TYNDP 2020

SCENARIO REPORT

Final Report, June 2020

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Contents

Foreword

We are delighted to present to you the electricity and gas joint Scenario Report,

the second report of its kind to involve ENTSO-E and ENTSOG working closely together to develop three scenarios for Europe. Scenario work is the first important step to capture the interactions between the gas and electricity systems and is therefore paramount to deliver the best assessment of the infrastructure in a hybrid system. The joint work also provides a basis to allow assessment for the European Commission's Projects of Common Interest (PCI) list for energy, as ENTSOG and ENTSO-E progress to develop their Ten-Year Network Development Plans (TYNDPs).

The outcomes of the work presented, illustrates the unique position of the gas and electricity TSOs to provide quantitative and qualitative output: In total almost 90 TSOs, covering more than 35 countries, contributed to the process. The combined expertise and modelling capabilities enabled ENTSO-E and ENTSOG's joint working group to build a set of ambitious and technically robust scenarios.

Stakeholder collaboration and feedback has been an immensely important element of the process and will continue to be in future editions. The publication of the draft Scenario Report on 12 November 2019 was followed by an external Stakeholder Workshop on 5 December and an extensive public consultation. ENTSOG and ENTSO-E have finalised their Scenario Report considering the feedback and recommendations of more than 40 external stakeholders.

A core element of ENTSO-E and ENTSOG's scenario building process has been the use of supply and demand data collected from both gas and electricity TSOs to build bottom-up scenarios. This approach is used for the **National Trends** Scenario, the central policy scenario of this report, recognising national and EU climate targets, notably the National Energy and Climate Plans (NECPs). In view of the 1.5°C target of the Paris Agreement, ENTSOs have also developed the **Global Ambition** and **Distributed Energy** Scenarios using a top-down approach with a full-energy perspective.

Jan Ingwersen
General Director ENTSOG

Laurent Schmitt
Secretary-General ENTSO-E

As ENTSO-E and ENTSOG look to the future, it is evident that innovation, integration and efficiency are key to meeting European energy consumers' needs, whilst also achieving EU decarbonisation goals. Both gas and electricity networks connect countries and lead to regional and pan-European solidarity and economies of scale, while ensuring electricity and gas are delivered reliably to customers throughout the year, including peak demand situations. Both networks play a key role in supporting the uptake of new technologies and meeting decarbonisation challenges. Energy conversion projects must progress: Power-to-Gas, for example, allows electricity from renewables to be transformed into renewable gases, to be stored and transported via the gas infrastructure.

Integration of the electricity and gas sector can optimise the assessment and usage of both grids, whilst continuing to meet the European energy policy objectives of sustainability, security of supply and competitiveness. A hybrid energy infrastructure – consisting of a system of interconnected electricity and gas systems – as cross-border energy carriers will result in flexibility, storage and security of supply.

The integrity of the network development process is reliant on a comprehensive, reliable and contrasted set of possible energy futures – the collaborative efforts of ENTSO-E and ENTSOG, energy industries, NGOs, National Regulatory Authorities and Member States have shown the commitment to ensure this is the case. The development of the Scenarios outlined in this report will allow the TYNDPs to perform a sound assessment of European infrastructure requirements. We look forward to working with you again as we follow the next important steps in the TYNDP process.

1 Introduction

What is this report about?

The TYNDP 2020 Final Scenario Report describes possible European energy futures up to 2050. **Scenarios are not forecasts**; they set out a range of possible futures used by the ENTSO-E and ENTSOG to test future electricity and gas infrastructure needs and projects. The scenarios are ambitious as they deliver a low carbon energy system for Europe by 2050. ENTSO-E and ENTSOG have developed credible scenarios that are guided by technically sound pathways, while reflecting country by country specifics, so that a pan European low carbon future is achieved.

Forward-looking scenarios to study the future of gas and electricity

Regulation (EU) 347/2013 requires that the ENTSO-E and ENTSOG use scenarios for their respective Ten-Year Network Development Plans (TYNDPs) 2020. ENTSO-E use scenarios to assess electricity security of supply for the ENTSO-E Mid-Term Adequacy Forecast (MAF).

All scenarios head towards a decarbonised future and have been designed to reduce GHG emissions in line with EU targets for 2030 or the United Nations Climate Change Conference 2015 (COP21) Paris Agreement objective of keeping temperature rise below 1.5°C.

Why do ENTSOG and ENTSO-E build scenarios together?

The joint scenario report is a basis towards an interlinked model of ENTSO-E and ENTSOG. TYNDP 2018 was the first time ENTSOG and ENTSO-E cooperated jointly on scenario development. There are strong synergies and co-dependency between gas and electricity infrastructures, it is increasingly important to understand the impacts as European policy seeks to deliver a carbon-neutral energy system by 2050.

Joint scenarios allow ENTSOG and ENTSO-E to assess future infrastructure needs and projects against the same future outlooks. The outcomes from the joint scenarios provide decision makers with better information, as they seek to make informed choices that will benefit all European consumers. Combining the efforts from gas and electricity TSOs give ENTSOG and ENTSO-E an opportunity to tap into cross-sectoral 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.

First step towards the 2020 edition of electricity and gas TYNDPs

The joint scenario building process has three storylines for TYNDP2020. **National Trends** is the central policy scenario of this report, designed to reflect the most recent EU member state National Energy and Climate Plans (NECP), submitted to the EC in line with the requirement to meet current European 2030 energy strategy targets. **National Trends** represents a policy scenario used in the infrastructure assessment phase of ENTSOG's and ENTSO-E's respective Ten-Year Network Development Plans (TYNDP) 2020, with a more in-depth analysis as compared to the other scenarios.

In addition, ENTSO-E and ENTSOG have created two scenarios in line with the COP21 targets (**Distributed Energy** and **Global Ambition**) with the objective to understand the impact on infrastructure needs against different pathways reducing EU-28 emissions to net-zero by 2050. The three scenario storylines developed in consultation with stakeholders are detailed extensively in ENTSOG and ENTSO-E Storylines Report[1] released in May 2019. Distributed Energy has been further adapted on the 2040–2050 time horizon taking into account stakeholder feedback and to ensure higher differentiation with the other COP21 Scenario, Global Ambition.

Visualise and download scenarios data

The joint scenario package provides an extensive data set resource that is used for the ENTSO TYNDP and is the basis for other studies. Scenario information contained in this report is provided in EU-28 terms unless stated otherwise. The technical datasets submitted to the TYDNP process and available to download extend beyond the EU-28 countries, including countries such as Norway, Switzerland, Turkey.

ENTSOG and ENTSO-E invite stakeholders to use the scenario data sets for their own studies. All data from the scenarios can be accessed via the visualisation platform[2].

Whereas **Distributed Energy** and **Global Ambition** have been built as full-energy scenarios with a perspective until 2050, **National Trends** is based on electricity and gas related data aligned with NECPs and developed until 2040.

Methodology in details

The development of the scenarios builds on storylines and a methodology to translate the storylines into parameters and eventually figures. The TYNDP 2020 Scenario Methodology Report[3] provides full transparency on how the scenarios are elaborated and how the development of different demand technologies, generation and conversion capacities, renewable shares and all other parameters are considered.

1 https://www.entsog.eu/sites/default/files/2019-06/190408_WGSB_Scenario%20Building%202020_Final%20Storyline%20Report.pdf

2 https://www.entsos-tyndp2020-scenarios.eu/visualisation-platform/

3 https://www.entsos-tyndp2020-scenarios.eu/wp-content/uploads/2020/06/TYNDP_2020_Scenario_Building_Guidelines_Final_Report.pdf

2 Purpose of the scenario report

What is the purpose of the scenarios and how should they be used?

As outlined in Regulation (EU) 347/2013, ENTSOG and ENTSO-E are required to use scenarios as the basis for the official Ten Year Network Development Plans (created every two years by ENTSO-E and ENTSOG) and for the calculation of the cost-benefit analysis (CBA) used to determine EU funding for electricity and gas infrastructure Projects of Common Interest (PCI). The scenarios were designed specifically for this purpose. Where possible, they have been derived from official EU and member-state data sources, and are intended to provide an impartial quantitative basis for infrastructure investment planning.

The scenarios are intended to project the long-term energy demand and supply for ENTSOG's and ENTSO-E's Ten Year Network Development Plan development within the context of the ongoing Energy Transition. They are designed in such a way that they specifically explore those uncertainties which are relevant for gas and electricity infrastructure development. As such, they primarily focus on aspects which determine the infrastructure utilisation. 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 should provide the user with insight into the energy system of the future and the role of electricity and gas carriers in this energy system. Users are able to determine the effects of changes in supply and demand on the energy system. The European and global perspectives for these scenarios enable the user to track supply and demand developments geographically as well as temporally and to gain greater insight into the challenges facing energy infrastructure during the Energy Transition.

What *isn't* the purpose of the scenarios?

The Working Group Scenario Building has gone to great lengths to build on the 2020 Scenario Report and to increase its ambitions, especially in considering external factors such as the Energy Transition and the decarbonisation of the European energy system on energy infrastructure. Nonetheless, it is important to recognise that the scope of these scenarios remains focused on providing sufficient input data to model future infrastructure needs.

The Working Group Scenario Building have sought to avoid making political statements with these scenarios and, as far as possible, to anchor key parameters in widely accepted data and assumptions. The National Trends scenario exists within an input framework provided by official data sets (such as PRIMES) and official energy policies (the NECPs of the EU member states). The goal of the Working Group Scenario Building has been to maintain a neutral perspective to these inputs.

While the top-down scenarios have greater room for innovation to meet more ambitious decarbonisation of the Energy system up to 2050, it is not the intention of the Working Group Scenario Building to use these scenarios to push political agendas attached to the use or non-use of specific energy carriers or technologies. The main focus of the TYNDP Scenario Report is the long-term development of energy infrastructure. As such, the differences between the two top-down scenarios (Global Ambition and Distributed Energy) are predominantly related to possible variations in demand and supply patterns.

To this end, all the scenarios in the TYNDP 2020 Scenario Report remain technology and energy-carrier neutral. The energy mix deployed in each of these scenarios has been designed to reflect a broad consensus within the energy industry and correlates to a large extent with official literature – most prominently with the EU's own Long-Term Strategy scenarios.

Where the scenarios have incorporated parameters defined by external analysis (such as the calculation of a carbon budget by Climate Action Network Europe or the Biomethane Tool designed with the support of Navigant), the external analysis conforms to the widely accepted understanding of these topics.

The TYNDP 2020 Scenario Report attempts to reflect the Energy Transition and the decarbonisation efforts of the European energy system in its scenarios. This is incorporated by the use of the COP21 Agreement (in the form of a carbon budget calculation) as one of the key input parameters for the top-down scenarios. However, it is important to recognize that it is beyond the scope (and indeed the resources) of the Working Group Scenario Building to analyse political, environmental and indeed societal developments on the widest scale.

Above all it is important to recognize the fast-moving nature of the Energy Transition in Europe. The Working Group Scenario Building recognises the reality that some of the input parameters used in the creation of these scenarios may well need to be adjusted in the months and years to come as the energy policy of the EU and its member states evolves to meet the challenges of climate change. We take this opportunity to remind the reader that the TYNDP Scenario Building Process is an iterative process and it continues to evolve based on external influences. A scenario is a picture of the future; however, it is also a reflection of the present knowledge and the foreseeable challenges face today.

3 Highlights

1) To comply with the 1.5°C targets of the Paris Agreement, carbon neutrality must be achieved by 2040 in the electricity sector and by 2050 in all sectors together. Additional measures to reach net negative emissions after 2050 are necessary.

2) To achieve net-zero emissions, innovation in new and existing technologies is required to:
   - reduce the levelised cost of energy from renewable energy sources
   - increase the efficiency and type of end user appliances
   - support renewable and decarbonised gas[4]
   - develop technologies that will support negative emissions

3) "Quick wins" are essential to reduce global temperature warming. A coal to gas switch in the power sector can save at least 85 $MtCO_2$ by 2025.

4) To optimise conversions, the direct use of electricity is an important option – resulting in progressive electrification throughout all scenarios. Gas will continue to play an important role in sectors such as feedstock in non-energy uses, high-temperature processes, transport or in hybrid heating solutions to make optimal use of both infrastructures.

5) To move towards a low carbon energy system, significant investment in gas and electricity renewable technologies is required. Further expansion of cross border transfer capacity between markets will contribute to ensuring renewable resources are efficiently distributed and dispatched in the European electricity market.

6) Wind and solar energy will play an important role in the European energy system, however, the scenarios point out that the decarbonisation of gas will have a significant part to play as well. The scenarios show that the decarbonisation of the gas carrier is necessary, employing technologies to increase the share of renewable gases, such as bio-methane and Power-to-Gas, and decarbonised gases associated with Carbon Capture and Storage (CCS).

7) At present gas as an energy carrier is mainly based on methane, as the main component of natural gas. However, in the longer-term hydrogen could become an equally important energy carrier towards full decarbonisation of the gas carriers in 2050.

8) Sector Coupling enables a link between energy carriers and sectors, thus it becomes key in contributing to achieve the decarbonisation target. In the long-term, Power-to-Gas and Power-to-Liquid will play a key role in both the integration of electricity from variable renewables and decarbonising the supply of gas and liquid fuels. This would require close to 800 GW of dedicated wind and solar[5] in 2050. Gas-fired power plants will continue to provide peak power flexibility to support an energy mix based on increasingly variable electricity generation.

9) Today, the EU28 imports most of its primary energy (ca. 55 %[6]). Decarbonisation will also change this pattern. In a way, the "insourcing" of energy production will reduce the import dependency to ca. 20 % to 36 %. However, imports remain an important vector in the future energy supply making use of competitive natural resources outside the EU territory. For gas in particular, import shares increase in all scenarios until 2030 due to the declining natural gas production in the EU.

4 Decarbonised gas is natural gas for which the carbon dioxide is removed by pre- or post-combustion carbon capture and storage (CCS) technology. Renewable gas on the other hand originates from renewable sources. For example, biomethane produced from organic material or hydrogen/synthetic methane from electrolysis (P2G). More information definitions can be found in the glossary or in the methodology report.

5 According to the P2G and P2L modelling approach, the dedicated wind and solar is simulated outside the integrated electricity system.

6 See EUROSTAT (link)

4 Special Focus: Pathways towards a decarbonised economy

4.1 National Trends – the central policy scenario aligned with draft NECPs

Meeting European targets considering current policies

National Trends aims at reflecting the commitments of each Member State to meet the targets set by the European Union in terms of efficiency and GHG emissions reduction for the energy sector. At country level, National Trends is aligned with the NECPs of the respective Member States[7], which translate the European targets to country specific objectives for 2030.

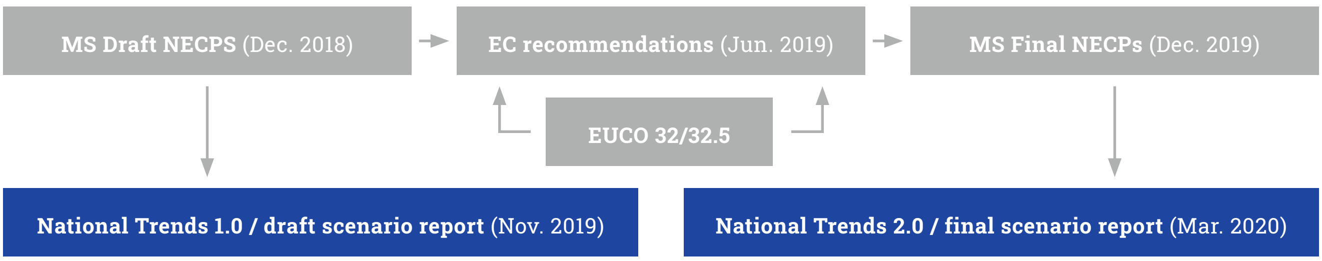


Figure 1: National Trends scenario interactions with NECPs (Final NECPs, EUCO scenarios)

7 Most Member States submitted their final NECP by the end of 2019. At the time of drafting this scenario report, some NECPs are still under revision though. For these countries, the ENTSOs took the draft NECPs instead.

4.2 COP21 scenarios – a carbon budget approach

Below +1.5°C at the end of the century with a carbon budget

Distributed Energy (DE) and Global Ambition (GA) (also referred to as "COP21 Scenarios") scenarios are meant to assess sensible pathways to reach the target set by the Paris Agreement for the COP21: 1.5°C or at least well below 2°C by the end of the century. For the purpose of the TYNDP scenarios, this target has been translated by ENTSO-E and ENTSOG into a carbon budget to stay below +1.5°C at the end of the century with a 66.7% probability[8].

A carbon budget defined with environmental organisations

To limit the global warming to +1.5°C by the end of the century, there is a maximum quantity of GHG the EU – including the energy system – can emit. This defines the carbon budget for the EU, and to a more restrictive extent, the share allocated to the energy system that the COP21 scenarios consider. To define the carbon budget until the year 2100, ENTSO-E and ENTSOG have worked with the environmental NGOs Renewable Grid Initiative and Climate Action Network Europe.

A carbon neutral energy system by 2050

The other objective set in the COP21 scenarios is to reach carbon neutrality[9] of the energy system by 2050. This objective therefore places further demands on the speed of decarbonisation the energy system should reach.

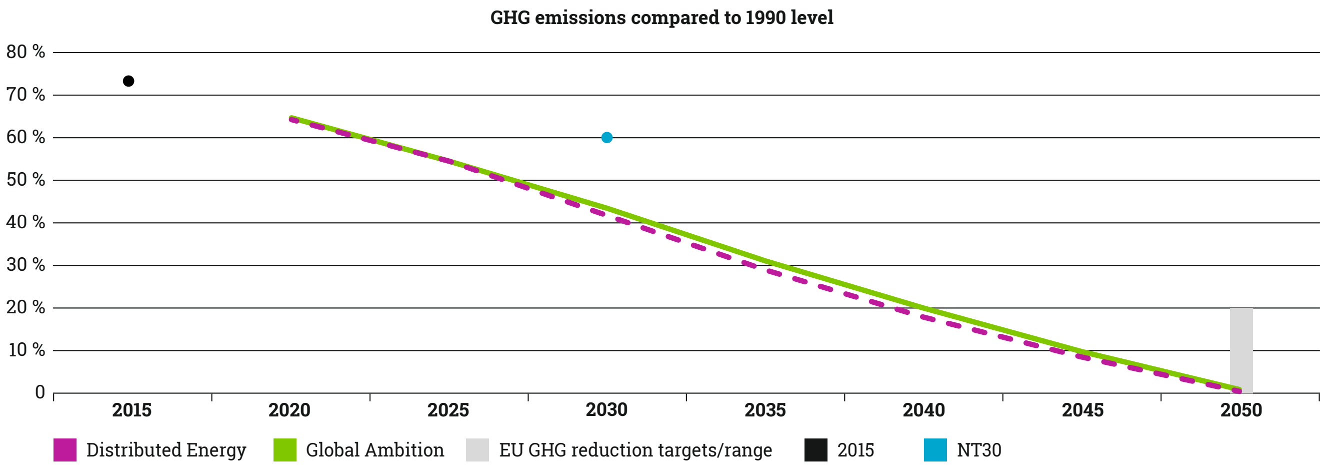
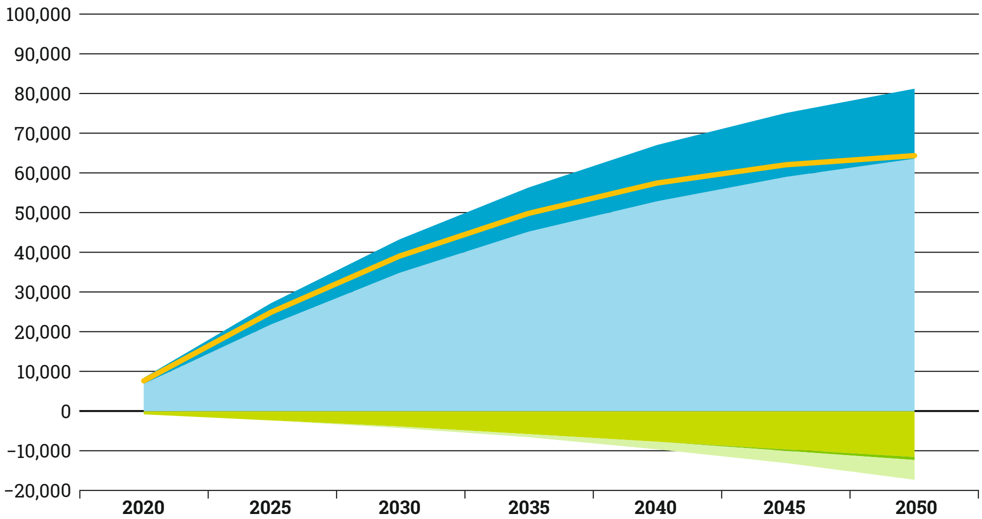


Figure 2: GHG emission in ENTSOS' scenarios

8 The Intergovernmental Panel on Climate Change, Special Report, 2018, https://www.ipcc.ch/sr15/

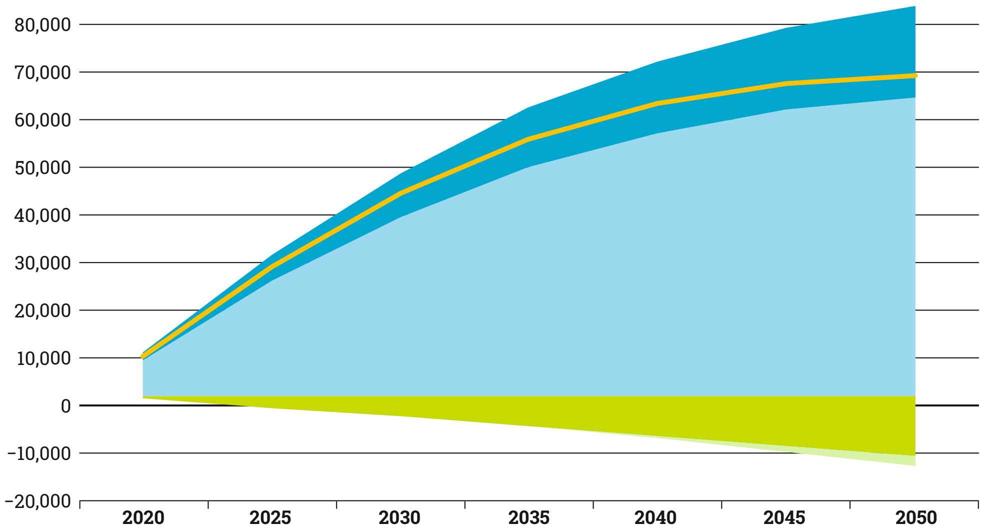
9 "Carbon neutrality (or net zero) means having a balance between emitting carbon and absorbing carbon from the atmosphere in carbon sinks. Removing carbon oxide from the atmosphere and then storing it is known as carbon sequestration. In order to achieve net zero emissions, all worldwide greenhouse gas emissions will have to be counterbalanced by carbon sequestration" (European Parliament (link)). The ENTSOs consider all greenhouse gas emissions measured in terms of their carbon dioxide equivalence.

EU 28 cummulative GHG emissions – Global Ambition



	2020	2025	2030	2035	2040	2045	2050
Cummulative non-CO_2 emissions	1,534	5,135	8,401	11,311	13,844	16,000	17,780
Cummulative CO_2 emissions	6,743	21,953	34,686	44,995	53,008	59,075	63,504
Cumulative credits from pre- and post-combustive CCS	0	0	−136	−679	−1,673	−3,034	−4,676
Cummulative credits from BECCS	0	0	0	−32	−128	−356	−808
Cummulative credits from LULUCF	−627	−2,253	−3,963	−5,757	−7,635	−9,598	−11,644
Net Cummulative CO_2eq emissions	7,650	24,835	38,988	49,838	5,7416	62,087	64,155

EU 28 cummulative GHG emissions – Distributed Energy



	2020	2025	2030	2035	2040	2045	2050
Cummulative non-CO_2 emissions	1,534	5,132	8,394	11,298	13,821	15,963	17,725
Cummulative CO_2 emissions	6,735	21,985	34,486	43,860	50,456	54,784	57,113
Cumulative credits from pre- and post-combustive CCS	0	0	−56	−260	−642	−1,165	−1,778
Cummulative credits from BECCS	0	0	0	0	0	0	0
Cummulative credits from LULUCF	−627	−2,253	−3,963	−5,757	−7,635	−9,598	−11,644
Net Cummulative CO_2eq emissions	7,642	24,864	38,860	49,141	55,999	59,984	61,416

Figure 3: EU28 Cummulative Emissions in COP21 Scenarios in $MtCO_2$

Carbon neutrality can be reached by 2050 within a budget of 61 $GtCO_2$ …

Both Distributed Energy and Global Ambition scenarios show that a centralised or decentralised evolution of the energy system can achieve carbon neutrality by 2050. The scenarios also show that, considering different development of technologies – and starting from 2018 onwards – the energy system can limit its emissions to reach not more than 64.2 $GtCO_2$ at EU level until 2050 in Global Ambition, and not more than 61.4 $GtCO_2$ in Distributed Energy.

… but negative emissions are needed after 2050

However, the scenario budget defined to limit the global warming to 1.5°C with a 66.7 % probability considers that the cumulative EU GHG emissions should be limited to 48.5 $GtCO_2$ by the end of the 21st century. This means net negative emissions of 15.7 $GtCO_2$ have to be achieved between 2050 and 2100 in case of Global Ambition, provided the EU is carbon neutral in 2050. For Distributed Energy, due to lower cumulative emissions until 2050, 12.9 $GtCO_2$ of net negative emissions are needed to reach the 1.5°C target by 2100.

