Overview of the proposed Gas and Electricity TYNDP 2020 Scenario Building Storylines

Date: 2 July 2018

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1. Purpose of ENTSO-E & ENTSOG Scenario Storylines

Joint Scenario Development

The ENTSOs consistent and interlinked electricity and gas model in accordance with Article 11(8) of Regulation (EU) No 347/2013 of the European Parliament and of the Council of 17 April 2013, was submitted in December 2016 and details the foundations of the joint scenario building process.

The scenarios go beyond the EU-28 to the ENTSO-E & ENTSOG perimeters which includes members, observers and associated partners. In total over 80 participants, covering more than 35 countries, are involved in the process.

Gas and Electricity TSOs are in a unique position to provide quantitative European focused scenarios on the impact of the energy transition on the European Electricity and Gas infrastructure needs and challenges for the long-term horizons.

The framework for the joint ENTSOs scenarios was agreed during the development process for TYNDP 2018. The framework enables the ENTSOs to create storylines that are consistent up to the 2040 time horizon and illustrates that uncertainty increases over the 2020-2040 time horizon. Figure 1 graphically represents this framework, using the circles to show that the spread between the scenarios will be greater, but within a plausible range of possibility.

What regulation states…
According to Article 8(3)(b) of Regulation 714/2009 and Article 8(3)(b) of Regulation715/2009, ENTSO-E and ENTSOG have to publish their TYNDPs on a biennial basis. Annex V of Regulation (EU) No 347/2013, covering the methodology for a harmonised energy system-wide cost-benefit analysis for projects of common interest, specifies that: *(1) The methodology shall be based on a common input data set representing the Union's electricity and gas systems in the years n+5, n+10, n+15, and n+20, where n is the year in which the analysis is performed. This data set shall comprise at least:* *(a) in electricity: scenarios for demand, generation capacities by fuel type (biomass, geothermal, hydro, gas, nuclear, oil, solid fuels, wind, solar photovoltaic, concentrated solar, other renewable technologies) and their geographical location, fuel prices (including biomass, coal, gas and oil), carbon dioxide prices, the composition of the transmission and, if relevant, the distribution network, and its evolution, taking into account all new significant generation (including capacity equipped for capturing carbon dioxide), storage and transmission projects for which a final investment decision has been taken and that are due to be commissioned by the end of year n+5;* *(b) in gas: scenarios for demand, imports, fuel prices (including coal, gas and oil), carbon dioxide prices, the composition of the transmission network and its evolution, taking into account all new projects for which a final investment decision has been taken and that are due to be commissioned by the end of year n+5.*

Table 1. Regulatory requirements

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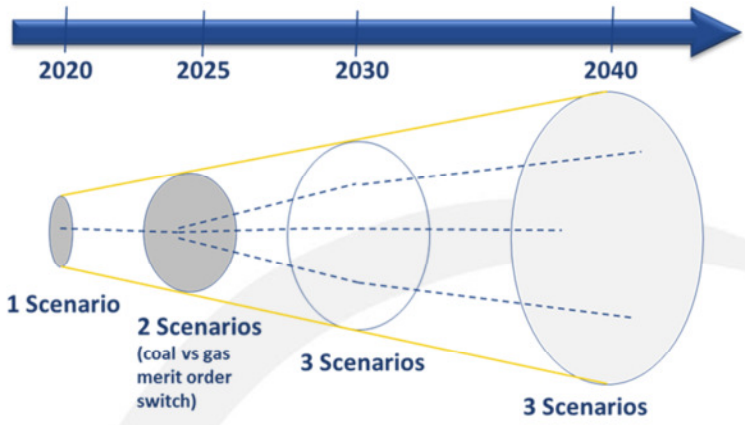

Figure 1. High level framework for Joint ENTSO-E & ENTSOG Storylines

The scenario building process for TYNDP 2020 builds on the work from TYNDP 2018 and seeks to improve the quality of the storylines that are jointly developed.

Figure 2 provides a starting point to assist the discussion on the new storylines for the ENTSOs respective TYNDP 2020 processes. The chart frames the development of the scenario storylines within the context of reaching a low carbon future in 2050.

The timeline to 2050 is split into 3 distinct parts; in the short-term we can look at a **Definable Forecast**, in the mid-term a future with **Dynamic Fluctuations**, and finally a common outlook on decarbonisation to a **Definitive Future** in 2050.

The storylines are developed so that they capture multiple trajectories that show the plausible pathways that enable a low carbon, affordable, and secure energy system for Europe.

