cars	Lower	Higher
Technologies	Aviation and shipping	Liquids (methane, hydrogen, bio or synthetic fuels)	Lower	Higher
Technologies	Aviation and shipping	Electricity	Higher	Lower
Technologies	Industry: high temperature heat	Methane	Lower	Higher
Technologies	Industry: high temperature heat	Hydrogen	Lower	Higher
Technologies	Industry: high temperature heat	Electricity	Higher	Lower
Technologies	Carbon economy	CCS (all sources)	Lower	Higher
Technologies	Sector coupling	Share of P2X	Higher	Lower
Technologies	Electricity supply for direct electricity demand	Solar-PV	Higher	Lower
Technologies	Electricity supply for direct electricity demand	Onshore wind	Higher	Lower
Technologies	Electricity supply for direct electricity demand	Offshore wind	Lower	Higher
Technologies	Electricity supply for direct electricity demand	(New) nuclear	Lower	Higher
Technologies	Electricity supply for direct electricity demand	Small Scale CHP (including fuel cells)	Higher	Lower
Technologies	Electricity supply for direct electricity demand	Large Scale CHP (including fuel cells)	Lower	Higher
Technologies	Electricity supply for direct electricity demand	Concentrated Solar Power	Lower	Higher
Technologies	Electricity balancing	Thermal Generation	Similar	Similar
Technologies	Electricity balancing	DSR based on Smart Metering	Higher	Lower
Technologies	Electricity balancing	Flexible power to heat	Higher	Lower
Technologies	Electricity balancing	Batteries (behind the meter)	Higher	Lower
Technologies	Electricity balancing	Large scale electricity storage	Lower	Higher
Technologies	Electricity balancing	Smart charging	Higher	Lower
Technologies	Electricity balancing	P2x	Higher	Lower

The qualitative levels refer to the storyline differentiation at the 2050 time horizon. Most of the drivers will see an evolution in the same direction when compared to the present situation.

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).

Bottom-Up: This approach of the scenario building process collects supply and demand data from Gas and Electricity TSOs.

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

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 sequestering CO₂ and storing it in such a way that it won't enter the atmosphere.

CHP: Combined heat and power

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.

ECI: Energy System Integration Strategy from the European Commission

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 optimize energy efficiency.

ICE: Internal combustion engine

IEA: World Energy Outlook.

Indirect electricity demand: Indirect electrification means electricity demand for production of other energy carriers like hydrogen or synthetic liquids for replacing the use of fossil fuels. Besides industrial processes and hydrogen electrolysis, this could be e.g. heat pumps and electric boilers for district heat production.

IPCC: Intergovernmental Panel on Climate Change

LNG: Liquefied natural gas.

LTS: Long Term Strategy

LULUCF: Land Use, Land Use Change and Forestry. Sink of CO₂ made possible by the fact that atmospheric CO₂ 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 Organization.

P2G: Power to gas. Technology that uses electricity to produce hydrogen (Power to Hydrogen – P2H₂) by splitting water into oxygen and hydrogen (electrolysis). The hydrogen produced can then be combined with CO₂ to obtain synthetic methane (Power to Methane – P2CH₄) or can be converted to other energy carriers like for example synthetic ammonia (P2NH₃)

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

P2X: Aggregation of power to gas and power to liquids.

PCI: Project of Common Interest.

Power-to-Hydrogen/P2Hydrogen: Hydrogen obtained from P2H2.

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

RES: Renewable energy source.

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.

Top-Down: The “Top-Down Carbon Budget” scenario building process is an approach that uses the “bottom-up” model information gathered from the Gas and Electricity TSOs. The methodologies are developed in line with the Carbon Budget approach.

TSO: Transmission System Operator.

TYNDP: Ten-Year Network Development Plan.

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