	<2050	2050	>2050	Total
Energy and non-energy related CO_2 emissions	57.1	Carbon-Neutrality	Additional measures needed, e.g.: LULUCF, BECCS, CCS, DAC	
Non-CO_2 GHG emissions (including methane and Fluorinated gases)*	17.7			
Carbon sinks**	−13.4			
Net cumulative emissions	61.4		−13	EU28 carbon budget share based on its population 48.5 $GtCO_2$

* Data for methane and fluorinated gases emissions is taken from the European Commission's most ambitious 1.5TECH and 1.5LIFE scenarios (average) as published in the "A Clean Planet for all"-Study (link).

** Data for LULUFC is taken from the European Commission's most ambitious 1.5TECH and 1.5LIFE scenarios (average) as published in the "A Clean Planet for all"-Study (link).

Table 1: Cumulative emissions and required net negative emissions in Distributed Energy

4.3 Sector-Coupling – an enabler for (full) decarbonisation

For ENTSOG and ENTSO-E, sector coupling describes interlinkages between energy carriers, related technologies and infrastructure. Major processes in this regard are gas-fired power generation, Power-to-Gas (P2G) as part of the broader Power-to-X and hybrid demand technologies.

ENTSOs' scenarios are dependent on further development of sector coupling, without these interlinkages a high or even full decarbonisation in the energy sector will not be reached.

Assuming a switch from carbon-intensive coal to natural gas in 2025, a minimum of 85 $MtCO_2$ could be avoided in the power generation. With increasing shares of renewable and decarbonised gases, gas-fired power plants become the main "back-up" for variable RES in the long-term. Distributed Energy even shows a further need for CCS for gas power plants to reach its ambitious target of full decarbonisation in power generation by 2040.

On the other hand, P2G becomes an enabler for the integration of variable RES and an option to decarbonise the gas supply. Hydrogen and synthetic methane or liquids allow for carbon-neutral energy use in the final sectors. Distributed Energy is the scenario with the highest need for P2G and P2L, requiring 1,460 TWh of dedicated power generation[10] per year with more than 490 GW of capacities for wind and solar in 2040 to produce renewable gas.

Sector coupling in National Trends, with the assumption that P2G generation is limited to substitute otherwise curtailed electricity supply, amounts to 27 TWh with 22 GW of P2G to produce renewable gas.

10 According to the P2G and P2L modelling approach, the dedicated wind and solar is simulated outside the integrated electricity system.

5 Scenario description and storylines

To ensure consistency between successive TYNDP reports, it is necessary to preserve the scenarios essence to some degree. Therefore, the 2020 scenarios build on the 2018 scenarios. However, the energy landscape is continuously evolving, and scenarios must keep up with the main drivers and trends influencing the energy system.

Storyline drivers

ENTSOG and ENTSO-E identified two main drivers to develop their scenario storylines: Decarbonisation and centralisation/decentralisation. Decarbonisation refers to the decline in total GHG emissions while centralisation/decentralisation refers to the spatial set-up of the energy system, such as the share of large/small scale electricity generation (offshore wind vs. solar PV) or the share of indigenous renewable gases (biomethane and P2G) vs. share of decarbonised gas imports (either pre- or post-combustive). Figure 4 illustrates the relation of the two key drivers for all three scenarios.

For the short and medium-term, the scenarios include a "Best Estimate" scenario (bottom-up data including a merit order sensitivity between coal and gas in 2025). For the longer term, they include three different storylines to reflect increasing uncertainties.

- For 2020 and 2025, all scenarios are based on bottom-up data from the TSOs called the "Best Estimate" Scenario and reflecting current national and European regulations. A sensitivity analysis regarding the merit order of coal and gas in the power sector is included for 2025 following stakeholder input regarding the uncertainty on prices, even in the short term. These are described as 2025 Coal Before Gas (CBG) and 2025 Gas Before Coal (GBC).

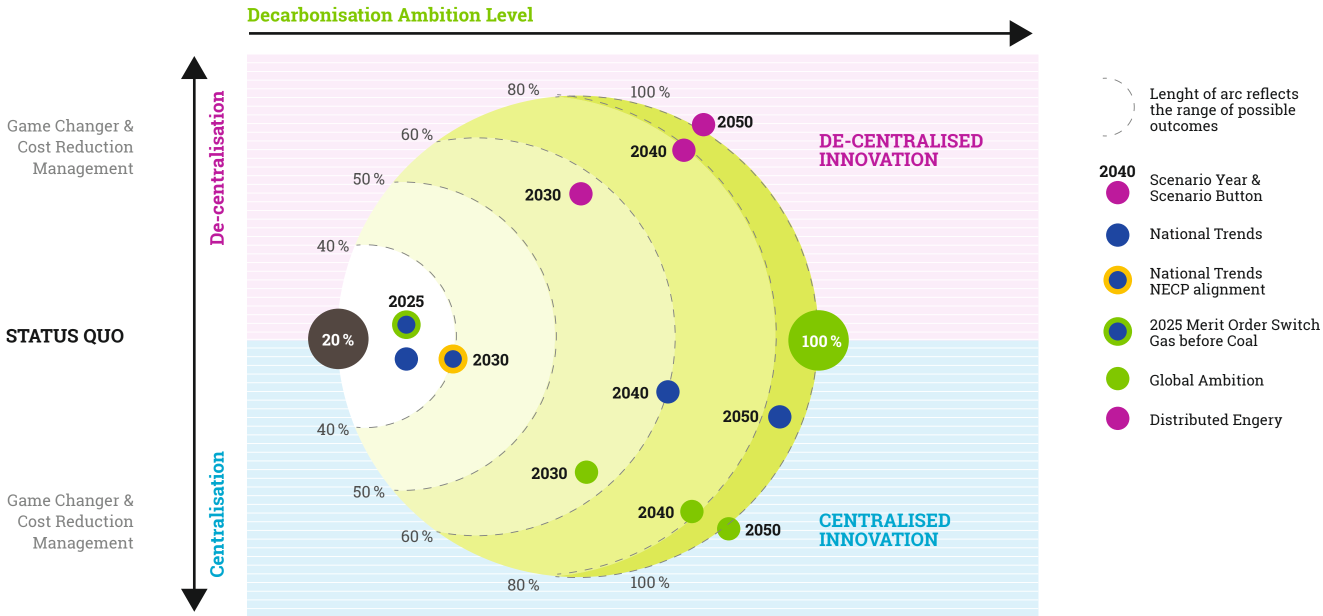


Figure 4: Key drivers of Scenario Storylines

- National Trends keeps its bottom-up characteristics, taking into account TSOs' best knowledge of the gas and electricity sectors in compliance with the NECPs. Country-specific data was collected for 2030 and 2040 (when available for electricity) in compliance with the TYNDP timeframe. For gas, further assumptions have been made to compute the demand for 2050 on an EU28-level.

- Distributed Energy and Global Ambition are built as full energy scenarios (all sectors, all fuels) with top-down methodologies. Both scenarios aim at reaching the 1.5°C target of the Paris Agreement following the carbon budget approach. They are developed on a country-level until 2040 and on an EU28-level until 2050.

The storylines for 2030 and 2040/2050 are:

- **National Trends (NT)** is the central bottom-up scenario in line with the NECPs in accordance with the governance of the energy union and climate action rules, as well as on further national policies and climate targets already stated by the EU member states. Following its fundamental principles, NT is compliant with the EU's 2030 Climate and Energy Framework (32 % renewables, 32.5 % energy efficiency) and EC 2050 Long-Term Strategy with an agreed climate target of 80–95 % CO_2 reduction compared to 1990 levels.

  National Trends relies on data provided by the latest submissions of country specific NECPs for 2030 at the freeze date of the data. Where, in particular for 2040, NECPs do not provide sufficient information or necessary granularity, National Trends is based on TSOs' best knowledge in compliance with national long-term climate and energy strategies.

- **Global Ambition (GA)** is a scenario compliant with the 1.5°C target of the Paris Agreement also considering the EU's climate targets for 2030. It looks at a future that is led by development in centralised generation. Economies of scale lead to significant cost reductions in emerging technologies such as offshore wind, but also imports of energy from competitive sources are considered as a viable option.

- **Distributed Energy (DE)** is a scenario compliant with the 1.5°C target of the Paris Agreement also considering the EU's climate targets for 2030. It embraces a de-centralised approach to the energy transition. A key feature of the scenario is the role of the energy consumer (prosumer), who actively participates in the energy market and helps to drive the system's decarbonisation by investing in small-scale solutions and circular approaches. Based on stakeholders' feedback on the Draft Scenario Report, a part of biomass usages has been transferred to both P2L and direct electricity consumption resulting in an updated Storyline Central Matrix. The updated scenario comes very close to 1.5 TECH/LIFE scenario of the European Commission for most of the parameters.

For more information on the development of the Scenario Storylines and how the stakeholder feedback has been taken into account please refer to section 10.

Category	Criteria	2040 Scenarios		
		National Trends	Global Ambition	Distributedion Energy
Primary mix	Coal	--	---	---
	Oil	--	---	---
	Nuclear	--	--	--
	Hydro	o	o	o
	Geothermal	o	+	++
	Biomass *	o	++	+
	Natural gas	-	--	---
	Wind onshore	++	+++	+++
	Wind offshore	+++	+++	++
	Solar	++	+	+++
	Wind for P2G and P2L**	o	+	+++**
	Solar for P2G and P2L	+	+	+++
	Imported Green Liquid Fuel	+	++	+
	Energy Imports	-	--	---
High temperature Heat	Total demand (all energy)	o	-	-
	Electricity Demand	+	+	++
	Gas Demand	+	++	o
Low temperature Heat	Total demand (all energy)	-	--	--
	Electricity Demand	+	++	+++
	Gas Demand	-	-	--
Transport	Total demand	-	--	--
	Electricity Demand	+	++	+++
Power and Lighting	Gas Demand	+	++	+
	Electricity Demand	o	-	-
CCS	CSS	o	+++	+

Change from today	---	--	-	o	+	++	+++
	Not available	Moderate Reduction	Low Reduction	Stable	Low growth	Moderate growth	High growth

* biomass use in National Trends is very close to current use and the evolution has been reduced to”Stable” compared to the Draft Scenario Report. For Distributed Energy scenario, the substitution of biomass by direct electrification and P2L has resulted in an update of the evolution from “Moderate growth” to “Low growth”.

** For Distributed Energy scenario, the substitution of biomass by direct electrification and P2L supplied with additional RES has resulted in an update of the evolution from “Moderate growth” to “High growth”.

Table 2: Storyline Central Matrix

Scenario Building Central Matrix

The Scenario Building Central Matrix is a tool used to identify the key elements of the storylines. The Central Matrix enables creation of scenarios that are consistent along a pathway, yet differentiated from other storylines.

The Central Matrix is a table that can provide an EU-wide qualitative overview of key drivers for the European energy system in 2050. The matrix uses +/– indicators to show how primary energy mix and final energy use change compared to sectors are assumed to change from today. It is important to note that country level and/or regional differences will be present, when compared to the EU-28 figures, the differences are driven by factors such as national policy, geographical and/or technical resource constraints.

To understand the matrix notation, the following assumptions must be considered:

- The growth or reduction indications are in relation to what is seen today, but also in relation to the rates observed within that category in comparison to the other scenarios. For example, compared to today, solar generation is expected to increase significantly in all scenarios from today, but only receives a +++ in Distributed Energy.
- Equally, growth and reduction rates across the different categories are not directly comparable. For example, two categories with ++ rating may differ significantly in their actual percentage increase from today, based on the starting point and ultimate potential.

Where storyline parameters have been updated based on consultation feedback on the Draft Scenario Report, the initial values are mentioned as footnotes.

Further information on how to read the Central Matrix can be found in the annex document Scenario Methodology Report.

Figure 5: The TYNDP 2020 Scenarios are defined by three Storylines

6 Scenario Results

The level of detail provided for each scenario depends on the approach to building the data set.

The National Trends bottom-up collection uses gas and electricity demand data from the TSOs aligned with the NECPs. The final energy demand supplied by other primary fuels, such as for heat and transport, is not in focus of the TSO data collection; therefore sector by sector energy demand splits cannot be reported. The bottom up data is based on member state NECPs, this underpins the assumption that the bottom up gas and electricity demand data contributes fairly towards the EU28 Clean Energy Package targets for 2030; 32 % renewable energy along with 32.5 % energy efficiency.

The new top-down scenario building approach provides ENTSOG and ENTSO-E with new opportunities to report on total primary energy and the sector splits for final energy demand. The top-down energy modelling approach evolves in five year steps from historical energy balance data, so it is possible to report on the sectoral final energy demand over time.

6.1 Demand

Note: All gas figures are expressed in gross calorific value (GCV) except when stated otherwise in net calorific value (NCV). Where needed, external scenario figures have been converted to gross calorific values by applying a factor of 110%. For the definition of gross and net calorific value please refer to the glossary section at the end of this document.

6.1.1 Final Energy Demand

The chart below shows the total energy sector demand for the storylines Distributed Energy and Global Ambition. A key driver in how the final energy demand volumes are derived is a EU28 target specifying a 32.5% reduction in final use energy demand by 2030 compared to 2005. The final use demand for the EU28 according to DEE2012/27/EU(10309/18)[11] should be around 11,100 TWh. The final use energy demand figure does not include the energy requirement for non-energy uses. When this adjustment is taken into account, final energy demand in 2030 for Distributed Energy is 10,500 TWh and Global Ambition 10,600 TWh. Both scenarios achieve in 2050 higher efficiency gain above 50%, higher than 1.5TECH and LIFE LTS scenarios.

Final energy demand can achieve ambitious reductions in energy volume due to changes to end user applications and energy efficiency measures. The scenario storylines capture themes such as, but not limited to:

- Converting from less efficient heating options to heat pump technologies, such as electric or hybrid (combined gas and electricity usage) air or ground heat pumps,

- Switching from low efficiency transport options to more efficient modes of transport

- Energy efficiency product standards; continue to deliver energy efficiency gains for end-user appliances

- In the built environment thermal insulation reduces demand for heat, while ensuring comfort level are maintained

- Behavioural changes where consumers actively reduce demand either by utilising more public transport or modifying heating and cooling comfort levels.

Although overall final energy demand is decreasing, gas and electricity show different trends. For gas at least until 2025 as well as for electricity in the long-run, the energy demand growth is driven by factors such as underlying gross domestic product (GDP) growth, additional energy demand from low temperature heat and transport sectors as these sectors switch away from carbon-intensive fuels, such as coal and oil. The storylines assume that at an EU level underlying GDP growth is tempered by the strong energy efficiency measures, so that final energy demand (which includes electricity demand) is reduced to meet the EU28 32.5% energy efficiency target for 2030.

The National Trends energy figures are based on the TSO data compatible with the latest available data from member state NECPs. The annual energy volumes come from national forecasts, that are summed up to provide information at EU28 level.

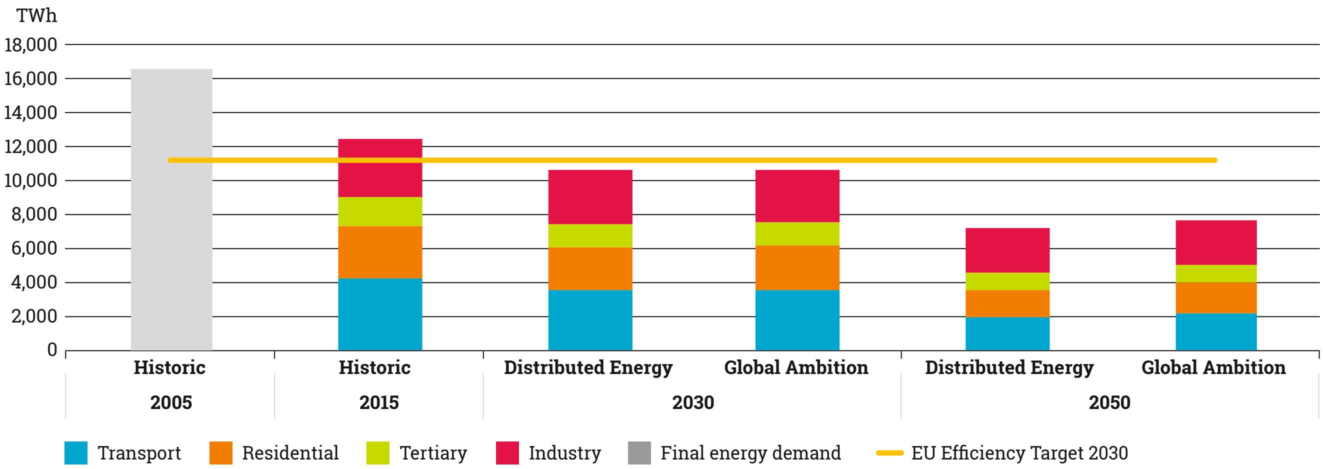


Figure 6: Final energy demand in COP21 scenarios

11 https://ec.europa.eu/energy/en/topics/energy-efficiency/targets-directive-and-rules/eu-targets-energy-efficiency

Scenario	EU-28 Annual Electricity Demand (TWh)					Compound Annual Growth Rate		
	2015	2025	2030	2040	2050	2015–2030	2030–2040	2040–2050
Historical Demand	3,086							
National Trends		3,199	3,237	3,554	3,696	0.3 %	0.6 %	0.4 %
Global Ambition			3,213	3,426	3,478	0.3 %	0.6 %	0.2 %
Distributed Energy			3,422	4,029	4,269	0.7 %	1.5 %	0.7 %

Table 3: Annual EU-28 electricity demand volumes and the associated growth rate

6.1.2 Direct Electricity Demand[12]

The scenarios show that higher direct electrification of final use demand across all sectors results in an increase in the need for electricity generation.

Distributed Energy is the scenario storyline with the highest annual electricity demand reaching around 4,000 TWh in 2040 and around 4,300 TWh in 2050. The results for scenarios show that there is the potential for year on year growth for EU28 direct electricity demand. The table provides annual EU-28 electricity demand volumes and the associated growth rate for the specified periods.

The growth rates for the storyline show that by 2040 National Trends is centrally positioned in terms of growth between the two more-ambitious top-down scenarios Distributed Energy and Global Ambition. The main reason for the switch in growth rates is due to the fact that Global ambition has the strongest levels of energy efficiency, whereas for Distributed Energy strong electricity demand growth is linked to high electrification from high uptake of electric vehicles and heat pumps (in households and district heating), overlaying electrical energy efficiency gains.

Peak electricity demand is defined as the highest single hourly power demand (GW) within a given year. Peak demand growth in the future will be impacted in a number of ways, for example;

- The roll out of smart metering, these may provide more opportunities for intelligent or efficient energy demand patterns by consumers in time

- High growth rates for passenger electric vehicles probably lead to pressures on the electrical grid, both at distribution and transmission levels. The scenarios assume that there is an inherent level of smart charging that shifts consumer behaviour away from peak periods.

- Electric and hybrid heat pumps. The demand time series created are weather dependent. The results show that electric heat pumps can add pressure to demand; i.e. there is more heat demand when the outside temperatures are low. There are a number of options to support direct electric heating, such as, thermal storage or hybrid heating systems. For example: Hybrid systems can help mitigate the adverse impact on the electricity grid by switching to gas during extreme cold periods (typically less than 5°C).

- New peak demand challenges may result from additional new baseload demand, such as data centres assuming that digitalisation increases globally.

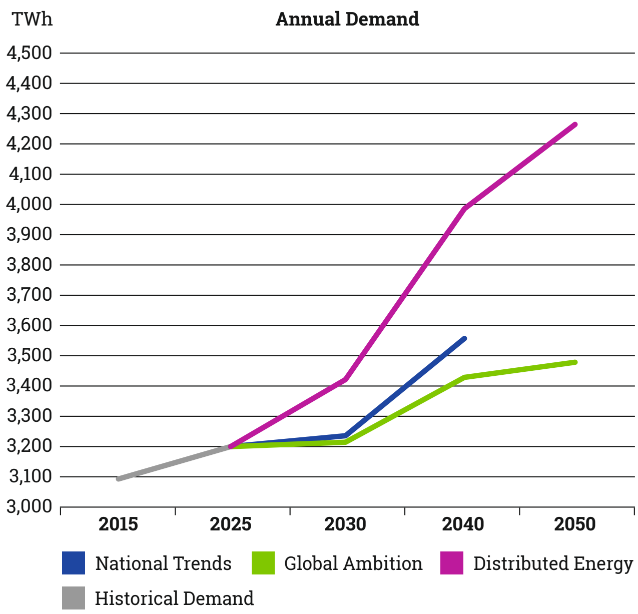


Figure 7: Direct electricity demand per scenario (EU28)

12 Direct Electricity Demand refers to the electricity end use in sectors such as residential, tertiary, transport and industry

The hourly demand charts show that the historical effects of GDP and energy efficiency continue influencing electricity demand growth in industry, tertiary and residential sectors. The scenarios show that direct electrification of transport and heating sectors starts to have a significant impact on the hourly profiles.

It is clear from the future demand profile composition that the impact of electric vehicles is noticeable throughout the year. The impact for heat pumps is however largely dependent on the outside weather temperature. Naturally, there is a reduced demand for heat in the summer, but electrified water heating remains part of the composition during summer periods.

Peak demand for electricity grows between 2030 and 2040 for each storyline. The electrification of heat and transport are two significant drivers in growth of electricity peak demand. The storyline assumptions mean that GDP related peak demand growth is moderated by energy efficiency. The impact of demand side response on peak electricity is modelled as a priced demand side response in the power market analyses.

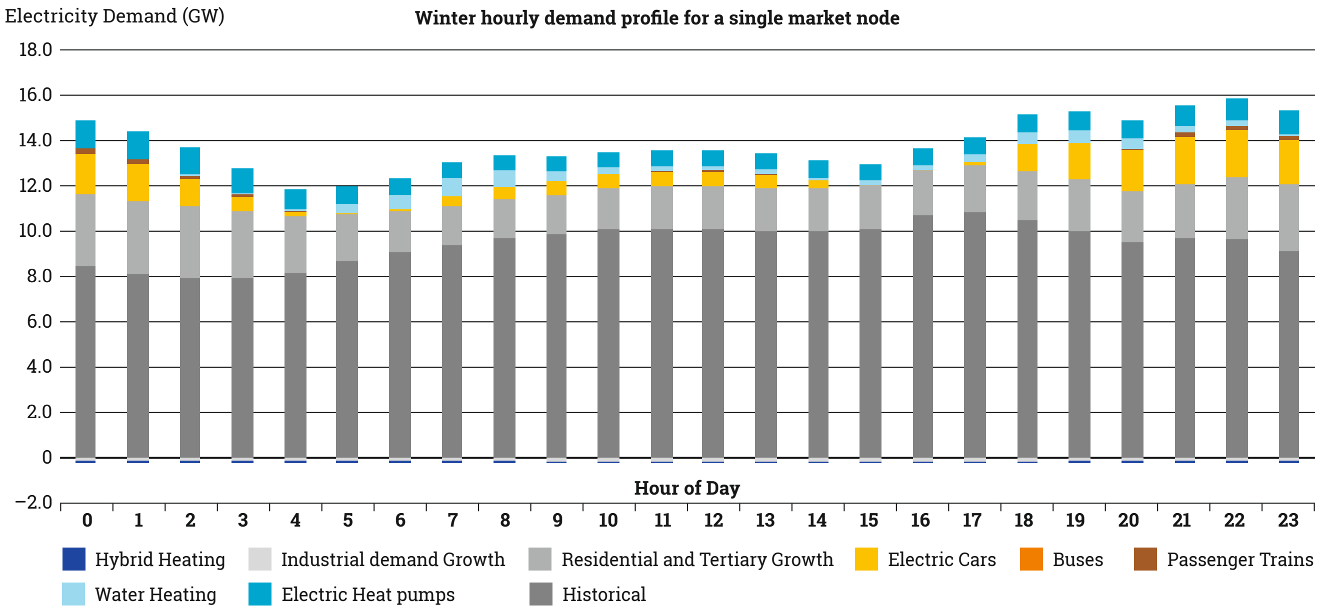


Figure 8: Example of winter hourly demand profile for a single market node – Impact of direct electrification in heating and transport sectors

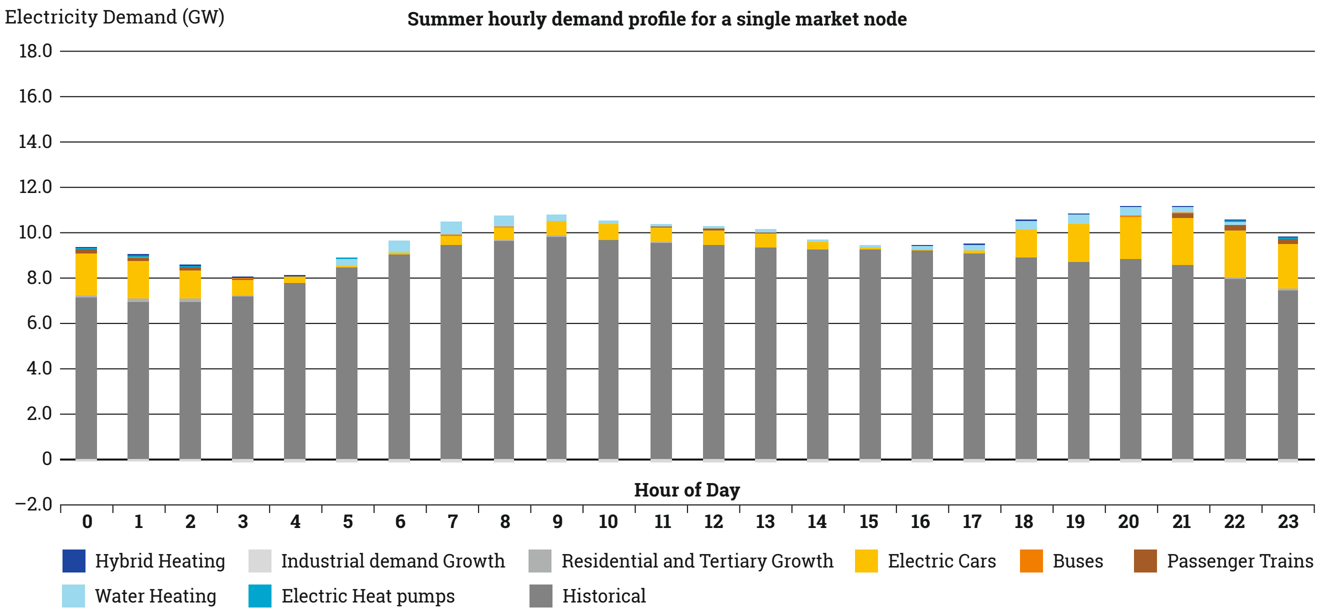


Figure 9: Example of summer hourly demand profile for a single market node – Impact of direct electrification in heating and transport sectors

The National Trends demand profiles are developed from the TSOs input based on latest available member state NECPs and where available national projections for 2040. For the top-down scenarios ENTSOG and ENTSO-E assume a high uptake of smart charging for transport, which will moderate peak demand growth rates. The demand profiles account for outside temperature and the impact on peak demand; this is important as the share of electricity within the heating sector increases.

For the top-down scenarios there is rational spread in peak demand growth rates between 2030 and 2040. Global Ambition is the scenario with the lowest levels of heat pumps, coupled higher energy efficiency results in this scenario in the lowest peak demand growth between 2030 & 2040. In Distributed Energy the main driver for higher peak demand is the higher rate of electrification across all sectors, however, it is important to note this can at the same time provide additional opportunities for demand side response, such as vehicle to grid or demand flexibilities at domestic level.

The peak demand growth rate in National Trends between 2030 and 2040 indicates a 1.0% year on year growth in peak demand. The growth rate for National Trends lies firmly in between the demand growth rates for Distributed Energy and Global Ambition. The spread in peak demand provides an opportunity for all three scenarios to enhance the understanding on the long-term impacts for the European transmission system.

Direct electrification of transport and heat

Electrification of heat and transport are two key areas that are necessary to decarbonise the European energy system. The information received from the TSOs and the COP21 scenarios show that electric vehicles and heat pumps have the greatest impact on electricity demand. The charts show how the scenario electric vehicles and heat pumps compare to external scenarios referenced in the chart as "range".

The scenarios aim to reduce emissions in line with the European targets and COP21 pathways. To achieve ambitious emission reduction in the heating sector, a shift away from fossil fuels is required. The scenarios show that moving away from oil and coal is a quick win to reduce emissions in the heating sector. The top-down and bottom up scenarios highlight the need for consumers to change how they use heat in their homes and businesses. The scenarios require a large shift towards electric and hybrid heat pumps, these technologies both reduce primary energy demand and final use energy demand due to the impact of heat pump co-efficient of performance. Heat pump technologies are used for space heating and sanity water heating.

		National Trends	Distributed Energy	Global Ambition
2025	Max	570,904		
	Average	520,101		
2030	Max	587,499	594,554	559,687
	Average	534,324	547,007	516,480
2040	Max	632,982	665,756	574,733
	Average	576,844	625,990	533,988
	CAGR (2015–2030)	0.54 %	1.01 %	−0.14 %
	CAGR (2030–2040)	0.77 %	1.36 %	0.33 %

Table 4: Annual peak demand and CARG per scenario

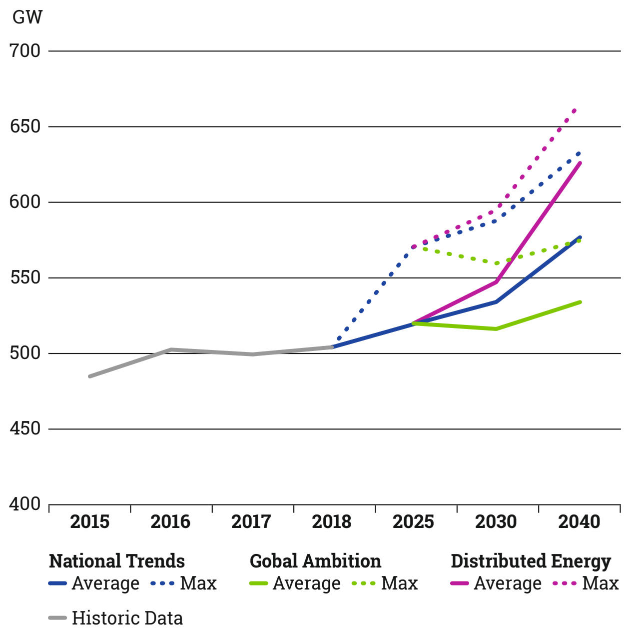


Figure 10: Peak electricity demand per scenario (EU28)

Distributed Energy shows the highest electrification with 245 Million electric vehicles and around 50 million heat pumps by 2040. The volumes relating to electric vehicles and heat pumps provide insight into why the Distributed Energy electricity demand reaches 4,000 TWh by 2040.

Global Ambition is a scenario where there is strong uptake of electric vehicles reaching around 200 million by 2040 but lower heat pump uptake at around 25 million devices. The scenario assumed more uptake of alternative low carbon heating to ensure that the emissions levels for the scenarios are achieved.

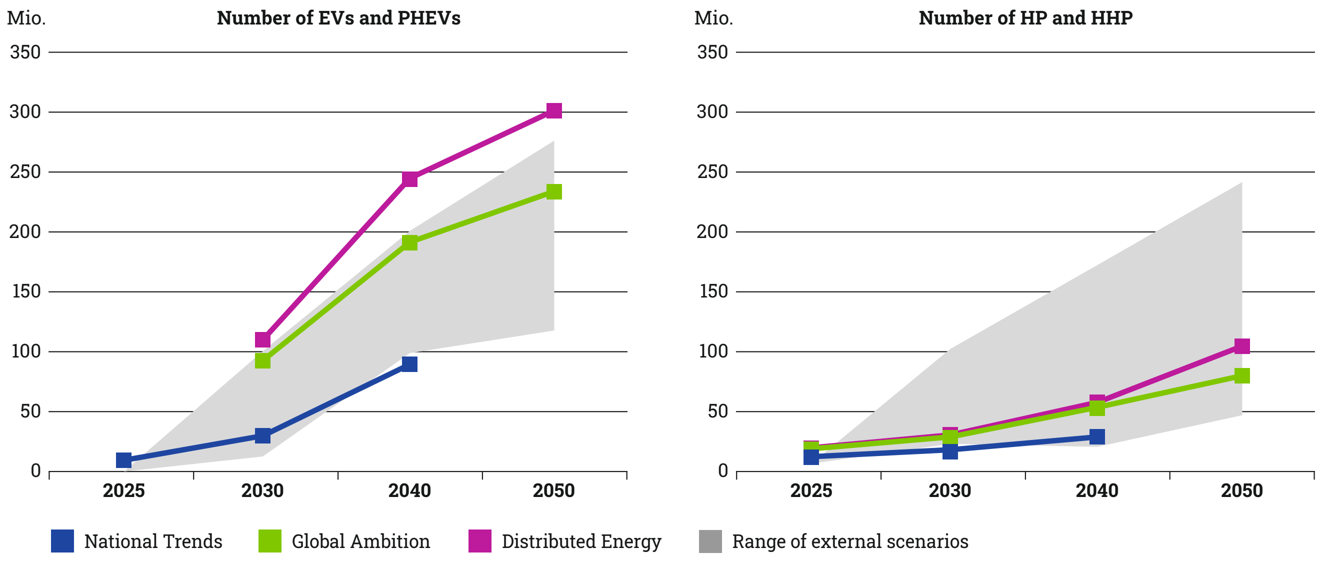


Figure 11: Number of electric and hybrid vehicles and heat pumps (excl. district heating) compared to a range based on analysis of third party reports

The National Trends scenario is based on TSO data and shows that there is a lower level of ambition for electrification of the transport sector around 100 million electric vehicles with around 60 million heat pumps by 2040. The scenario numbers for electric vehicles and electric and hybrid heat pumps technologies are shown on the charts. The shaded area represents a range of minimum and maximum values from 3rd party studies, see section 8 for further information. The charts show that the input assumptions for heat pumps and electric vehicles numbers lie within credible values.

6.1.3 Gas Demand

Total gas demand[13] is split up into final demand (residential, tertiary, industry incl. non-energy uses and transport) and demand for power generation. Whereas scenarios can show a decrease or increase for the total gas demand, the different sectors can evolve independently and in different directions.

By 2030, National Trends has the lowest total gas demand. In contrary to that, Global Ambition and Distributed Energy reach higher decarbonisation levels of the energy system with more gas. This is due to three main reasons:

- faster switch from carbon-intensive fuels, such as coal and oil to gas
- higher shares of renewable and decarbonised gases in the gas mix
- and in particular Distributed Energy projects a higher electricity demand in power generation due to a higher electricity demand

When comparing the sectoral split, all scenarios project a decrease in the residential and tertiary sector, but the uptake of gas demand in the transport sector can compensate parts of it in the COP21 Scenarios. These trends remain until 2040, resulting in lower demand for all scenarios: Distributed Energy decreases even to ca. 4,000 TWh (–20 % compared to today's level). On the other side, industry shows a more stable demand development and gas demand for transport increases throughout all scenarios, most significantly in Global Ambition.

It is worth mentioning, that the development of final gas demand differs from region to region. Due to a high dependency on coal, gas demand for heating rather increases in Central and Eastern Europe, whereas other regions head towards more electrification in the private heating sector. To give an example coal has a share of up to 50 % in the heating sector and 80 % in the power generation in Poland.

A switch from carbon-intensive coal to natural gas with lower carbon intensity by 2025, results in 186 TWh additional gas demand. However, this would lead to emissions reduction in the electricity generation of a minimum of 85 $MtCO_2$. At least until 2030 gas demand for power generation is increasing with the level of decarbonisation (including a fast coal-phase out) and electricity demand. Therefore, Distributed Energy as the scenario with the highest electricity demand has up to 26 % more gas demand for power generation than National Trends with the lowest gas demand for electricity generation. The picture changes for 2040, where also National Trends has accomplished the coal phase-out but shows lower renewable power generation. As a result, National Trends has the highest gas demand for power in 2040.

13 Total gas demand can also be referred to as "Gross Inland Consumption" of gas as done by Eurostat (link)

Peak demand generally follows the annual trends

The high daily-peak and 2-week demand requirements[14] reflect the changing nature of residential and commercial demand, as temperature-depending space heating typically drives peak gas consumption. As a result, final demand for peak day and 2-week decreases in all scenarios due to efficiency measures with an even further decrease in Distributed Energy, due to a higher penetration of electrical heat pumps. The decrease in final demand is for the most part compensated by an increasing peak demand for gas in power generation as the main back-up of variable renewables. National Trends observes the most limited change as consumers have invested in more traditional technologies, although they are considered less efficient.

The gas system can support the high development of variable RES

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

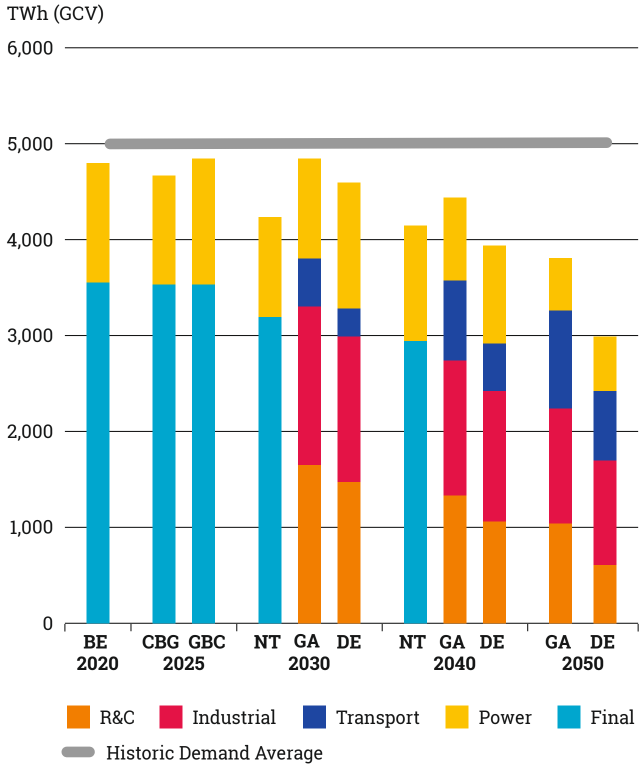


Figure 12: Sectoral breakdown of total gas demand in EU28

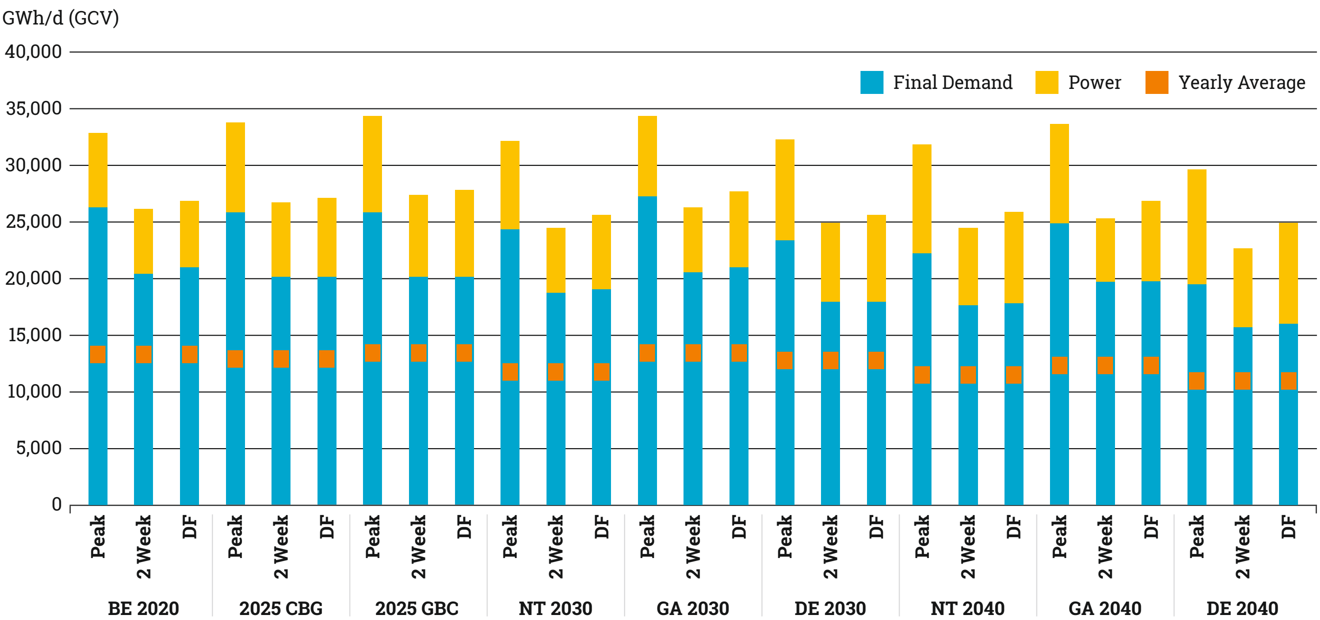


Figure 13: Gas demand in high demand cases (Peak, 2-Week cold spell, Dunkelflaute*)

* "Kalte Dunkelflaute" or just "Dunkelflaute" (German for "cold dark doldrums") expesses a climate case, where in addition to a 2-week cold spell, variable RES electricity generation is low due to the lack of wind and sunlight.

14 The "2-week demand" refers to a two-week period during a cold spell with very low temperatures resulting in high heating demand

Decarbonisation of the energy system comes with an uptake of the hydrogen demand

As a consequence of an increasing volume of hydrogen generation, the COP21 scenarios consider contrasted development of the hydrogen demand that could materialise to make use of this potential:

- Distributed Energy considers a higher penetration of P2G technologies with significant volumes produced more locally and thus a similar development of the Hydrogen demand.
- Global Ambition considers a more centralised decarbonisation where the increasing demand is mainly supplied by pre-combustive hydrogen production.

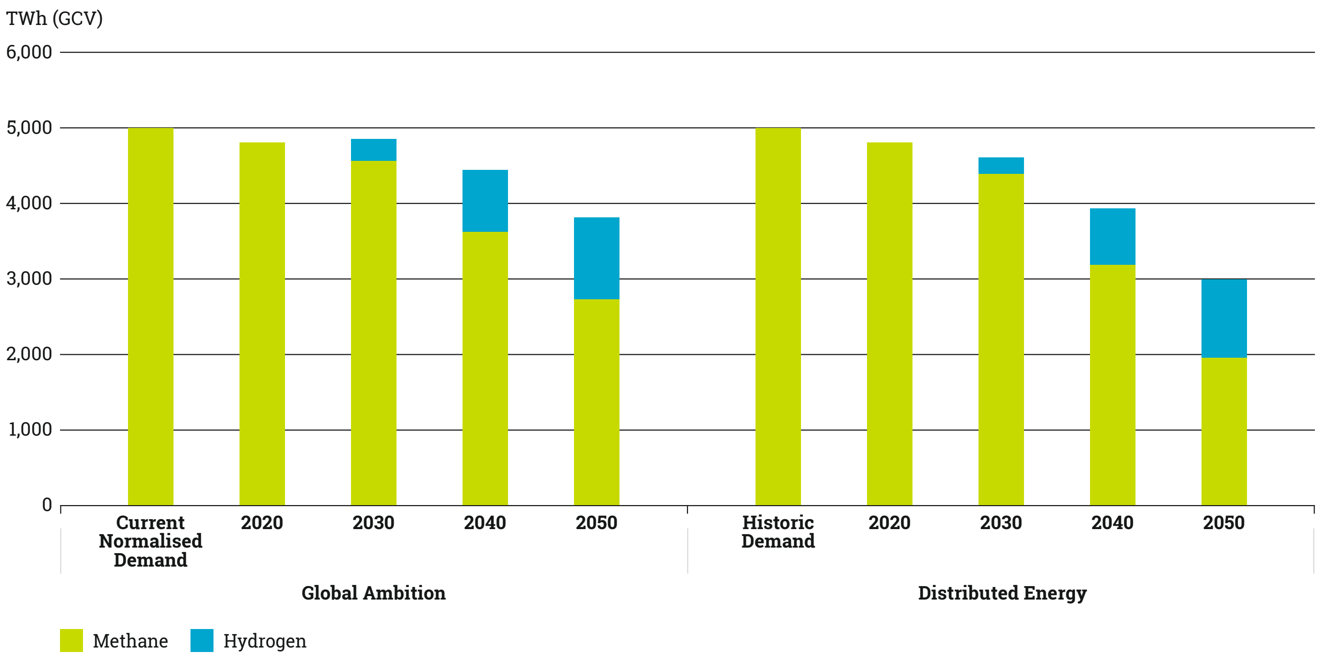


Figure 14: Total methane and hydrogen demand in COP21 scenarios

6.2 Supply

6.2.1 Primary energy supply

For the COP21 Scenarios, the overall energy mix becomes carbon-neutral by 2050. To fully decarbonize, both COP21 Scenarios register a significant increase in both renewables and further CO_2 removal technologies, while reducing primary energy demand. Whereas both scenarios reach similar levels of primary energy demand decrease of around 40% compared to 2015, the RES share in Global Ambition reaches 69 % by 2050 but is still outbid by Distributed Energy with a RES share of 82%.

The vast majority of energy stems from renewables. In 2050, wind, solar and hydro cover roughly 52% of primary energy demand in Europe within the scenario Distributed Energy and about 34% in Global Ambition, while nuclear as a CO_2 neutral generation source contributes between 6 and 9 %. Biomass and energy from waste materials contribute significantly – in Distributed Energy they cover 22 % and in Global Ambition 28 % of the primary energy mix.

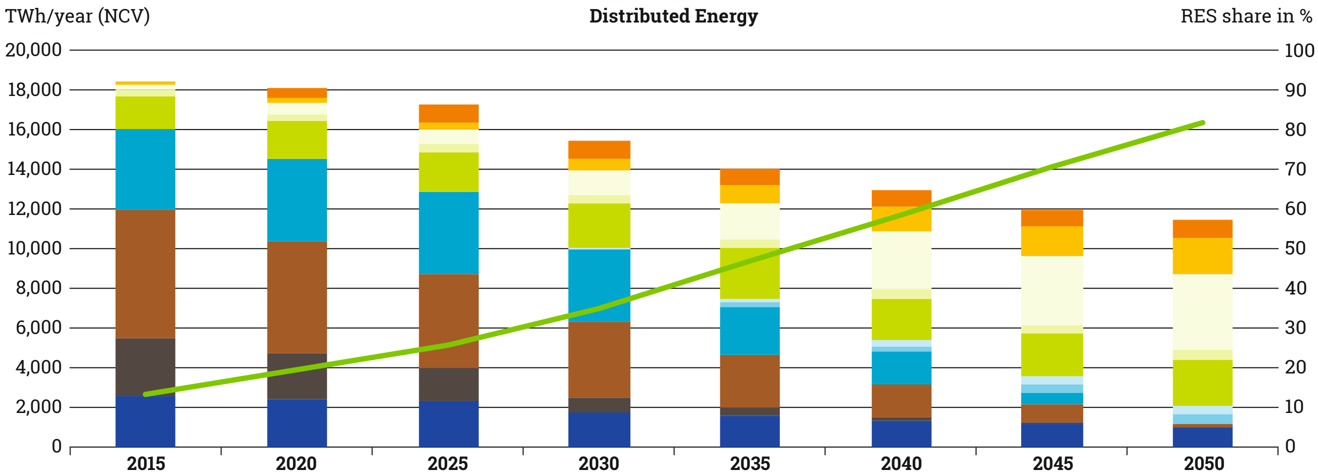


Figure 15: Primary energy mix and RES share in Distributed Energy (EU28)

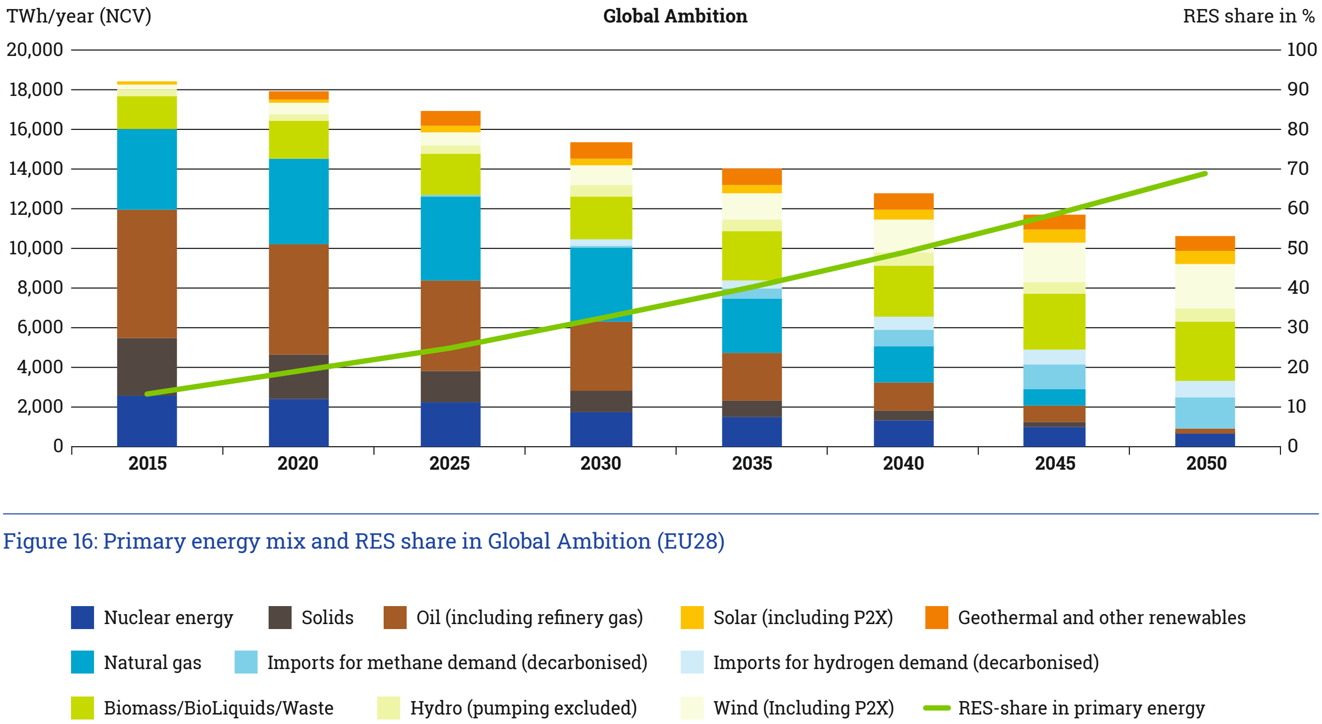


Figure 16: Primary energy mix and RES share in Global Ambition (EU28)

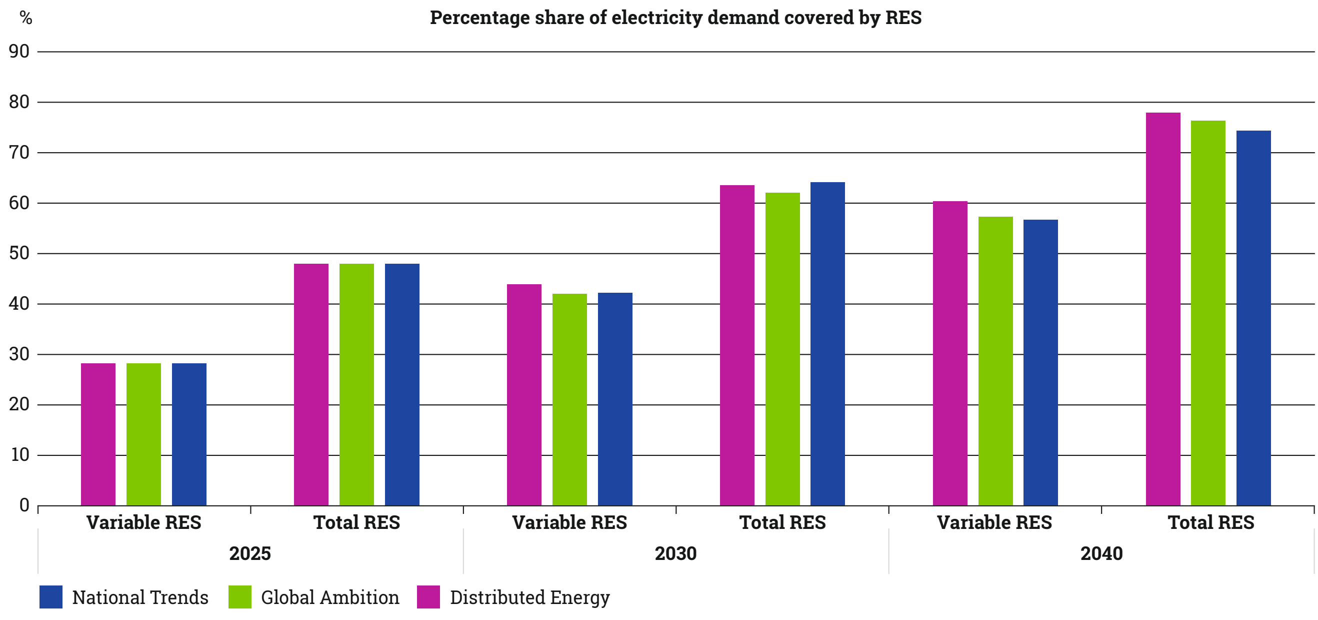


Figure 17: Share of final electricity demand covered by RES

Biomass can be directly used in industrial processes, or as feedstock to produce biofuels or biomethane – both can be used in all sectors, with a main focus in power generation, transport and heating. Since coal is assumed to be phased out in Europe by 2040, the remaining demand is covered by oil, nuclear and gas imports. The increase in renewable energy production results in declining "all-energy" import shares, from 55 % to 60 % nowadays, to ca.18 % in Distributed Energy and 31 % in Global Ambition[15].

A key enabler for the transition is the conversion of wind and solar power to P2G and P2L, which balances the variable electricity supply to energy demand and allows utilization of energy sourced from renewable electricity in final consumption sectors when there is no electricity demand.

6.2.2 Electricity

In the COP21 Scenarios, the electricity mix becomes carbon neutral by 2040. In EU-28, electricity from renewable sources meets up to 64 % of power demand in 2030 and 78 % in 2040. Variable renewables (wind and solar) play a key role in this transition, as their share in the electricity mix grows to up to 44 % by 2030 and 61 % by 2040.

The remaining renewable capacity consists of biofuels and hydro. All figures stated above exclude power dedicated for P2X use, which is assumed to be entirely from curtailed RES, and newly build renewables that are not grid-connected, and therefore not considered in this representation.

There is an increase in renewable capacity foreseen in all scenarios …
… but the speed of the uptake is contingent on the storyline associated with each scenario.

Distributed Energy is the scenario with the highest investment in generation capacity, driven mainly by the highest level of electrical demand. Distributed Energy mainly focuses on the development of solar PV. This technology has the lowest load factor, as result solar PV installed capacity will be higher compared to offshore or onshore wind to meet the same energy requirement. The scenario shows a larger growth in onshore wind after 2030.

In 2030, solar covers 14 % of the total electrical energy and wind covers 29 %. In 2040, solar covers 18 % of the electrical energy and 41 % comes from wind. The scenario also shows the least amount of electricity produced from nuclear out of the three scenarios, providing 16 % of electricity in 2030 and 10 % in 2040.

Global Ambition has a lower electricity demand, with a general trend of higher nuclear and reduced prices of offshore wind. Consequently, the capacity required for this scenario is the lowest as more energy is produced per MW of installed capacity in offshore wind. Nuclear provides 19 % of energy in 2030 and reducing to 12 % in 2040. In 2030, solar covers 10 % of the total electrical energy and wind covers 31 %. In 2040, solar covers 13 % of the electrical energy and 44 % comes from wind.

15 For the calculation of import shares, it is assumed that all oil and nuclear energy is imported in 2050.

National Trends is the national policy-based scenario. The variable renewable generation rests between the two top down scenarios. In 2030, Solar covers 12 % of the total electrical energy and wind cover 29 %. In 2040, Solar covers 15 % of the electrical energy and 41 % comes from wind. 17 % of electrical energy is still produced from nuclear in 2030, reducing to 12 % in 2040.

The scenarios include repowering of renewable generation technologies in 2040 resulting in the integration of load hours.

Shares of coal for electricity generation decrease in all scenarios. This is due to national policies on coal phase-out, such as stated by UK and Italy or planned by Germany. Coal generation moves from 8 % in 2025, to 3 %–6 % in 2030 and negligible amounts in 2040.

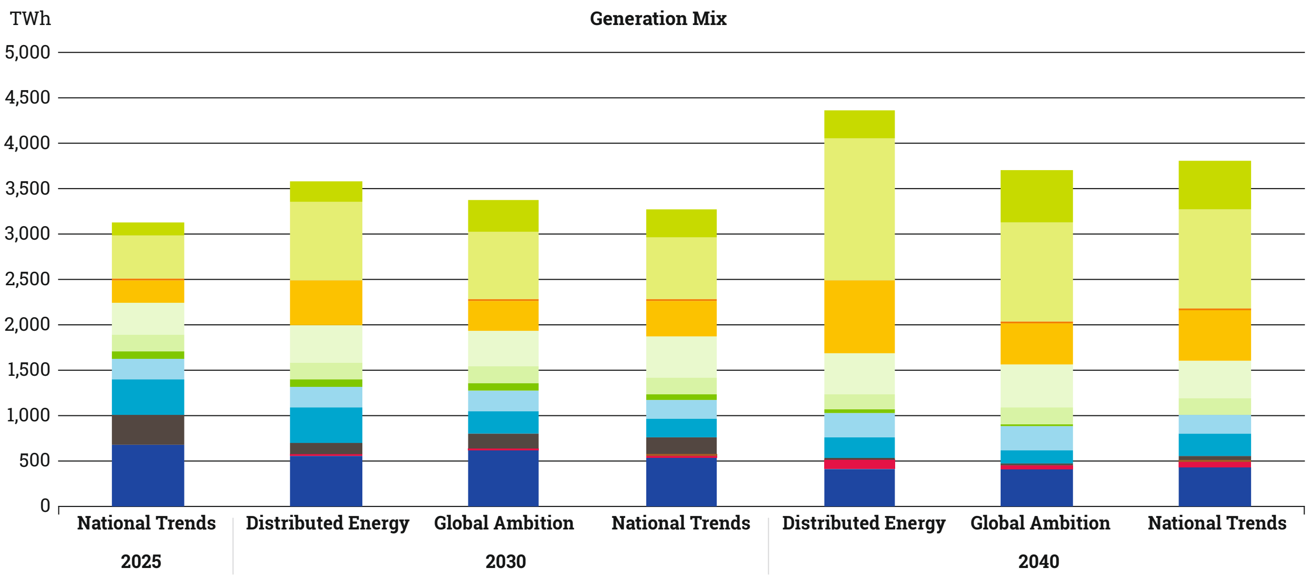


Figure 18: Electricity generation mix in Distributed Energy (EU28)

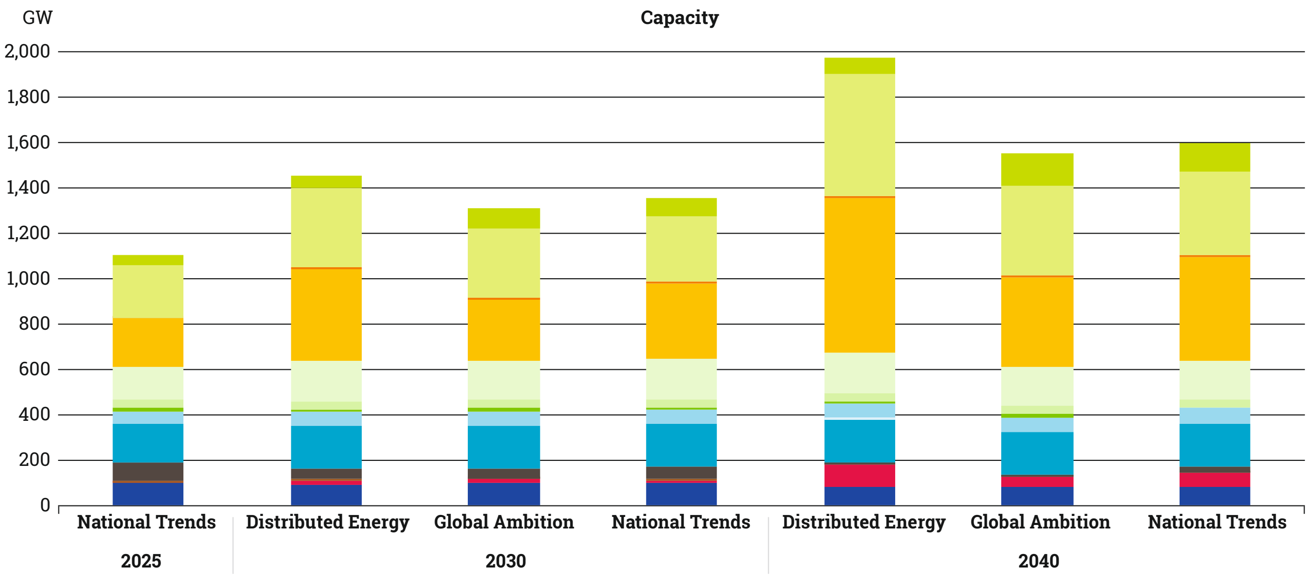


Figure 19: Electricity capacity mix in Distributed Energy (EU28)

Gas, however, has a share of 20 % in 2025, which reduces in 2040 to 10–12 %. It is important to note level of decarbonised and renewable gases in the gas mix, increases to 13 % in 2030 and 54 % in 2040. Distributed Energy starts to show a need for CCS in 2040, which will lead to negative emissions in plants burning biomethane.

Considerations on Other Non-Renewables (mainly smaller scale CHPs) source are important for decarbonisation. As it stands, carbon-based fuels are still widely used in CHP plants throughout Europe. This includes oil, lignite, coal and gas. In order to follow the thermal phase-out storylines, oil, coal and lignite should be phased out by 2040 and replaced with cleaner energy sources. Gas will contribute to decarbonisation by increasing shares of renewable and decarbonised gas.

Other RES contains generation technologies such as marine, small biofuel and geothermal. The generation from this collection of technologies remains stable in all scenarios.

Generation from hydro increases in 2030 due to an increase in capacity from 145 GW in 2025 to 174 GW in 2030 but remains stable after 2030. As hydro potential is determined by very specific conditions, bottom up data is used for all scenarios.

Thermal capacities are reduced, not only to national phase-out policies, but the fact that some generation units will no longer be economically viable due to reduced running hours or will reach the end of their lifetime.

The scenarios show that there is potential for demand side technologies and batteries to take part in the market and help to smoothen demand peaks and level prices. While the impact of these technologies in terms of energy may be low, they show a vast potential to reduce generation from carbon based peaking units, supporting decarbonisation, contribute towards system adequacy at lower costs and help to integrate increasingly variable electricity generation.

Distributed Energy shows the highest increase in usage of these technologies in 2030, whilst the other scenarios incorporate relatively moderate to low usage. Distributed Energy shows more use of demand side resources as the cost of residential solar and battery systems are discounted. In 2040, there is a much larger increase in use of battery technologies in all scenarios, the most noticeable are Distributed Energy and National Trends.

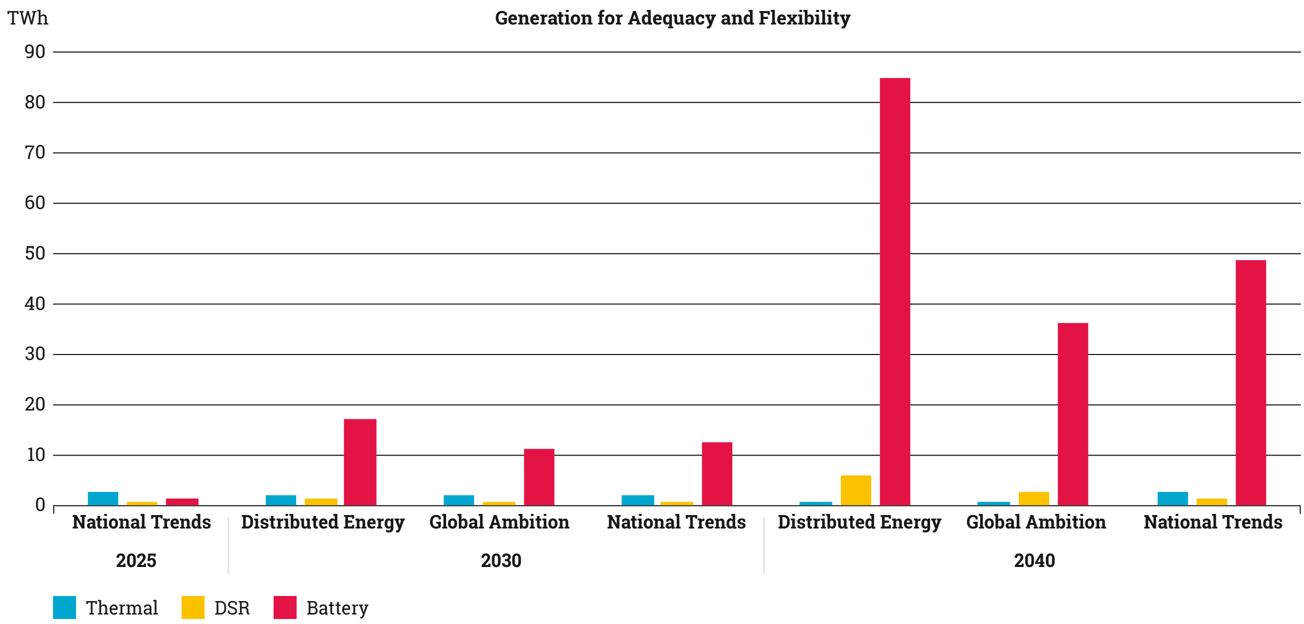


Figure 20: Peak generation, demand side response and battery technology (EU28)

6.2.3 Gas

6.2.3.1 Gas supply potentials

Indigenous production: contrasted views captured by the COP21 scenarios

All scenarios consider similar decrease of the conventional indigenous production. However, the assumptions on the indigenous renewable gas production, such as biomethane and P2G, differ across the scenarios:

- 2020 and 2025 rely on Best Estimates for the TSOs. Due to the decreasing domestic conventional gas production and rather stable gas demand, gas imports will increase.

- National Trends relies on bottom-up data for the indigenous production for natural gas (including unconventional gas, such as shale gas) and biomethane. Additionally, P2G is added assuming that curtailed electricity will be used to produce hydrogen and synthetic methane.

- Distributed Energy considers a significant uptake of local renewable gas production supplying 65 % of the EU gas consumption in 2050. Considering a gradually decreasing gas demand after 2025, gas imports decrease by 70 % compared to today's level.

- Global Ambition scenario considers the uptake of renewable gas production capacities to a lesser extent with a more import-oriented vision and large-scale decarbonisation. Imports represent 70 % of the EU gas consumption in 2050. Considering a gradually decreasing gas demand after 2025, gas imports still decrease by 30 % compared to today's level.

The contrasted approach towards the supply configurations is essential when assessing the infrastructure for the next twenty years since it directly impacts the way the European gas system is used.

Enough gas potential to satisfy the EU demand until 2050

All scenarios consider a maximum utilisation of indigenous production in the European gas supply mix until 2050. The supply potential assessment run by ENTSOG and discussed with stakeholders in July 2019[16] concludes that for all scenarios, the import potentials are high enough to ensure the supply and demand adequacy of the EU until 2050. This is despite the decline of the conventional indigenous production. In this regard, it can be highlighted that the

16 https://www.entsog.eu/entsog-workshop-supply-potentials-and-market-related-assumptions-tyndp-2020#

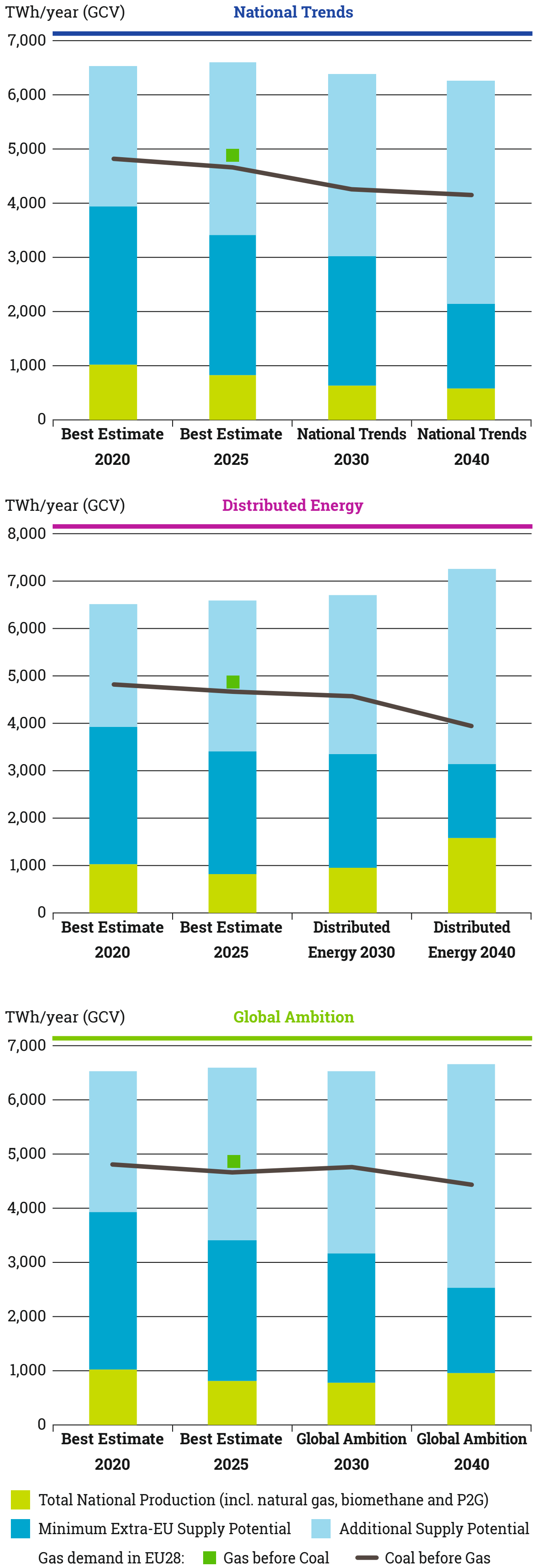


Figure 21–23: National Trends, Distributed Energy, Global Ambition

Dutch Government has decided to stop production at Groningen, Europe's largest onshore natural gas field, by 2022. Additionally, the supply mix will be further diversified with new sources looking towards 2050.

Furthermore, whilst Norwegian supply is produced in Europe, it is considered as an import source to the EU since Norway is not a Member of the Union.

The import supply mix will be dominated by gas from Russia, Norway and LNG

Even though the supply mix will be diversified, the import supply mix will still be dominated by the current three largest supply sources: Russia, Norway and liquefied natural gas (LNG). Which of these sources, who will have the largest share of the import supply mix, will be dependent on market prices, and the supply chain's adaptation of the growing demand for decarbonised gases.

Figure 21, Figure 22 and Figure 23 highlight the adequacy of scenario specific gas demand and supply. Supply is split into three categories:

- Total EU indigenous Production covers all domestic production of conventional natural gas, biomethane and P2G for both hydrogen and methane.
- Minimum Extra-EU Supply Potentials: minimum gas imports based on long-term contracts and their assumed prolongation
- Additional Supply Potential: additional gas imports options which will be used based on arbitrage

All scenarios show enough supply potentials to meet the future demand.

6.2.3.2 Gas supply composition

A technology neutral approach

The decarbonisation of the gas supply can be done in many ways. Gas can either be produced from renewable energy such as biomethane or hydrogen from P2G, but it can also be decarbonised from conventional natural gas with different technologies such as steam methane reforming (associated with carbon capture and sequestration process) or pyrolysis.

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 (therefore included in Bio-Energy Carbon Capture and Sequestration (BECCS) category). However, CCS processes come with efficiency factors to account for the part of the CO_2 that cannot be captured in the process and that is therefore released in the atmosphere.

In order to capture all possible impacts of the development of one or another technology, the scenarios come with contrasted assumptions regarding the penetration of renewable or decarbonised gases in the supply mix of the EU.

A source neutral approach

TYNDP 2020 scenarios consider contrasted possible developments of the gas demand including different gas qualities. ENTSOG and ENTSO-E have improved their methodology and introduced a more detailed breakdown of the gas demand between methane and hydrogen.

However, there are different technological ways both those demands can be satisfied. Methane and hydrogen demands can of course primarily be satisfied respectively by methane and hydrogen production. However, depending on the penetration of the different generation technologies, methane can be decarbonised to generate hydrogen and therefore satisfy the hydrogen demand. On the other hand, hydrogen can be methanised to create methane and therefore satisfy the methane demand. It should be noted that any conversion process incorporates energy losses taken into account as efficiency factors when building the scenarios.

In line with the neutral approach of ENTSOG towards the infrastructure submitted to TYNDP, the scenarios are technology neutral. Therefore, unless a piece of infrastructure is actually commissioned no choice is made by ENTSOG and the scenarios do not pre-empt the location of the conversion of the gas supply to satisfy the demand. The conversion could therefore be centralised at transmission level or be decentralised at city/consumer gate.

6.2.3.2.1 National Trends

The gas supply mix considered in National Trends reflects the current European targets and respective Member States' NECPs. The level of information regarding the gas supply mix can be very different depending on how the targets are set in the NECPs. Thus, due to lack of consistency between the individual NECPs, the gas supply mix for National Trends is not split into different gas qualities. Based on information available for demand and national production, National Trends will require similar gas imports levels as today, with a peak of 4,000 TWh in 2025.

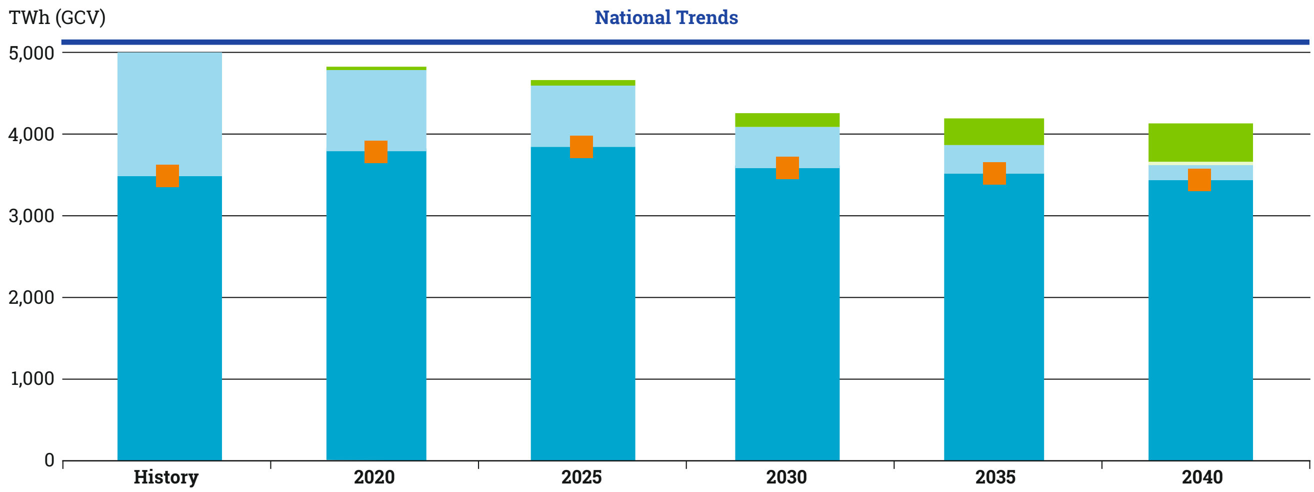


Figure 24: Gas source composition – National Trends

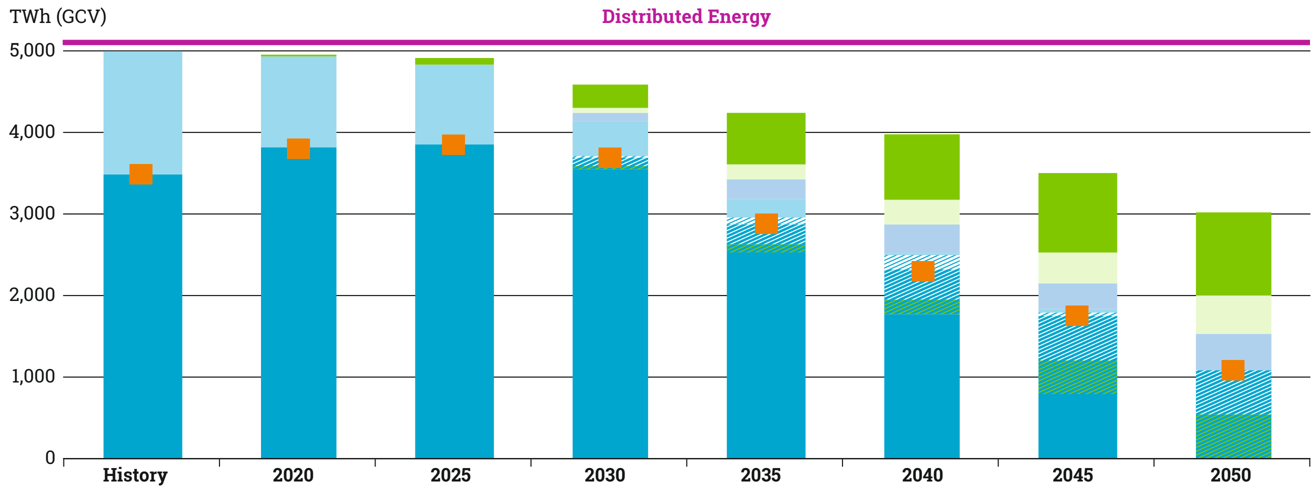


Figure 25: Gas source composition – Distributed Energy

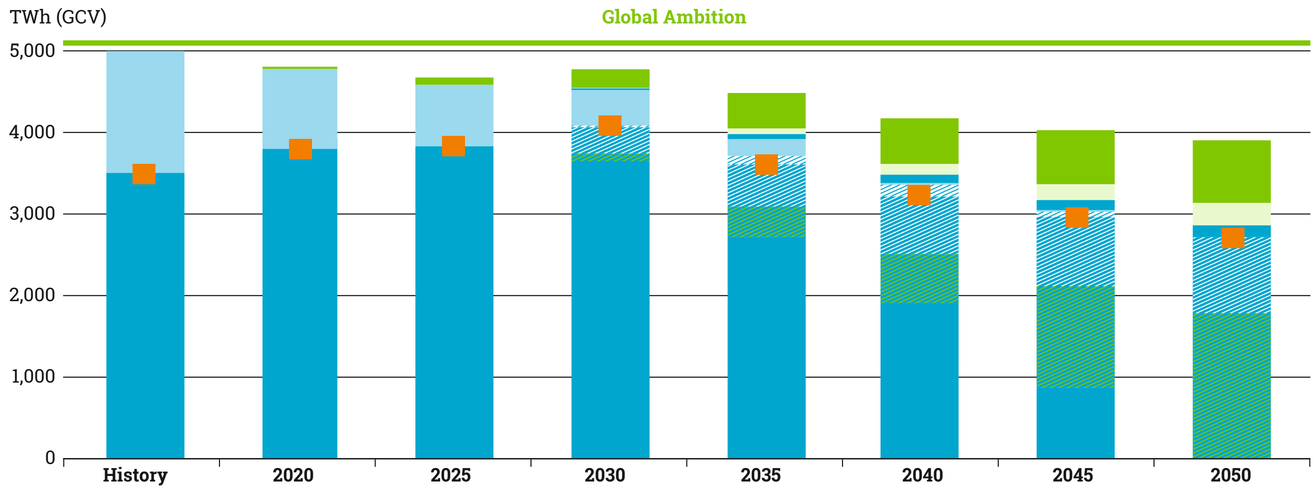


Figure 26: Gas source composition – Global Ambition

Imported Natural Gas: Unabated
Indigenous Natural Gas: Unabated, Abated
Power-to-Hydrogen
Power-to-Methane
Biomethane
Imports (incl. Norway)
Imports for Methane Demand*
Imports for Hydrogen Demand**

*decarbonised, either by natural gas imports with post-combustive CCU/s or any other technology
**natural gas converted to hydrogen at import point/city gate or direct hydrogen imports

6.2.3.2.2 Distributed Energy Scenario

As a decentralised scenario, Distributed Energy considers a high level of indigenous production of renewable gas. Since both decarbonisation and a 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. Moreover, with almost 1,000 TWh Distributed Energy projects the highest biomethane production of all scenarios. On the other side, imports are reduced by 70 % between 2020 and 2050, accounting for 2,386 TWh in 2040, and 1,050 TWh in 2050. The level of imports is the lowest of all the scenarios and to reach carbon neutrality by 2050 means that the remaining imports must be decarbonised or renewable by then. However, aiming for decarbonisation requires a significant increase in renewable electricity generation to meet the P2G demand.

6.2.3.2.3 Global Ambition

As a centralised scenario, Global Ambition combines both high decarbonisation levels with a global gas supply and access to a variety of sources. However, thanks to general demand decrease also imports decrease by 25 % by 2050 compared to current levels (–830 TWh). To reach carbon neutrality gas imports to be decarbonised or renewable by then are of a larger scale (2,670 TWh/y). than in Distributed Energy.

Both P2G as well as Biomethane are higher than in National Trends but lower compared to Distributed Energy. Together they contribute with 1,150 TWh by 2050.

6.3 Sector Coupling: Capacity and Generation for P2G and P2L

Distributed Energy has a significantly higher demand for EU produced hydrogen, synthetic methane and liquids than Global Ambition in 2030 and 2040. The Distributed Energy storyline assumes a reduction by 70 % of gas imports by 2050 (from 3,700 TWh in 2020 down to 1,050 TWh in 2050) combined with the decarbonisation of the gas supply. It also assumes a quasi phase-out of fossil oil by 2050 replaced by European biofuel and P2L.

Distributed Energy and Global Ambition have a specific demand for domestically produced hydrogen. In these scenarios, P2G and P2L plants are operated outside the energy markets, using dedicated renewables, but the curtailed electricity from the market is used to feed these plants. National Trends does not have a specific top down demand for hydrogen, therefore the power-to-gas plants are built solely based on curtailed renewables.

In the COP21 scenarios, the main source used for electrolysis is offshore wind, but where regional constraints exist, onshore wind and solar PV will be the alternative.

The generation profiles match the capacities build. There is more RES capacity in Distributed Energy 2040 therefore it is natural that there is more curtailed energy in this scenario.

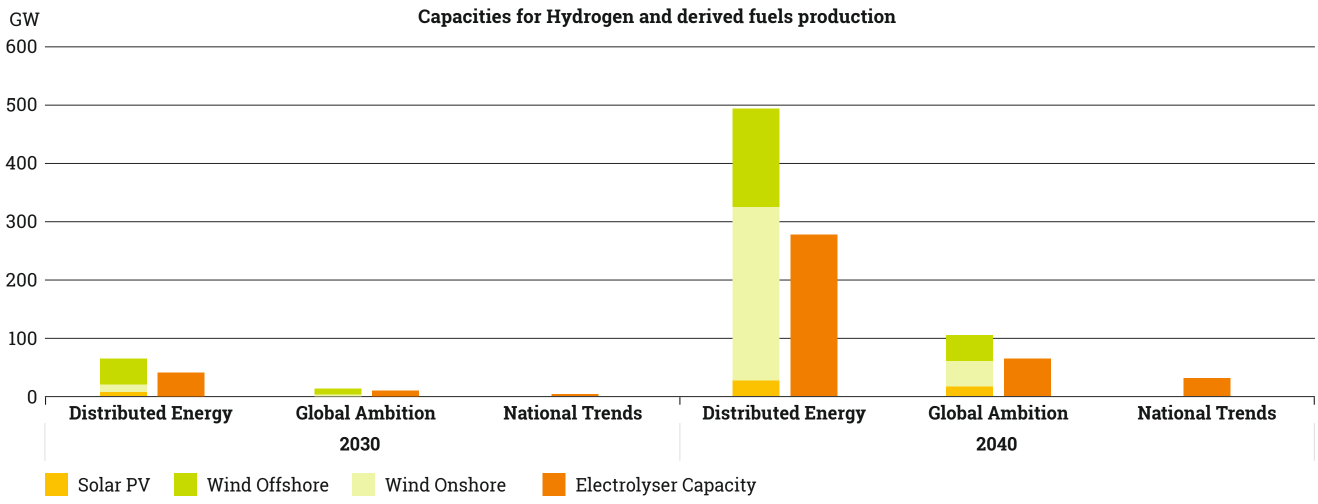


Figure 27: Capacity for hydrogen production

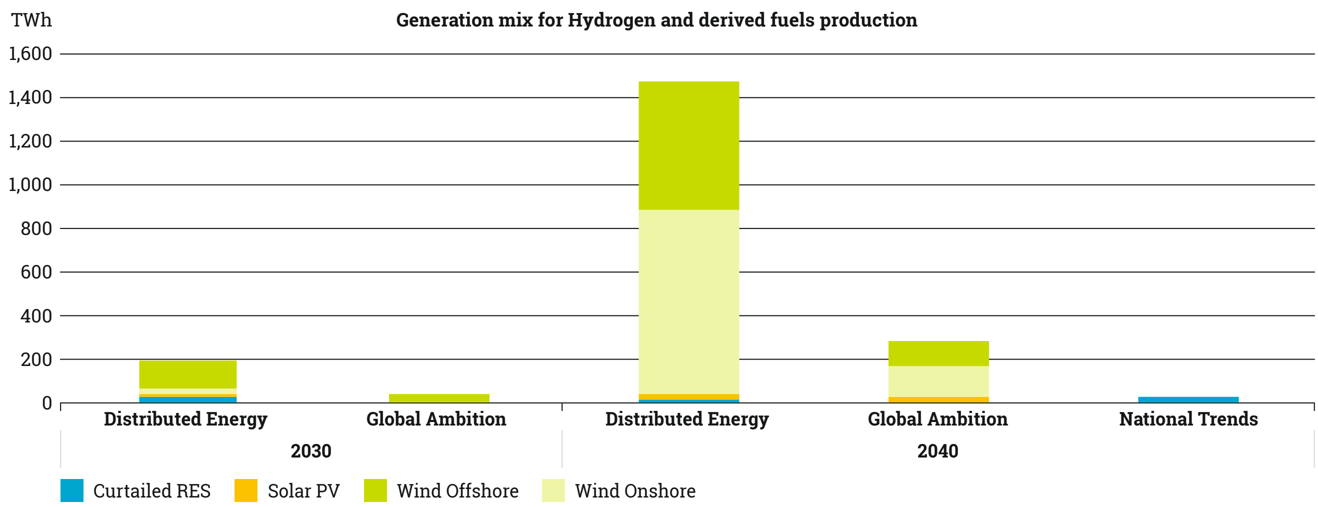


Figure 28: Generation mix for hydrogen and derived fuels

6.4 Reduction in overall EU28 CO_2 Emissions and necessary measures

Following the EU's long-term goal, National Trend is treated to reach 80% to 95% of decarbonisation by 2050. Although the commonly agreed target for 2030 is 40% GHG emission reduction, the latest adoptions to the 2030 climate and energy framework (32,5% improvement in energy efficiency, 32% share for renewable energy) will consequently result in higher GHG emissions reductions. This is also shown by the European Commission's Long-term Strategy Scenarios. On the other hand, the COP21 scenarios go for carbon neutrality by 2050, as suggested by the latest IPCC Special Report[17] and targeted by the European Commission.

As mentioned in Section 6.2.1, both COP21 Scenarios register a significant decrease in primary energy demand with increasing shares of renewables, mainly biomass and variable electricity (both for direct use and P2G production). Whereas electricity generation has already faced some level of transition, other carriers such as gas need to follow. ENTSOs' scenario building exercise shows that to decarbonise all sectors as well as all fuel types, additional measures such as CCU/S, also in combination with bioenergy, are needed. Full decarbonisation also needs the contribution of non-energy related sectors, such as the decarbonisation of agriculture/meat production and further afforestation. It should be noted, that for GHG emissions related to non-CO_2 emissions (e.g. methane emissions) and LULUFC, ENTSOs' scenarios rely on the average given by the 1.5TECH and 1.5LIFE scenarios of the European Commission's Long-term Strategy.

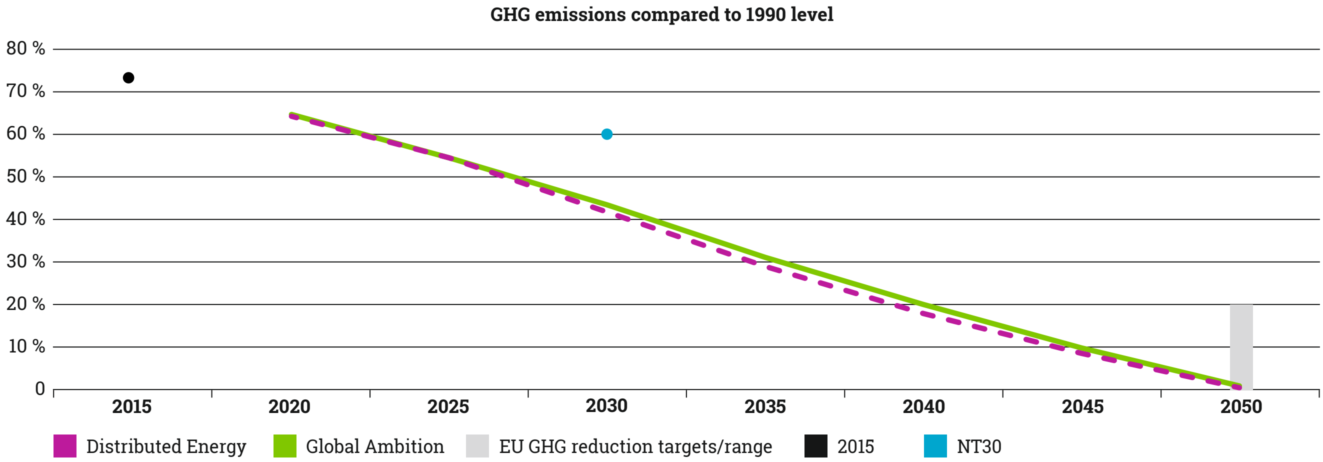


Figure 29: GHG emission reduction pathways until 2050

17 IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, Intergovernmental Panel on Climate Change, 2018

Electricity Generation

In 2030 the electricity sector produces emissions of between 363 and 402 $MtCO_2$, a reduction of around 76 % as compared to 1990. Distributed Energy shows the largest the emission reduction is on par with National Trends. In the COP21 Scenarios, the electricity mix becomes almost carbon neutral by 2040 with emissions of 74 $MtCO_2$ in Distributed Energy and 87 $MtCO_2$ in Global Ambition. In this case both scenarios have the gas before coal merit order, but as the demand is higher in Distributed Energy, there is more consumption of both gas and coal. However, to meet the ambitious targets in the electricity generation, fuel input into small scale CHP, mainly gas, needs to be 83 % decarbonised. Moreover, in Distributed Energy also CCU/S needs to be applied to CCGTs by 2040.

National Trends sees emissions of 196 $MtCO_2$, on target with the 2°C scenarios shown in the Long-term Strategy from the European Commission.

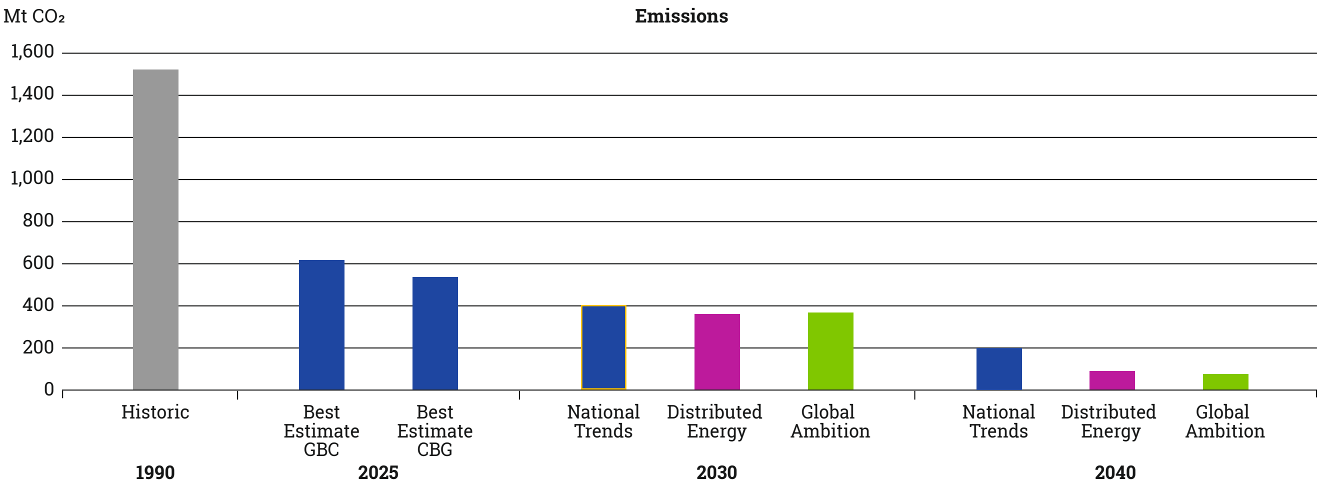


Figure 30: CO_2 emissions in the Electricity Generation

Gas supply

Gas as an energy carrier with increasing shares of renewable and decarbonised gases plays a key role in the decarbonisation of the economy. Biomethane and renewable gases produced via P2G do not have CO_2 emissions, but if CCU/S (post-combustive or during the production of biomethane) is applied their consumption can even lead to negative emissions. Apart from indigenously produced renewable gases, also the consumed natural gas needs to be decarbonised with carbon capture technologies, either pre-combustive in combination with steam methane reforming or methane pyrolysis, or post-combustive in large-scale industrial sites or power plants. However, post-combustive CCS may mostly be applied to large scale process such as industrial sites or power plants and its carbon capture rate is usually around 90 %.

In Distributed Energy in 2050, 65 % of the gas will be renewable, but for the other 35 % needs to be decarbonised with carbon capture technologies: in 2050, to be carbon-neutral, 90 $MtCO_2$ need to be captured during the conversion of natural gas into hydrogen and additionally 50 $MtCO_2$ need to be removed post-combustive at industrial sites.

Figure 31 shows the emissions related to the consumption of gases and the average carbon intensity (in $kgCO_2$/kWh) of the gas mix in Distributed Energy. Due to above mentioned restrictions for post-combustive CCS, the CO_2 intensity of the gas mix decreases by 86 % in Distributed Energy by 2050 compared to conventional natural gas.

Due to higher imports, Global Ambition sees a broader need for CCU/S to decarbonise the gas mix to reach carbon neutrality. To produce hydrogen from natural gas up to 264 $MtCO_2$/year need to be captured and stored or used. Additionally, up to 83 $MtCO_2$/year need to be removed post-combustive. Furthermore, 88 $MtCO_2$ needs to be captured from biomethane, which allows for negative emissions. The CO_2 intensity of gas decreases by 86 % in Global Ambition in 2050 compared to conventional natural gas.

In this context ENTSOG and ENTSO-E' assumptions on the need and application of CCS are guided by the European Commission's Long-term Strategy and its most ambitious 1.5°C scenarios: 1.5LIFE and 1.5TECH see the necessity of 281 to 606 $MtCO_2$ captured (see section 8.5 for a benchmark with these scenarios).

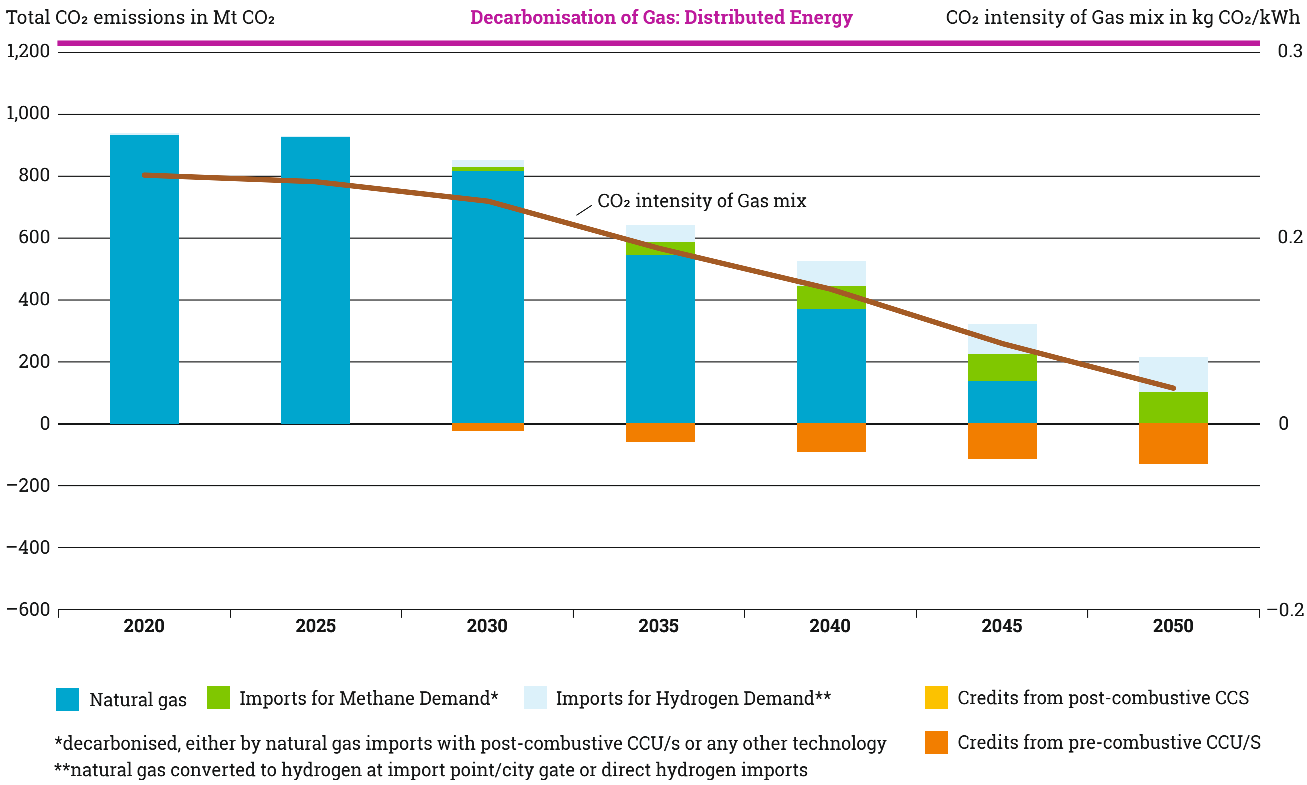


Figure 31: Decarbonisation path of gas in Distributed Energy

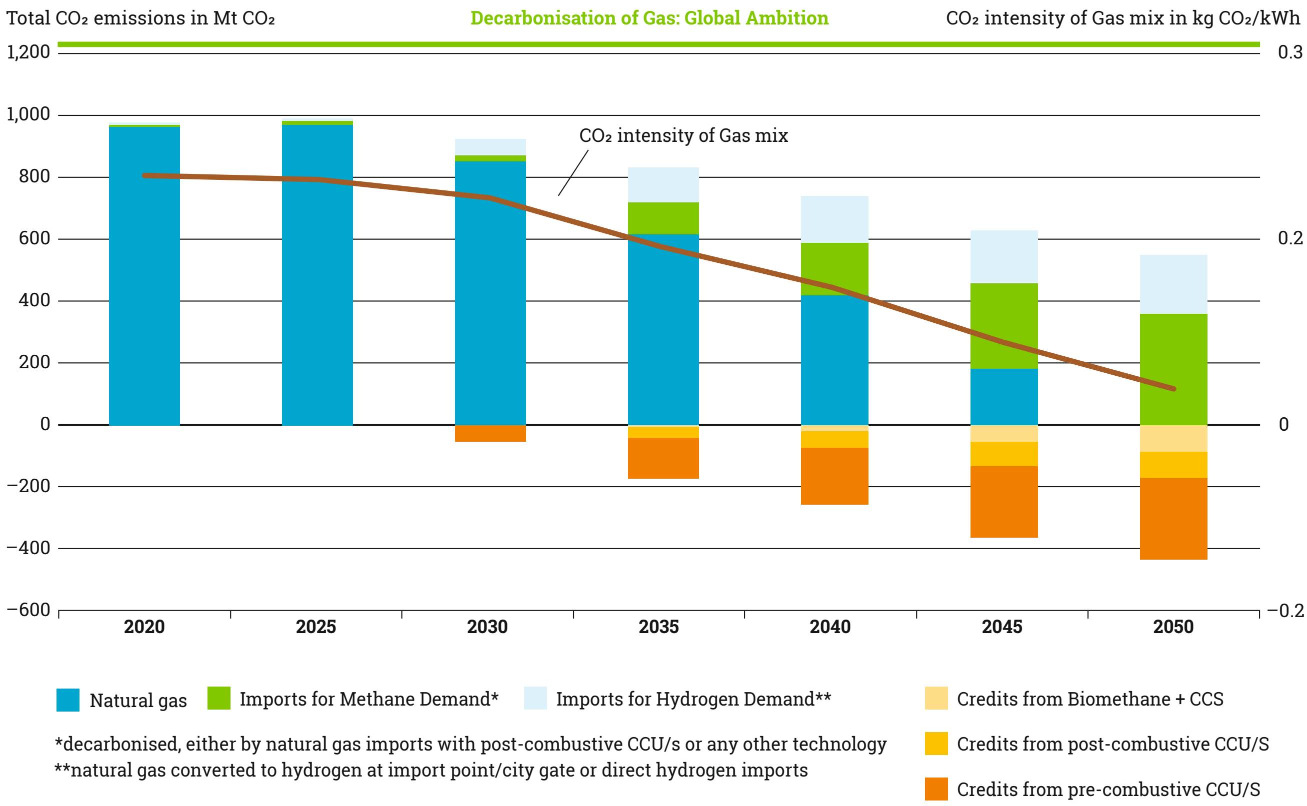


Figure 32: Decarbonisation path of gas in Global Ambition

7 Electricity Costs

The CO_2 price and electricity demand directly affect the marginal cost of the scenarios. Distributed Energy has the highest CO_2 price and electricity demand in both timeframes, therefore the marginal cost is the highest. The cost assumptions of wind and solar, influence the CO_2 price having an effect on the Levelized cost of electricity in each market node, and the electricity marginal costs of the scenarios.

Levelised cost of electricity

Across all the scenarios new capacity for electricity generation comes mainly from wind and solar power. Global trends show that incentives, innovation, and investment have matured the solar and wind industry; their levelised costs of electricity (LCOE) is significantly lower compared to other low carbon generation technologies, such as tidal or CCGTs with CCS.

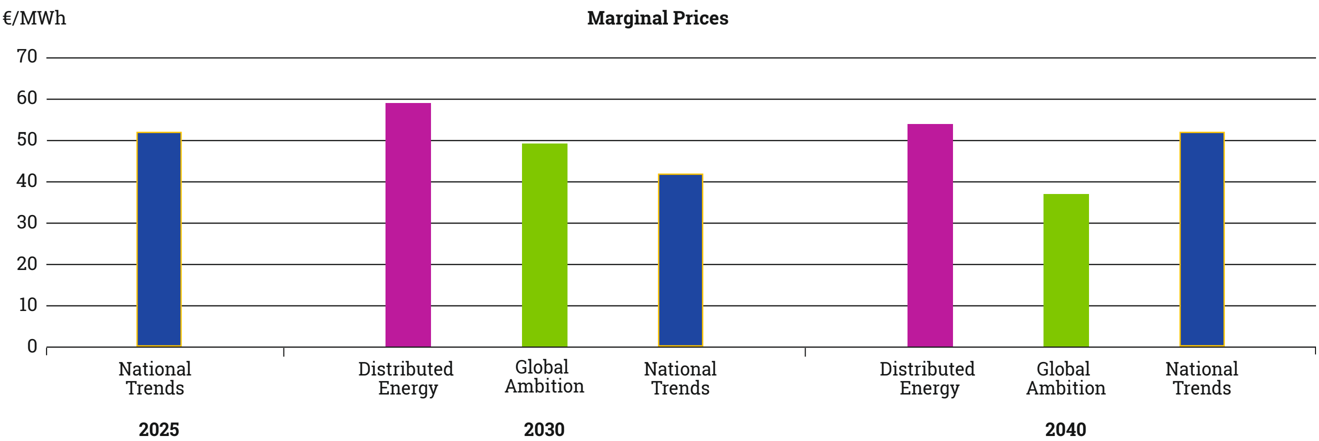


Figure 33: Marginal costs

A power system investment model relies on the LCOE of a particular technology to make decisions on whether it can be built. The investment model ensures that the CAPEX and fixed costs of a technology are recovered over the economic/technical lifetime of the investment. Annex II provides an over view of the investment CAPEX and fixed cost assumptions for each of the technologies considered by the scenario building process.

The decision to build a particular technology is driven by the achieved electricity price for a particular market area, i.e. the weighted average price from hours when the wind/solar generator is producing, which is impacted by general supply/demand situation and the amount of previously installed capacity of the same technology. Typically in an investment model will prevent over investment in a particular technology, such as Solar PV, as similar output profiles reduce the marginal price, so that further investment is not economically viable. Furthermore, the cost and availability of flexibilities such as interconnection or storage, such as P2X and batteries, impact the investment decisions, since higher amounts of storage may improve the achieved price for variable renewable technologies.

	Offshore Wind	Onshore Wind	Solar PV
Average	43 %	28 %	14 %
Max	51 %	40 %	22 %
Min	27 %	19 %	9 %

Table 5: Wind and Solar Capacity Factor Characteristics

Conventional and Renewable LCOE are variable and dependent on differing factors. The LCOE of Renewable energy sources are impacted by resource availability both in a geographical and climatic sense. The cost of technology for residential PV is typically stable across Europe however the ability to convert the energy to electric is wholly dependent on the geographical location, based on our Cost assumptions for DE2040 Spain could achieve an LCOE of ~€17/MWh compared to ~€40/MWh Finland for the same investment cost, the difference is driven entirely by the facts that a Spain PV yields approx. 22 % energy from 1MW compared to 9 % energy from 1MW in Finland.

The decision on building new conventional thermal plants is not a dependent on location, but rather the SRMC and the residual demand on the system. The decision to build new conventional plant will be based on the need to meet the residual demand and ensure security of supply for a particular market. The charts shows demonstrate that in the long term horizon renewable energy is more cost effective than thermal generation. The variability of renewable however means that backup supply is more critical, the investment decision to build thermals will rely on whether or not security of supply is highlighted in a market area and high price signals enable the building of baseload or peaking thermal plant. Typically OCGT or Light oil units will recover cost over a small number of hours whereas baseload or mid-merit plants will require a significant number of hours where the price is high enough to make an economic decision to build.

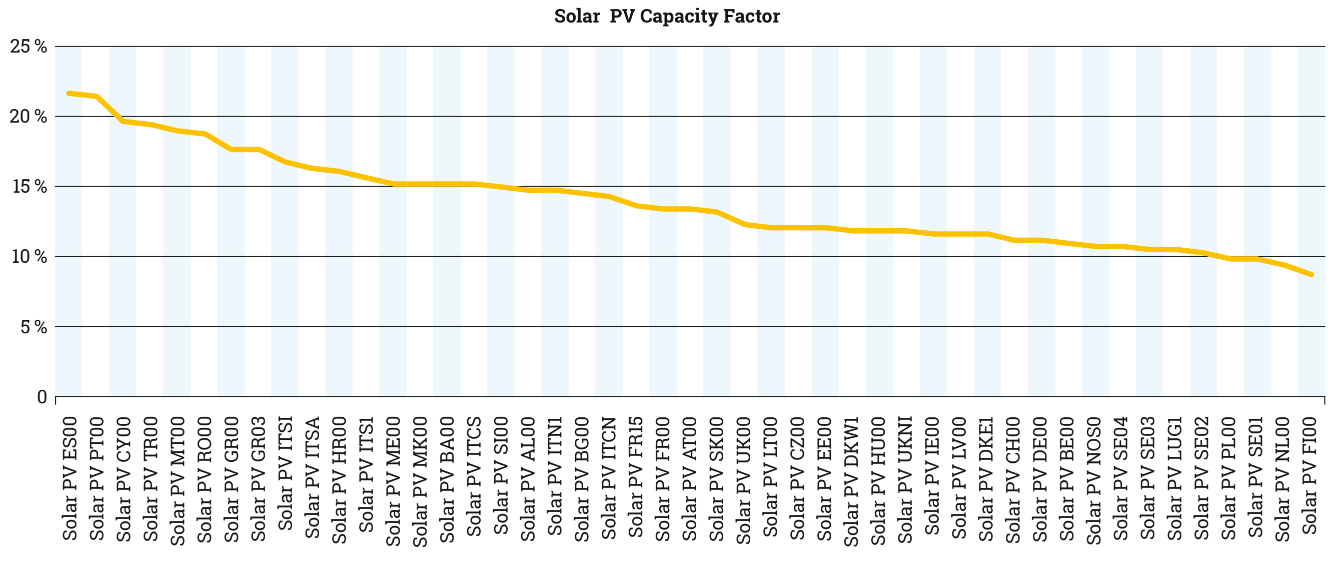


Figure 34: Solar PV Capacity Factor

Our analysis shows that investment in new conventional forms of energy such as nuclear and CCGTs with CCS are difficult due to the high CAPEX and the need for high operational hour's 60-70 % of Gas CCGTs and 80-85 % for CCGT with CCS and Nuclear power plants.

Global Ambition assumes very strong cost reductions for offshore wind, with offshore wind economical competitive to onshore wind and solar PV. Distributed Energy assumes strong reduction in solar PV costs. Wind onshore is generally competitive in both scenarios. Solar PV is generally most competitive in Southern Europe, whereas onshore wind is particularly competitive in Northern and Western Europe. For offshore wind, the lowest costs take place in North Sea and southern Baltic Sea regions.

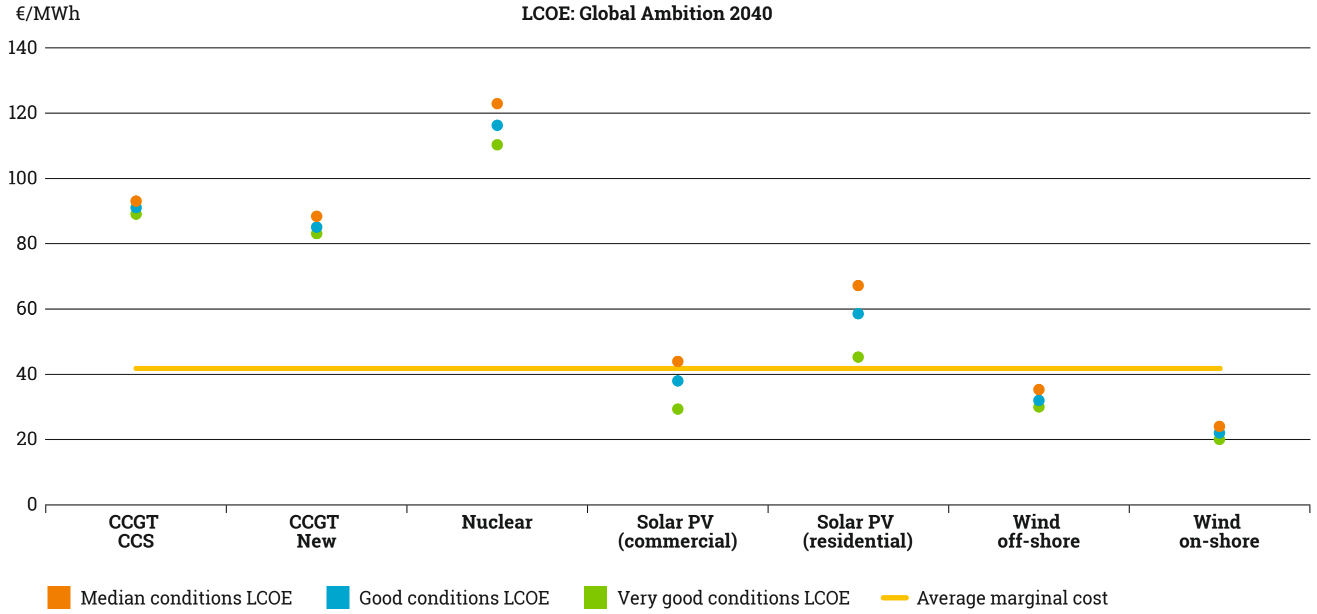


Figure 35: RES LCOE in Global Ambition 2040

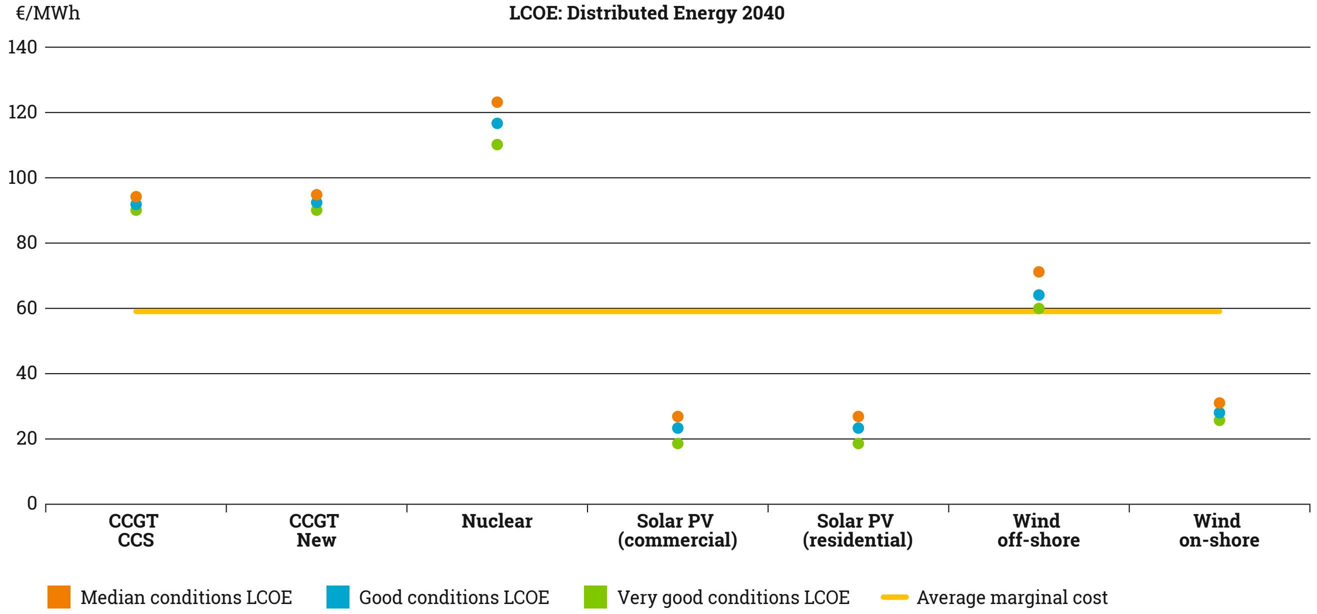


Figure 36: RES LCOE in Distributed Energy 2040

8 Benchmarking

A literary review of relevant external studies is a best practice approach when undertaking a complex task such as developing scenario for ENTSOG and ENTSO-E and EU28 perimeter. The purpose of the exercise is to understand whether or not the input assumptions and methodologies that ENTSOs employ result in credible and plausible outcomes compare to other expert opinion and methods.

As part of our internal quality process for scenario building, ENTSOG and ENTSO-E have compared their TYNDP 2020 Scenarios to the European Commission's Scenarios:

a) EUCO32/32.5 scenario (EC, 2018).
b) A Clean Planet for all – A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy" (EC, 2018), in particular with
   a. Baseline Scenario ("Baseline")
   b. 1.5TECH Scenario ("1.5TECH")
   c. 1.5LIFE Scenario ("1.5LIFE")

It is acknowledged that there are different approaches and purposes for both listed studies. The studies each have a view on the EU28 electricity and gas sectors. It is possible to create plausible ranges for scenario parameters such as, low to high ranges for demand; EV uptake, Heat Pump uptake; installed capacity for generation, low to high range gas for imports etc. In the following sections ENTSOs have focused their benchmarking on the overall electricity and gas demand, electrification and gas supply.

8.1 Final Electricity Demand

The highest final electricity demand corresponds to Distributed Energy, with the actual growth being due to the very strong increase in electric vehicles and heat pumps. The Global Ambition scenario has the lowest final electricity demand, due to the higher gas share.

Electrification rates

The final electricity energy demand divided by final energy demand indicates the direct electrification of different scenarios. The general increase in the share of electricity in final use demand, illustrates that electrification is one key driver trying to achieve a sufficient decarbonization up to 2050. The electrification trajectories of the TYNDP 2020 scenarios 3–4 percentage points above or below the EC LTS 1.5 scenarios. As displayed for the year 2050, the Distributed Energy scenarios achieves an electrification rate of 54 % points above the 1.5TECH scenario. The Global Ambition scenario achieves an electrification rate of 47 %, 2 points below the 1.5LIFE scenario .

The sectorial breakdowns of the industry, residential and commercial sectors illustrate that the COP21 scenarios are, with regard to electrification, in the order of magnitude compared to the EC LTS scenarios.

A similar statement can also be made to the transport sector for the mid-term horizon (2030 and 2040), where the electrification is in the ballpark of other external scenarios. For 2050, the transport electrification in ENTSOG and ENTSO-E COP21 scenarios matches the EC's 1.5TECH scenario.

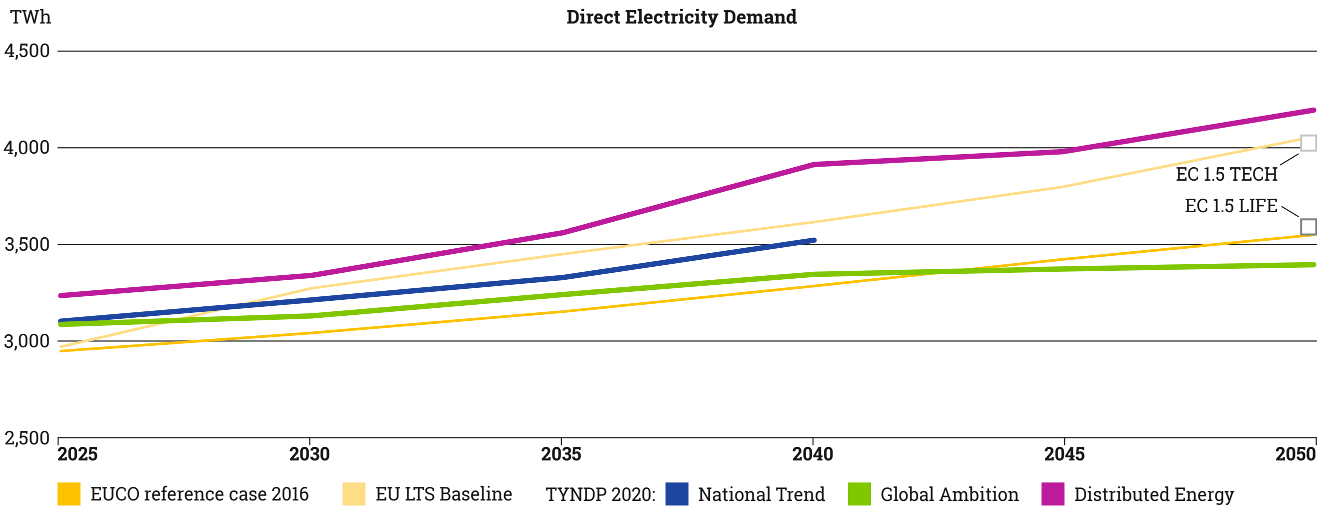


Figure 37: Benchmarking of projected electricity demand and wind/solar generation for EU28

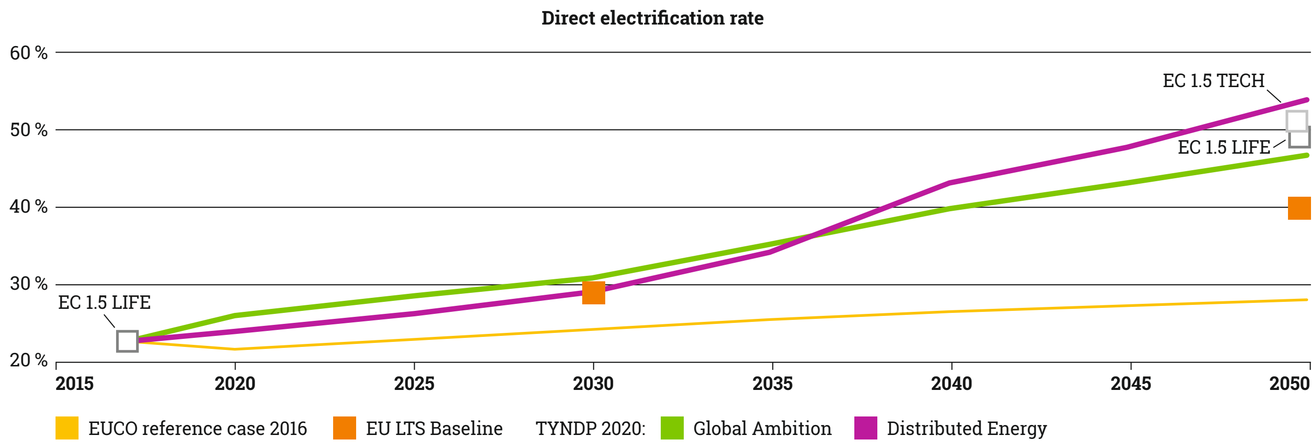


Figure 38: Benchmarking of projected electrification rate for EU28

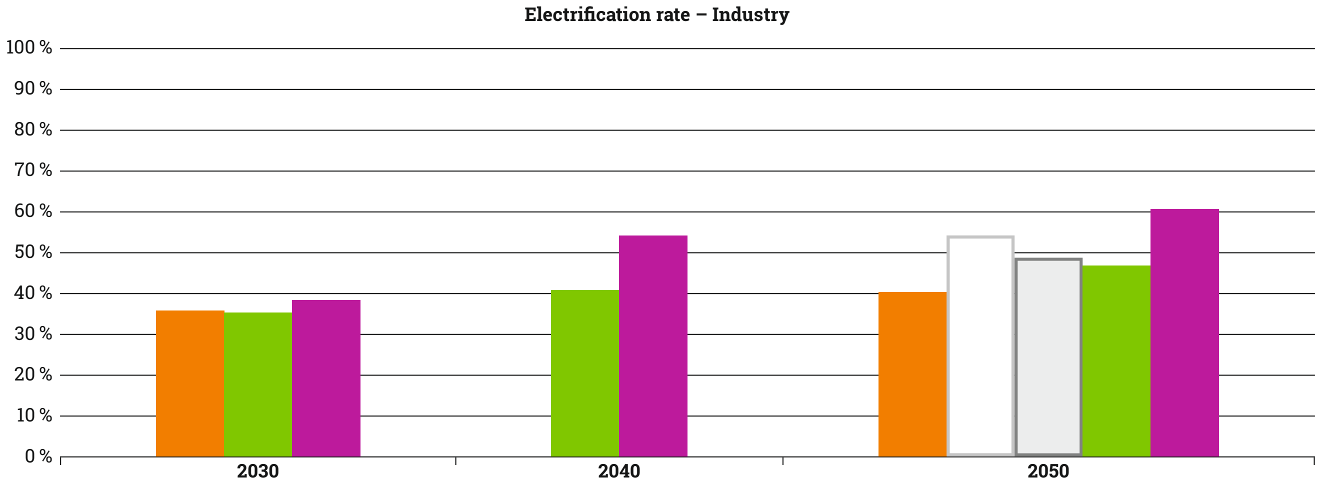


Figure 39: Benchmarking of projected electrification in the industrial sector for EU28

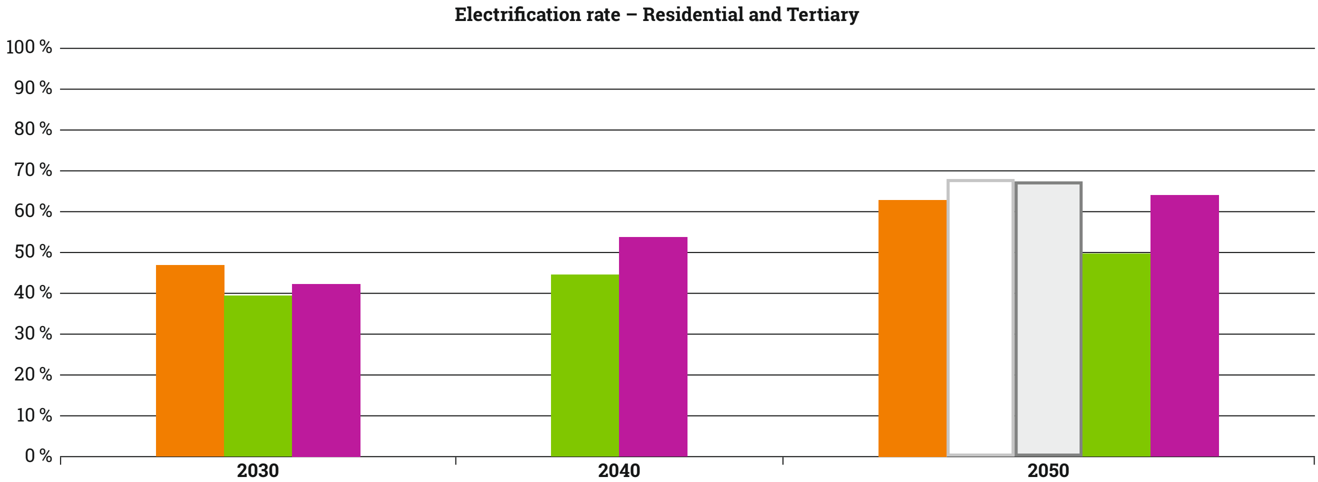


Figure 40: Benchmarking of projected electrification of residential and commercial sectors in EU28

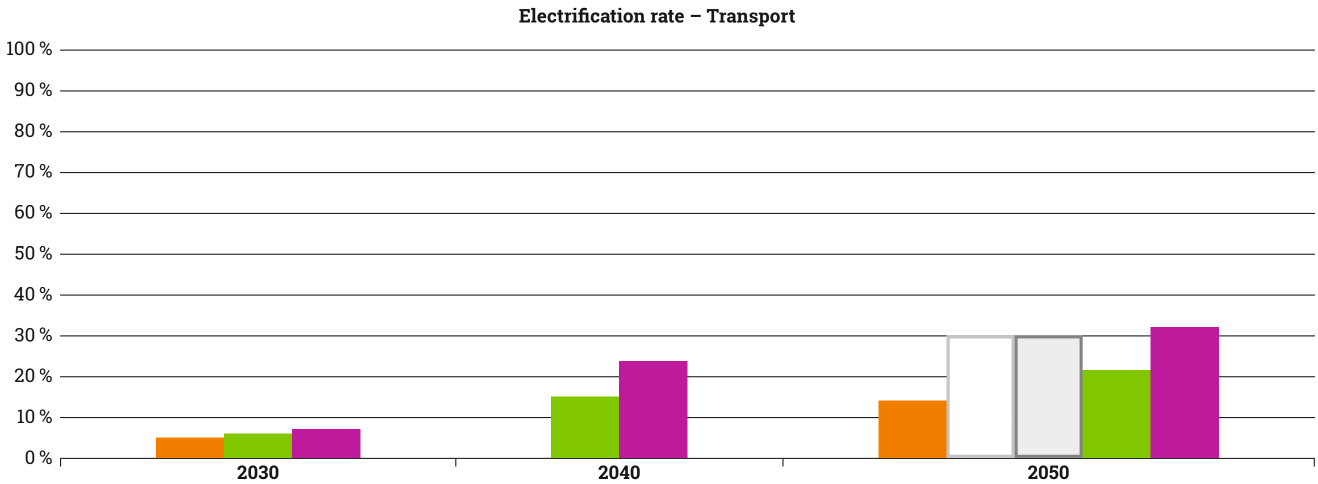


Figure 41: Benchmarking of projected electrification in the transport sector for EU28

TYNDP 2020: Global Ambition, Distributed Energy; EC LTS 1.5 TECH; EC LTS 1.5 LIFE; EU LTS Baseline

8.2 Gas demand

Although ENTSOs scenarios follow their specific assumptions and methodologies, they are designed to meet the same EU climate objectives as other external scenarios.

ENTSOs scenarios in the range of EC scenarios

In the timeframe 2020–2040, National Trends projects ca. 10 % higher gas demand than EUCO32/32.5 and the Baseline scenario. Part of the difference can be explained by national coal-phase out policies captured by National Trends taking into account latest information from the NECPs or national climate strategies (such as the German coal-phase out).

In 2050, Distributed Energy reaches the EU climate targets with 3,000 TWh ranging between 1.5TECH and 1.5LIFE. Global Ambition reaches the same objectives with a gas demand of 3,800 TWh, ranging above 1.5TECH.

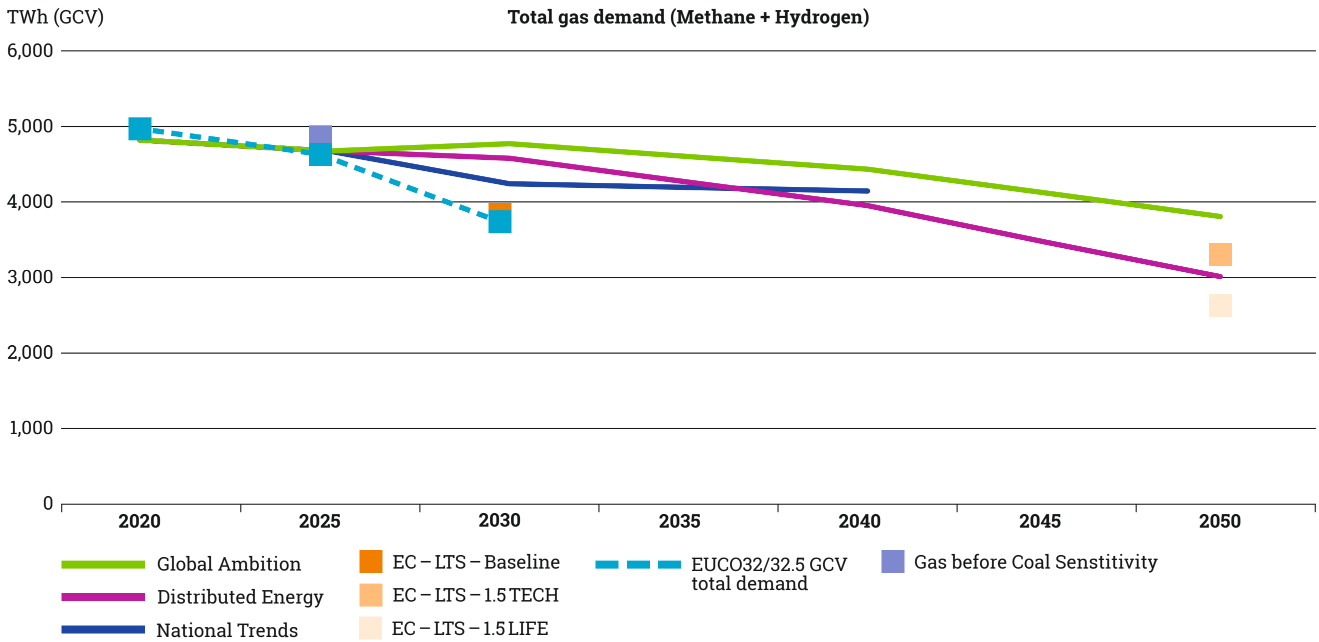


Figure 42: Total primary gas demand – Benchmark with EC Long Term Strategy

Gas demand for final use and for power generation follow different evolutions

When looking into the gas demand more in detail, the total gas demand (methane and hydrogen) can be divided in the gas demand for final use, where gas is directly used as energy (in residential, tertiary, industry and transport) or as feedstock (only industry) and the gas demand for power generation, where the gas is converted into electricity in power plants, CHP or in the long run fuel cells.

Till 2025, all TYNDP scenarios show high alignment with the EUCO32/32.5 scenario for both demand categories. For 2030, The TYNDP scenarios show different demand developments compared to the EUCO32/32.5 scenario.

- **Final demand:** With regard to the gas final demand, the TYNDP Scenarios consider more gas in sectors such as transport and industry compared to the EUCO32/32.5 scenario, which also lead a slightly higher demand.

- **Power Demand:** In case of National Trends, the difference can be explained by recently stated policies and their reflection in the NECPs. In case of Distributed Energy and Global Ambition, the reason is two folded: both scenarios combine a higher electricity demand with an early coal-phase out. The combination leads to an increasing role for gas in power generation.

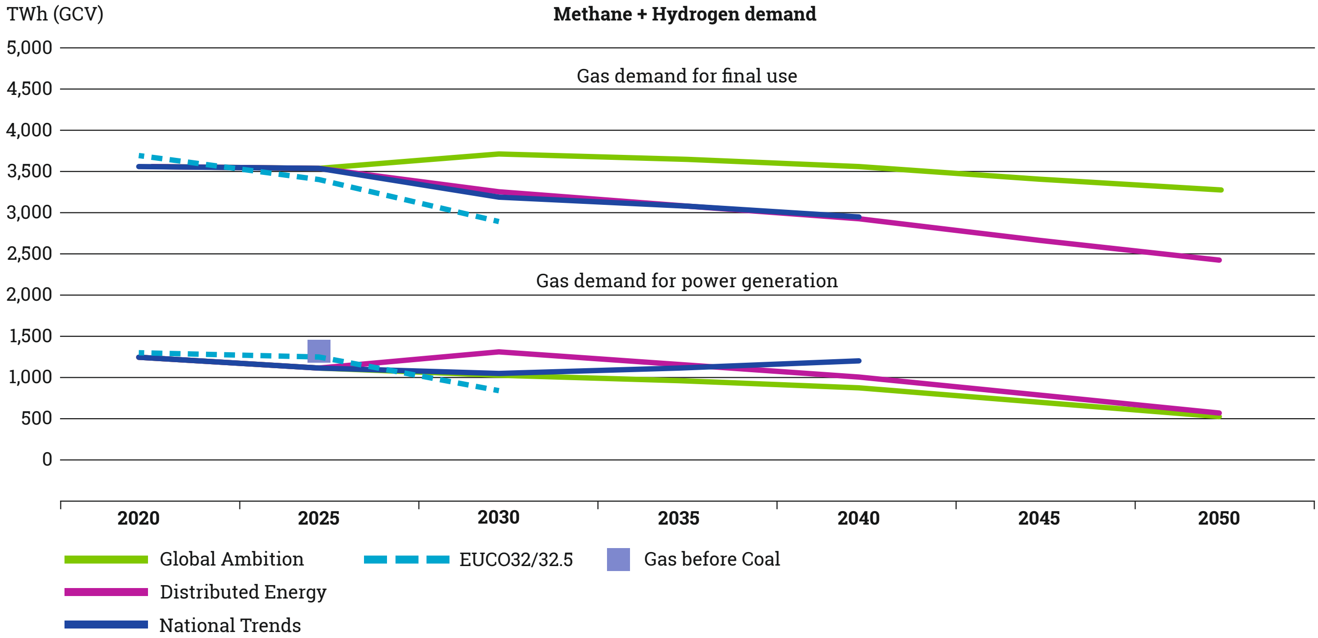


Figure 43: Primary gas demand for final use and for power generation

8.3 Renewable gas supply

The renewable gas production in the next thirty years can be divided in three different categories: production of biomethane, Power-to-Methane ($P2CH_4$) and Power-to-Hydrogen ($P2H_2$).

Biomethane in the range of EC LTS scenarios and Gas for Climate study

Biomethane generation in Global Ambition is comparable to 1.5TECH and 1.5LIFE scenarios of EC LTS, whereas Distributed Energy considers a higher generation of biomethane within the EU comparable to the P2X scenario. with National Trends having the most limited penetration of biomethane, all scenarios are therefore in the range of the EC Long-Term Strategy. Additionally, Distributed Energy shows comparable generation to the Gas for Climate study by Navigant (1,200 TWh in gross calorific value).

Power-to-gas sees a limited development compared to EC LTS

As a result of the assumptions on the generation potential as well as the development rate of P2G technologies, ENTSOG and ENTSO-E scenarios all look more conservative than EC LTS, explaining the limited gap between the overall indigenous generation considered in EC LTS and ENTSOs scenarios.

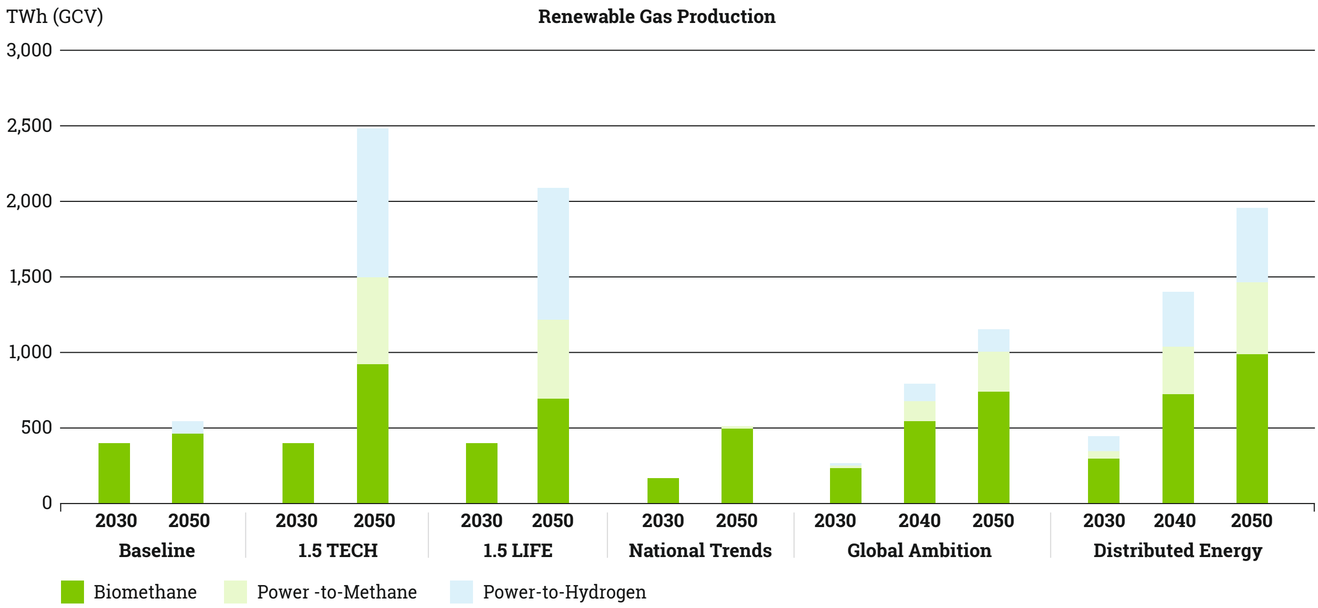


Figure 44: Renewable gas production – ENTSOs vs EC LTS (P2X, 1.5TECH, 1.5LIFE)

8.4 Energy imports

The figure below compares the energy import in 2050 between ENTSOs and EC LTS scenarios. As Distributed Energy focuses on higher European self-sufficiency, this scenario foresees the lowest levels of energy import. Even well below the energy imports in the EC LTS scenarios. Total energy import in Global Ambition is quite comparable with both 1.5TECH and 1.5LIFE scenarios. The type of energy carrier, which are imported differ, however. Compared to the EC scenarios, Global Ambition foresees less import of oil and more import of (renewable) gas. The higher gas import however stems explicitly from the scenario storyline of this scenario. Furthermore, compared to the LTS baseline scenario the gas imports in Global Ambition are still reasonable.

Figure 46 presents the developments of gas imports over time. Although gas import might see limited increase in the next five years, all scenarios foresee a decrease in gas import after 2025. With high shares of indigenously produced renewable gases, Distributed Energy shows alignment with EC's most ambitious 1.5TECH Scenario. On the other hand, Global Ambition shows a balanced development of gas imports on a trajectory which seems similar to the NECP based National Trends.

The difference in imports for 2020 reflects the recent reduction of Groningen field production decided by the Netherlands, which is not considered in the other external scenarios (EUCO32/32.5 in particular).

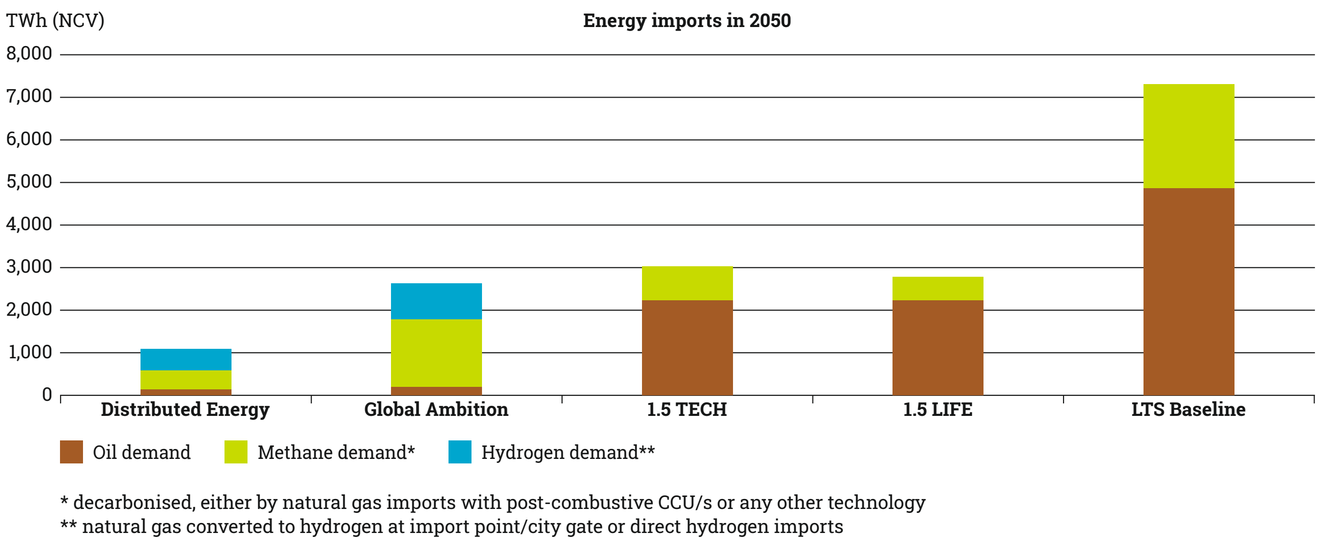


Figure 45: Energy imports in 2050 by energy carrier

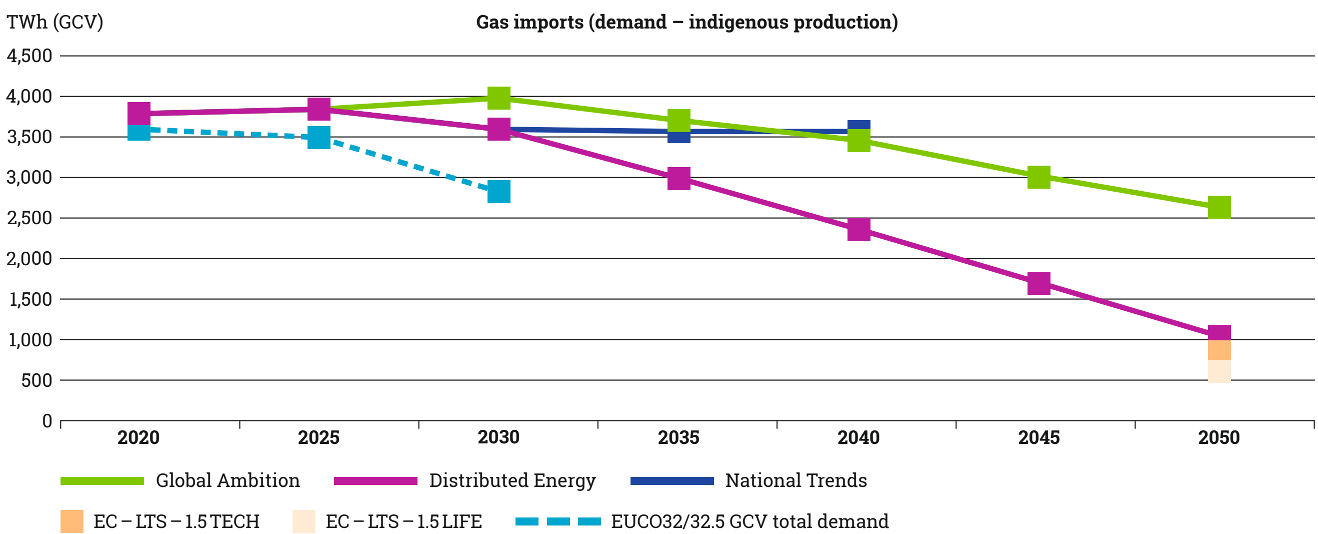


Figure 46: Gas imports per scenario and per year

8.5 Carbon Capture and Storage

Both Distributed Energy and Global Ambition scenarios show an increased application of carbon capture and storage (CCS). Distributed Energy foresees about a growth of up to 130 MT per year in 2050. This is slightly above EC LTS 1.5LIFE, but well below EC 1.5TECH. Global Ambition does exceed EC LTS scenarios however. But in comparison with for example Gas for Climate (Navigant) the amount CCS in this scenario still seems reasonable.

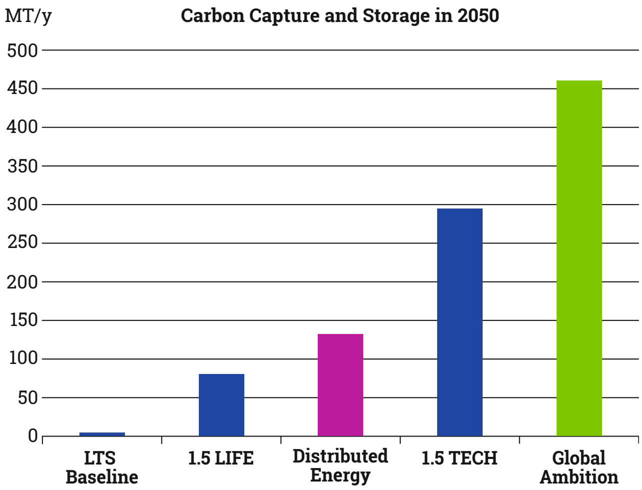


Figure 47: CCS in 2050 in ENTSOs and EC scenarios

8.6 Conclusion

Benchmarking the demand, renewable generation and electrification with the most important reference studies illustrates the reasoning behind then TYNDP 2020 Scenarios in their assumptions and methodologies. National Trends is based on the national policies towards meeting the EU's climate targets for 2050. However, the benchmark confirms both Global Ambition and Distributed Energy scenarios to be plausible pathways towards meeting the COP21 targets considering contrasted evolutions of the energy system.

In addition, it should be noted that the Distributed Energy scenario comes very close to EC's 1.5°C scenarios for most of their features.

ENTSOs scenarios robust and fit for purpose

The contrasts in demand and production technologies as well as the centralised/de-centralised approach to the development of renewable technologies and its impact on the energy imports make ENTSOG and ENTSO-E scenarios the best support for assessing the infrastructure needs of the energy system for the next decades.

9 Fuel Commodities and Carbon Prices

Fuel prices are key assumptions for the power market modelling as they determine the merit order of the electricity generation units, hence the electricity dispatch and resulting electricity prices.

ENTSOG and ENTSO-E have used several sources to benchmark the different price forecasts and projections in order to conclude on the reference source to be used for the scenarios (IEA, Primes, Bloomberg, IHS). This assessment shows that the prices provided by the PRIMES, which considers the global context and development that influences commodity prices, in-line with the EC targets, is robust enough to be used as a reference for gas, oil and coal prices as well for the CO_2 price. Prices for nuclear, lignite and biofuels are kept the same as considered for TYNDP 2018.

The following table summarizes the source for each fuel type and CO_2.

Starting from the PRIMES reference price for National Trends 2030, the CO_2 price will be increased in order to achieve a specific carbon budget as defined for each specific storyline and year.

The table below summarizes all the resulting prices per scenario.

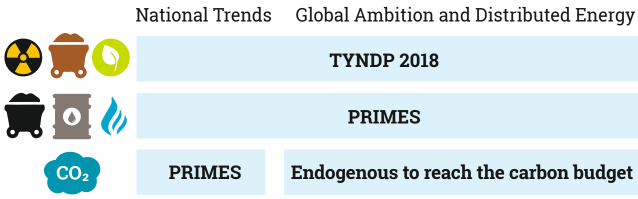


Figure 48: Summary of fuel price references

		2020	2021	2023	2025		2030			2040		
					BE	G2C	NT	DE	GA	NT	DE	GA
€/GJ	Nuclear	0.47	0.47	0.47	0.47		0.47			0.47		
	Lignite	1.1	1.1	1.1	1.1		1.1			1.1		
	Oil shale	2.3	2.3	2.3	2.3		2.3			2.3		
	Hard Coal	3.0	3.12	3.4	3.79		4.3			6.91		
	Natural Gas	5.6	5.8	6.1	6.46		6.91			7.31		
	Light Oil	12.9	14.1	16.4	18.8		20.5			22.2		
	Heavy Oil	10.6	11.1	12.2	13.3		14.6			17.2		
€/tCO_2	CO_2 price	19.7	20.4	21.7	23	56	27	53	35	75	100	80

Table 6: Fuel prices in TYNDP 2020 scenarios

10 Stakeholder feedback and how it shaped the scenarios

External stakeholders representing the gas and electricity industries, customers and environmental NGOs, regulators, EU Members States and the European Commission were key in building an ambitious, yet technically sound, set of scenarios.

The Scenario Building process was set up by ENTSOG and ENTSO-E work jointly with stakeholders through interactive workshops, webinars and web-consultations. Dozens of stakeholders provided input to formulate, with ENTSOG and ENTSO-E, the new scenarios storylines.

Why do we do external stakeholder interaction?

Stakeholders for the TYNDP 2020 Scenario Building process are divided into two groups: internal and external – and therefore above questions requires a differentiated answer:

Internal Stakeholders

Since the scenarios are developed by ENTSO-E and ENTSOG – the representatives of European electricity and gas transmission operators – the participants in these organisations are regarded as internal stakeholders. Representatives of ENTSO-E and ENTSOG form the steering committee for the Scenario Building process. They receive updates on the development of the process, are directly consulted on major process-decisions (e.g. the decision to engage Climate Action Network Europe and the Renewables Grid Initiative in the calculation of a Paris-compliant carbon budget), and ultimately approve the scenario report for publish.

External Stakeholders

To ensure complete transparency and to encourage the widest possible range of opinions, participation in the external stakeholder activities is entirely open. Any organisation or private individual which wishes may take part in the external stakeholder events which accompany the scenario building process. Any organisation or private individual may also offer feedback in the two consultation periods during the process with one exception: In order to ensure transparency when taking external stakeholder feedback into account, feedback from members of ENTSO-E and ENTSOG is not considered in the external consultations.

Since the scenarios also form the basis for the Ten Years Network Development Plans for electricity and gas, and therefore also have a direct influence on the cost-benefit analysis for Projects of Common Interest, the European Commission and the Agency for the Cooperation of Energy Regulators (ACER) are consulted regularly and bilaterally throughout the entire scenario building process.

How does the external stakeholder interaction work?

The external stakeholder interaction was designed to accompany the entire scenario building process. The interaction can be generally grouped into two phases: consultation of the qualitative scenario elements in the first year of the process, and the consultation of the final scenarios – incorporating both qualitative and quantitative scenario elements – in the in the second year of the process. Consultations were preceeded by stakeholder workshops. While many similar studies or scenario development processes often hold workshops after the completion of a consultation phase, the Working Group Scenario Building felt it would be more beneficial to hold workshops prior to consultation. This gave stakeholders a better understanding of the scenarios and the opportunity to ask questions before taking part in the consultation process.

The development process is covered in detail by the material released prior to the publication of this report, the high-level process for these storylines followed the steps below:

1. **Public workshop: "TYNDP 2020 Scenario Development Workshop", 29 May 2018** (link)

2. **Publication of first draft of five storylines describing potential relevant futures for the electricity and gas system in Europe developed by ENTSO-E and ENTSOG, 2 July 2018** (link)

3. **Public consultation of storylines: "2020 Scenario Storylines ", 2 July to 14 September 2018** (link)

4. **Public Webinar on "Scenario Development Process Update", 21 November 2018 (presentation send to participants via email)**

5. **Public Webinar on Final Storyline Release, 18 April 2019** (link)

6. **Publication of Final Storylines, 29 May 2019** (link)

7. **ENTSOG's Public Workshop on the Supply Potentials and Market Related Assumptions for TYNPD 2020, 10 July 2019** (link)

8. **TYNDP Cooperation Platform (with EC and ACER) and High-Level Meetings throughout the whole process with main focus on National Trends as the central policy scenario.**

9. **Public Workshop on "Draft Scenario Report 2020", 5 December 2020** (link)

10. **Public consultation on "Draft Scenario Report 2020", 25 November 2019 to 22 January 2020** (link)

10.1 Storyline Consultation

The initial storylines were presented for consultation in the summer of 2018. Before the beginning of the consultation, a stakeholder workshop was held in Brussels on 29 May 2018. The goal of this workshop was to introduce the five initial qualitative storylines and the storyline matrices. Stakeholders were given the opportunity to interact with members of the Working Group Scenario Building directly and to offer opinions and ask questions about the underlying assumptions for all five storylines.

After the workshop the Storyline Report was published for consultation. Respondents were asked to remark on the consistency and credibility of the five storylines and to rank the storylines according to their preferences. They were also asked about their opinions on key issues underpinning the storylines such as disruptive technologies which might play a major role in the EU energy system by 2050, the role of coal in the Energy Transition, and the potential (or not) of CCS to support decarbonisation. The results of the first stakeholder consultation provided some important feedback for the quantification of the scenarios.

Storyline Feedback and Storyline Selection

Feedback on Distributed Energy

The Distributed Energy storyline received the most positive feedback of the five storylines presented and was generally seen as consistent and credible. Criticism of this storyline principally revolved around possible limitations or weaknesses in the decentralised energy model. For example, the high level of electrification at the expense of gas (including low-carbon gases) was noted by several stakeholders as were concerns with maintaining security of supply with decentralised generation. Finally, several stakeholders felt that the role of distribution grids in the storyline needed to be considered in greater detail. However, this storyline was clearly the most popular among respondents.

Feedback on European Focus

The European Focus Storyline was a placeholder for an external Scenario, as requested by the European Commission in the TYNDP 2018 Scenarios. ENTSOs, European Commission and ACER have jointly decided not to use an external Scenario, but instead to align National Trends with the NECPs to the utmost possible. However, the European Focus Storyline received less direct feedback than the other storylines but was generally positively received. Several respondents noted the similarity of this storyline to the National Trends storyline and, likewise, criticised it for apparently failing to reach EU Targets. European Focus was the second-most popular storyline among respondents, narrowly ahead of National Trends and Global Ambition.

Feedback on National Trends

The consensus amongst respondents was that the storyline was both consistent and credible. Many respondents spoke of this storyline as forming a „reference“ scenario in comparison to the more ambitious top-down scenarios. Nonetheless, the lack of ambition in this scenario also drew criticism as many stakeholders (correctly) recognised that such a scenario would not achieve the necessary climate change goals by 2050. Several stakeholders also noted that adjustments to the current ETS model would be crucial to achieving climate targets and doubted whether the adjustments assumed in the National Trends storyline would be sufficient. National Trends ranked third among respondents, slightly behind European Focus and slightly ahead of Global Ambition.

Feedback on Global Ambition

The majority of stakeholders were unsatisfied with the consistency and credibility of the Global Ambition storyline. Many environmental and societal stakeholders viewed the 95 % reduction in CO_2 emissions as unrealistic, especially as this would be achieved through the global scale-up of several low-carbon technologies (PtX, CCS) which respondents considered immature today. While the global focus of the storyline received praise from some respondents, other criticised the higher levels of (renewable) energy imports that would entail. Global Ambition ranked fourth among respondents, slightly behind both European Focus and National Trends.

Feedback on Delayed Transition

The Delayed Transition storyline was by-far the least popular storyline among stakeholders who felt it lacked both consistency and, in particular, credibility. The storyline was criticised for its lack of ambition and negative message it would send if such a scenario were included in the final report. Multiple respondents noted that this scenario would entail the greatest societal costs due to the increases in global temperatures which would occur if this scenario occurred worldwide. The storyline ranked last out of the five.

The Role of CCS

As a mature but controversial technology, with the potential to support decarbonisation, stakeholders were asked for their opinion on what role CCS should play in the scenarios. Many of the respondents held a skeptical view of CCS, largely this was based on a perceived immaturity of the technology and an expected lack of social acceptance on the European mainland. On the other hand, respondents also suggested to include CCS with regard to "hard to decarbonize" sections (such as non-energy demand or cement/fertilizer production) and net negative emissions as also expressed by the IPCC 1.5 Special Report.

The Role of Coal

Stakeholders were asked about whether coal fired power generation would play a role in the European energy system in 2050 and, if not, which measures should be used to induce a coal phase-out. While many stakeholders believed that coal should not play any role in the future, others felt that it would continue to play at least a minor role in some countries until 2050. However, there was a general consensus that achieving EU climate change targets by 2050 would be extremely difficult if coal continued to play a major role in the energy mix. There were major discrepancies in the feedback regarding whether the coal phase-out should be policy- or economically-driven. The majority of stakeholders advocated for a policy driven approach, however many felt both policy and economy would have to play a central role in this process. Improvement of the ETS system and a greatly increased carbon price were the main policy options suggested in the consultation.

Disruptive Technologies

As part of the consultation, stakeholders were also asked their opinion on which potential disruptive technologies would have a major impact on the future European energy system. More than any other technologies, stakeholders mentioned energy storage technologies as potentially disruptive in the future. Power-to-X technologies were the second-most common response, followed by improved renewables generation technologies, smart grid technologies and CCS/CCU.

How did the Storyline Consultation influence the Scenario Building Process?

One of the central decisions made after completion of the Storyline Consultation was the final storyline selection. The Working Group Scenario Building had previously agreed to model three of the five storylines presented. This decision was made based on time and resource constraints within the group and with respect to the overall TYNDP projects and the adjacent Project of Common Interest selection process.

The Working Group Scenario Building agreed that two of the scenarios should have a higher level of climate-change ambition and remain within the Paris-compliant carbon budget calculated by CAN Europe and chosen by ENTSOG and ENTSO-E. To counterbalance these two scenarios, the third scenario should be a bottom-up scenario based on official EU and member-state data.As Distributed Energy had been the most popular storyline among respondents, it was chosen by the Working Group Scenario Building. The team also felt that Global Ambition offered the greatest contrast to Distributed Energy from an infrastructure-perspective and that the creation of a centralised, import-focused scenario juxtaposed especially well the decentralised, EU-focused narrative of Distributed Energy. Global Ambition also had a higher level of decarbonisation ambition than European Focus (although European Focus had been slightly more popular among external stakeholders).

As European Focus had been so popular among external stakeholders, the Working Group Scenario Building felt it should also be taken into account in the scenario development. Both the Working Group Scenario Building and external stakeholders had noticed the similarity between National Trends and European Focus and most of the key parameters of the two storylines were combined in the development of National Trends. In order to ensure alignment with the aims of the European Focus storyline and as jointly decided with the European Commission and ACER, the National Trends scenario was aligned with data from the National Energy and Climate Plans (NECP) of the EU member states.

Although ACER favoured the inclusion of the Delayed Transition storyline in the final Scenario Report, both the European Commission and the majority of external stakeholders were extremely critical of this. Moreover, ENTSOG and ENTSO-E take energy infrastructure readiness for the required energy transition for inevitable and therefore focus their TYNDP on the assessment of projects in compliance with national and EU-wide climate targets. Therefore, the Working Group Scenario Building decided it would be intransparent to include such a widely unpopular storyline in the final report.

10.2 Draft Scenario Report Consultation

The second phase of external stakeholder consultation began after the presentation of the Draft Report on 5 December 2019. The goals of the second external stakeholder consultation were far broader than during the first consultation. To this end, the consultation questionnaire was more detailed and entailed questions with two different broad foci:

- Presentation of data and engagement with external stakeholders
- Consistency and credibility of the scenarios, the methods used and their ambition

The Working Group Scenario Building received 42 direct responses to the consultation (this does not include bilateral or non-consultation feedback from institutions such as the European Commission and ACER). More than half of these came from project promoters, researchers and NGOs, showing the high level of engagement these organisations were able to achieve in the scenario building process.

Presentation of data and engagement with stakeholders

The majority of stakeholders were satisfied with the presentation and level of explanation provided by the Working Group Scenario Building. In particular the use of visualisation tools was praised for making the data sets more accessible, although some respondents still felt that better access to the raw data was needed to fully comprehend the scenarios. Stakeholders expressed less satisfaction with the level of engagement by the Working Group Scenario Building, however it should be noted that almost half of all respondents failed to answer the questions on this topic. The principal concerns regarding the stakeholder engagement process related to the timing of the final consultation period and the communication of its goals. Some respondents felt the second consultation occurred too late in the process. Indeed, several stakeholders mistakenly believed that the results of the TYNDP 2020 Scenario Report would be utilised for the 4th Project of Common Interest List[18] (released in October 2019 and confirmed by the European Parliament in February 2020) and therefore criticised the apparent lateness of the stakeholder consultation in this respect. The Working Group Scenario Building also noted that communication of the Scenario Methodology Report (published in parallel to the main report and available at ENTSOG and ENTSO-E TYNDP Scenario Report microsite) was apparently less successful than for the main Draft Scenario Report as many of the stakeholders questions regarding the scenario building process had been addressed in the Scenario Methodology Report. It is clear that in the 2022 scenario building process, greater emphasis should be placed on explaining and presenting the Scenario Methodology Report to stakeholders.

Consistency and credibility of the scenarios, the methods used, and their ambition

The vast majority of respondents agreed that the scenarios should use EU 2030 and 2050 climate change targets as a minimum standard. There was also general agreement that the National Trends scenario should be based on data from the National Energy and Climate Plans (NECPs) of the EU-28, although, as the Working Group Scenario Building also noted, this approach can create discrepancies between national energy and climate policies that undermine EU-wide decarbonisation measures.

The use of a carbon budget for the Distributed Energy and Global Ambition scenarios was widely regarded as a positive step. However, many respondents, especially those from environmental NGOs, found the scenarios were still too conservative and requested more extreme scenarios with greater levels of decarbonisation or completely excluding certain energy carriers from the models. Furthermore, several respondents felt that the Global Ambition and Distributed Energy scenarios did not differ sufficiently to provide truly alternative visions of the Energy Transition in 2050.

Several respondents also felt the levels of biomass and natural gas demand, especially in the Distributed Energy scenario were too high. They also argued that the use of CCS and, to a lesser extent, LULUCF to compensate for these fossil fuels in the energy mix was not credible considering the high decarbonisation ambitions attached to these scenarios.

How did the Draft Scenario Report consultation influence the Final Scenario Report 2020?

As the Working Group Scenario Building themselves noted, it will be necessary to restructure the timeline for the 2022 Scenario Report to ensure that the delays which occurred late in the 2020 process are not repeated. Certain respondents suggested shortening the storyline selection phase early in the process to allow more time for modelling. The Working Group Scenario Building will take this suggestion on board in the 2022 process. Respondents also requested better access to data sets in order to gain a

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better understanding of the process. The Working Group Scenario Building noted this concern and will endeavour to transparency of data sets in the 2022 Scenario Report and to allow stakeholders to view the core assumptions and parameters used to build the scenarios. To ensure that stakeholders can retain the high level of engagement in the early stages of the process, the Working Group Scenario Building suggest including key assumptions and parameters in the first external consultation phase in addition to the qualitative storyline elements.

In order to take into account feedback received on a lack of difference between the top-down scenarios, the considerable use of biomass, and a perceived lack of ambition in the electrification and RES development, the Working Group Scenario Building made the decision to update the Scenarios.

– National Trends

For National Trends, ENTSOG has run an additional data collection with its members to collect information from the final NECPs. Moreover, latest policy decisions have been taken into account, such as for the German coal-phase out or the Dutch gas production. Update of data compliant with the final NECPs and German Coal phase out. Updates on policies are also taken into account for Distributed Energy and Global Ambition.

– Distributed Energy

Gas demand: The gas demand for Distributed Energy in 2050 has been re-computed following a linear extrapolation of the development between 2025 and 2040 – with a new total gas demand of 3,000 TWh for Distributed Energy.

Bioenergy: Distributed Energy has been updated in the final report for the years 2040 and 2050. This was done by limiting the overall use of biomass to 2,424 TWh in 2040 and 2,757 TWh in 2050 in line with the 2,442–2,907 TWh range of the 1.5LIFE and 1.5TECH scenarios of the European Commission Long Term Strategy. The energy production deficit which resulted from this was compensated by an increase in electrification levels.

Biomass use was reduced by 26 % in the residential and tertiary sectors, by 80 % in the mobility sector and by 30 % in the industry. This has been compensated by an increase in direct electrification combined with P2L in transport according to the following table:

Electricity demand increase by sector (TWh)	2040	2050
Residential	53	42
Tertiary	16	16
Transport – Direct electrification – Power-to-Liquid	 35 648	 50 905
Industry	142	126

Table 7: Electricity demand increase in Distributed Energy

This additional electricity demand triggered an increase of dispatchable generation and the additional development of 740 and 1,415 GW of RES respectively in 2040 and 2050.

Additional RES for direct electrification have been modelled as part of the electricity system while the dedicated RES for P2L have been modelled outside the electricity system according to the P2G approach.

– Global Ambition

The gas demand for Global Ambition in 2050 has been re-computed following a linear extrapolation of the development between 2025 and 2040 – with a new total gas demand of 3,800 TWh for Global Ambition.

11 Improvements in 2020 Scenarios

Since TYNDP 2018 ENTSOG and ENTSO-E have aligned their TYNDP timelines and processes leading to the same TYNDP publication timeframes. Before that time, each organisation had its own individual process with the ENTSO-E TYNDP 2016 and ENTSOG TYNDP 2017 respectively. The joint development of the TYNDP Scenarios introduced at the TYNDP2018 project start must be highlighted as one of the most significant process improvement steps, as ENTSO-E and ENTSOG pooled their Scenario Building efforts and expertise in the frame of the interlinked model.

The focus study on the interlinkage between gas and electricity[19], performed by Artelys and presented to Copenhagen Infrastructure Forum 2019, concludes that most of the interlinkage is captured in the scenarios and the level of direct interaction mainly depends on the assumptions made on the different technologies for gas to power and power to gas conversion, as well as on the hybrid technologies. Those interactions defining the interlinkage between gas and electricity thus directly derive from the storylines defined and selected with the stakeholders.

Both ENTSOs consistently work to modernise their data, tools and methodologies between each release of the scenarios. Some of the key improvements for the Scenarios 2020 are presented below. The methodologies used by both ENTSOs to produce the scenarios are presented in detail in the Annex of this report.

19 https://www.entsog.eu/methodologies-and-modelling#consistent-and-interlinked-electricity-and-gas-model

11.1 More sustainability-oriented Scenarios (carbon budget)

With the introduction of a carbon budget as an input to the COP21 scenarios, ENTSOG and ENTSO-E can assess what the targets set by the COP21 require from the energy system beyond 2025 and hence, support the policy decision-making process.

The development of the carbon budget and the input assumptions to the scenarios have involved a wide range of stakeholders including environmental organisation, participating to the credibility of the two very different pathways the energy system could take towards reaching the European Union climate ambitions. Building on previous exercise, ENTSOG and ENTSO-E have kept the centralised and decentralised approach of, respectively, Global Ambition and Distributed Energy scenarios. Even if these scenarios should not be considered more likely than others, they will allow ENTSOG and ENTSO-E to consider the electricity and the gas system under the most contrasted situations, thus delivering the most comprehensive assessment.

11.2 Total Energy Scenarios (Top-down)

Whereas ENTSOs' TYNDP 2018 Scenarios were mainly based on bottom-up collected data for the gas and electricity sectors, for the first time, they have developed top-down Scenarios capturing the full energy system (all sectors, all fuels). In this sense, the joint Working Group Scenario Building developed an in-house energy model tool called the "Ambition Tool".

The main objectives were:

1) to better map the sectoral coupling and the associated interdependence between gas and electricity sector
2) to improve the methodologies to capture all GHG emissions and their development within a time period and thus ensure that the scenarios are in compliance with the Paris Agreement targets (carbon budget method as stated by the IPCC Special Report).

It is a policy driven top-down energy model, as no cost elements are considered and is linked to the Eurostat 2015 data as projection starting point. Working Group Scenario Building is looking at the European ambition level with levers sectoral technology split, fuel types, supply sources etc. and is working out the future energy carrier content (focusing on the gas and electricity system).

11.3 Electricity Demand

TRAPUNTA (Temperature Regression and loAd Projection with UNcertainty Analysis) is the next step in electricity load forecasting after about one year of development. This tool is a software that allows to perform electric load prediction starting from data analysis of the historical time series (electric load, temperature, other climatic variables) and evaluation of the future evolution of the market (e.g., penetration of heat pump, electric vehicles, batteries, population and industrial growth). It has been developed by Milano Multiphysics for ENTSO-E. TRAPUNTA is based on an innovative methodology for the electric load projection analysis based on regression, model order reduction and uncertainty propagation.

11.4 Gas Demand

Quality Split

Taking into account recent technologic and political trends, ENTSOs have decided to investigate the demand for methane and hydrogen separately. The term gas therefore stands for the sum of both gas types.

Taking into account recent technologic and political trends, ENTSOs have decided to investigate the demand for methane and hydrogen separately. The term gas therefore stands for the sum of both gas types.

Daily gas peak demand computation

As for TYNDP2018 Scenarios, the daily gas peak demand figures for gas have been collected from the TSOs for the bottom-up scenario National Trends. For the top-down scenarios, as the annual demand values were determined with the Ambition Tool, ENTSOs have developed a methodology to compute daily gas peak demand figures using sectoral full load hours and temperature-demand regression curves.

Dunkelflaute climatic case

Considering the level of development of renewable generation capacities in the COP21 scenarios, especially in 2040, ENTSOG and ENTSO-E have developed for the first time a Dunkelflaute climatic case (DF) to assess the possible impact of additional gas demand for power generation when minimum variable renewable generation is available for two weeks.

11.5 Electricity Generation

Co-optimisation

Following the exchange with internal and external stakeholders a co-optimization of generation capacity and grid was performed. This new method includes following key improvements:

- Endogenous and simultaneous optimisation of generation capacity and interconnectors
- Utilisation of scenario dependent CAPEX costs, OPEX costs and fuel prices with endogenous CO_2 level adjustment
- Endogenous CO_2 price setting as a function of carbon budget as main investment lever
- Consideration of household solar battery storage systems, vehicle to grid and industry demand side response
- Implementation of RES technology evolution by the usage of time horizon (2025, 2030 and 2040) related RES infeed time series

Trajectories collection

The Scenario Building process is developing "top-down" scenario data sets that are quantified using a number of optimisation loops according to the stakeholder agreed storylines. In order to improve the scenario quantification by setting plausible boundaries, the Working Group Scenario Building established a Trajectory data collection for various core supply and demand elements based on up to three national scenarios (with low, medium and high development trajectories). The main aim of this complementary information is to help better integrate uncertainties on national political decisions like coal phase-outs, nuclear fleet developments, RES support schemes but also to elaborate on upcoming technologies like electric vehicles, battery storages or P2G.

Based on those data, it is possible to:

- Ensure coherency with national studies
- Take into account national policies and political decisions/plans
- Set boundaries for technology developments
- Compare the outcomes of ENTSOG and ENTSO-E scenarios with national perspectives

11.6 Gas supply

In TYNDP 2018, gas supply assumptions consist of mainly bottom-up data for domestic production of natural gas, biomethane and P2G without a quality split in methane and hydrogen.

Import share

As done in external studies (e.g. EC's "Clean Planet for all") ENTSOs' developed generic assumptions on the import share for gas supply. This enables ENTSOG and ENTSO-E to test the gas infrastructure under different conditions (high import shares, low import shares). ENTSOs are convinced that centralisation and de-centralisation will have a major impact on future infrastructure needs.

Biomethane

To further improve the data quality and capture latest trends, ENTSOG in collaboration with the consultancy Navigant (previously Ecofys) has developed a "Biomethane Production tool", which is based on the assumptions of the "Gas for Climate" study. The tool considers anaerobic digestion and thermal gasification as technologies to produce biomethane. To capture the potential of both technologies it differentiates between several feedstock types and growing regions within Europe.

Hydrogen supply

For the first time, ENTSOs have identified the need for hydrogen supply considering three major technologies: P2G, Steam Methane Reforming plus CCU/S and Methane Pyrolysis. They have developed methodologies to identify the indigenous production of hydrogen by aforementioned technologies and, following their assumptions on the import share, the need for direct hydrogen imports and/or natural gas imports to convert it into hydrogen in Europe, respectively.

11.7 P2G and P2L

For the top-down scenarios, the quantification of the production of synthetic hydrogen, methane and liquid via P2G and P2L was extended to a two-step approach for the top-down scenarios. In a first step, curtailed electricity from the electricity market model is considered as source of renewable electricity to produce renewable gases (hydrogen, methane and liquids). In a second step, additional renewable electricity production is assumed and modelled to meet the demand for renewable gases. This is done via a dedicated model, which quantifies the needed RES, P2G and P2L capacities for the purpose of supplying synthetic gas.

Next editions will provide the opportunity to further enhance the modelling of P2X by taking into account different configurations (e.g. P2G supplied by dedicated RES, at the interface of electricity and gas systems or at consumer facility) and analyzing their impact on electricity and gas infrastructures.

11.8 Data Visualisation Platform

An online data visualisation platform was set up to engage with internal and external stakeholders and improve the transparency with regard to the scenario outcome. Stakeholders have simplified as well as extended data access with online analysis functions.

12 Next Steps

ENTSOG and ENTSO-E are currently working on the further development of their Interlinked Model and on the integration of the focus study recommendations for the identification of projects worth a dual assessment on both gas and electricity systems.

ENTSOG completed its project collection phase in July 2019. For the first time ENTSOG opened its TYNDP to Energy Transition Related projects including biomethane, P2G and ccs/u projects. ENTSO-E is collecting submissions in October–November 2019 and will run a second submission window for future projects after the release of its Identification of System Needs 2040 study in April 2020.

Over the coming months, ENTSOG and ENTSO-E will pursue their respective TYNDP 2020 development process, in a close timeline:

- The electricity and gas draft TYNDPs will be published in Q3 2020 for public consultation.

- Further to receiving the public consultation feedback as well as ACER's opinion, ENTSOG and ENTSO-E will publish the final TYNDPs, by end 2020 for gas and in spring 2021 for electricity.

- Both TYNDPs will support the 5th PCI selection process.

National Trends will serve as basis for ENTSO-E's Identification of System Needs study, which assesses pan-European network needs, their impact in regions, where grid projects should be considered, potential needed policy adjustments and technical challenges.

A cost-benefit analysis (CBA) of electricity transmission and storage projects will be performed for the National Trends (2025 and 2030 time horizons). Additionally, to illustrate the robustness of the proposed infrastructure projects, a subset of CBA parameters will be determined for Distributed Energy and Global Ambition (2030 time horizon). Projects will also be assessed in a 'Current Trends' scenario, an ENTSO-E scenario not included in this report which describes a future where the energy transition is slower than planned.

The scenarios will also feed into projects within ENTSO-E's Markets and System Operations committee, such as looking at market design and system operability in 2030.

ENTSOG TYNDP 2020 will include the Project-Specific CBAs (PS-CBAs) for those projects having declared their intention to apply for the 5th PCI list. Full PS-CBAs will be performed for transmission, storage and LNG terminal gas projects, and will consider all scenarios and the whole time-horizon of the TYNDP (from 2020 to 2040). Energy Transition Related (ETR) projects will be assessed with a reduced and sustainability-oriented CBA, to assess how they can deliver in terms of decarbonisation of the energy system and support the European climate ambitions.

Glossary

ACER: Agency for the Cooperation of Energy Regulators.

BECCS: Bio-Energy Carbon Capture and Storage. CCS applied to Bio-Energy, thus resulting in a net negative emission of carbon dioxide.

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.

Blue Hydrogen: Hydrogen obtained from natural gas or industrial residual gases by splitting them into hydrogen and CO_2. The CO_2 is then captured and stored/used.

CAGR: Compound annual growth rate.

CAPEX: Capital expenditure.

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.

Carbon price: cost applied to carbon pollution to encourage polluters to reduce the amount of greenhouse gases they emit into the atmosphere.

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.

CCU: Carbon Capture and Usage. The captured CO_2, instead of being stored in geological formations, is used to create other products, such as plastic.

CHP: Combined heat and power.

COP21: 2015 United Nations Climate Chance Conference.

Curtailed Electricity: Curtailment is a reduction in the output of a generator from otherwise available resources (e.g. wind or sunlight), typically on an unintentional basis. Curtailments can result when operators or utilities control wind and solar generators to reduce output to minimize congestion of transmission or otherwise manage the system or achieve the optimum mix of resources.

Coal phase-out: Coal is the most carbon intensive fossil fuel and phasing it out is a key step to achieve the emissions reductions needed to limit global warming to 1.5°C, as enshrined in the Paris Agreement.

DSR: Demand Side Response. Consumers have an active role in softening peaks in energy demand by changing their energy consumption according to the energy price and availability.

(Kalte) Dunkelflaute: German for „(cold) dark doldrums" expresses a climate case, where in addition to a 2-week cold spell, variable RES electricity generation is low due to the lack of wind and sunlight.

EC: European Commission.

EV: Electric vehicle.

GCV: Gross calorific value. The heat produced by combustion of a fuel at a constant pressure of 1 atmosphere, including the heat provided the condensation of all vapors produced by the combustion. With net calorific value on the other hand the heat provided b condensation is not included (see also NCV).

GDP: Gross domestic product.

GHG: Greenhouse gas.

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

IEA: World Energy Outlook.

Indirect electricity demand: Indirect electrification means that electricity is not used as a direct replacement for fossil fuels, but as an input in industrial processes.

LCOE: Levelised costs of electricity. It represents the average revenue per unit of electricity generated that would be required to recover the costs of building and operating a generating plant during an assumed financial life and duty cycle.

LNG: Liquefied natural gas.

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.

NCV: Net calorific value. The heat produced by combustion of a fuel at a constant pressure of 1 atmosphere, under the condition that all water in the products remains in the form of vapor. With gross calorific value on the other hand, the heat produced by condensation of all vapors is also included (see also GCV).

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.

OPEX: Operational expenditure.

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 be combined with CO_2 to obtain synthetic methane (Power to Methane – $P2CH_4$).

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.

PRIMES: The PRIMES energy model simulates the European energy system and markets on a country-by-country basis and across Europe for the entire energy system. The model provides projections of detailed energy balances, both for demand and supply, CO_2 emissions, investment in demand and supply, energy technology penetration, prices and costs.

RES: Renewable energy source.

Shale gas: Shale gas is natural gas that is found trapped within shale formations (e.g. via fracking).

Synthetic methane: fuel gas that can be produced from fossil fuels such as lignite coal, oil shale, or from biofuels (when it is named bio-SNG) or from renewable electrical energy.

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.

TRAPUNTA: Temperature REgression and loAd Projection with UNcertainty Analysis. Software that allows to perform electric load prediction starting from data analysis of the historical time series (electric load, temperature, other climatic variables) and evaluation of the future evolution of the market (e.g., penetration of heat pump, electric vehicles, batteries, population and industrial growth). It has been developed by Milano Multiphysics for ENTSO-E.

TSO: Transmission System Operator.

TYNDP: Ten Year Network Development Plan.

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