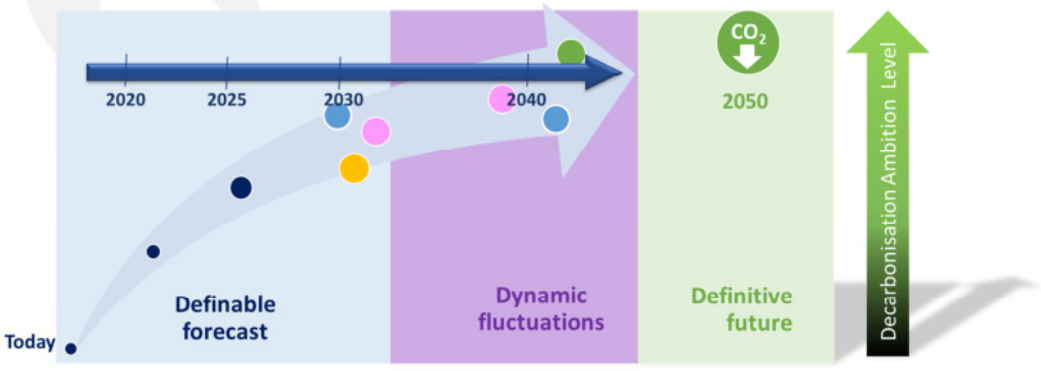

Figure 2. Scenario Building 2020 framework for Joint ENTSO-E & ENTSOG Storylines

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The **Definable Forecast** horizon is a region that captures current trends within the energy sector. A definable forecast typically captures the policies set out by National Development Plans (NDP) and near-term target for the 2030 target, currently being considered for adoption by Member States in accordance with ambitions set out by the Paris COP21 agreement.

- Subsidies within the energy sector mean that renewable technology development has been supported, so that in the longer term they are cost competitive with traditional technologies such as thermal power plants, or oil fire burners for domestic heating
- Within this time horizon, energy policy is agreed in the short-term up to 2020, but the targets for 2030 are being agreed and developed into new National Development Plans for countries co-operating within the COP21 framework
- The scenarios within this time horizon should provide credible scenarios for meeting EU policy expectations while taking into account technical and realistic build out rates for renewable and conventional technologies
- The definable forecast horizon has the flexibility to test scenario parameters that can have an impact on the gas and electricity systems. Useful scenario checks include merit order switches on grid power flows and gas demand, system adequacy, delayed or accelerated renewable development in the supply & demand sectors

The future time horizon covered by the **Dynamic Fluctuation** is becoming increasingly important.

- This horizon is an important area for future development. For COP21 ambitions that go beyond the 2°C, new and emerging technologies that can create zero carbon or negative carbon emissions become an important enabler in the ambition to decarbonise the European economy
- The development of large scale infrastructure tends to lag behind the development of renewable technologies, it is critically important for the planning of the European gas and electricity grid that we are prepared for various plausible outcomes
- Within this horizon it is important that a broader range of scenarios is developed to ensure that infrastructure needs are examined across a spectrum of plausible futures. This is to ensure that needs or gaps in system developments are assessed and future project needs promoted

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The **Definitive Future** time horizon looks at the point in time 2050. The range of uncertainty is clearly demonstrated by the broad spectrum of academic and governmental research in the area

- Current obligations mean that the EU target is set to 80-95 % of GHG reduction on 1990 levels by 2050
- However, the COP21 Paris agreement sets a more aspiring global climate change objective to keep the increase in global average temperature to well below 2°C above pre-industrial levels, aiming to limit the increase to 1.5°C
- Technologies and policies that are required to achieve the 2050 targets are not fully developed, but given that there are 32 years (16 TYNDP cycles) to deliver the necessary infrastructure, time is short and therefore it is critical that TSOs within the ENTSOs frameworks are prepared to discuss the possible futures out to 2050
- What will be the technology achievers that will enable a competitive European energy sector delivering value, security of supply and clean air to consumers in Europe and in support of our global effort to sustain our planet for future generations?

Where do scenarios fit into the network development exercise?

The scenarios represent the first step in any network development exercise. They offer the frame under which the future is analysed in view of identifying the investment needs and benefits of future electricity and gas projects. They provide a view on many elements e.g. energy demand, prices, technology developments, etc.

The elaboration of the electricity and gas TYNDPs 2020 have begun. Today the gas and electricity TYNDPs scenarios are at their very beginning – defining the assumptions.

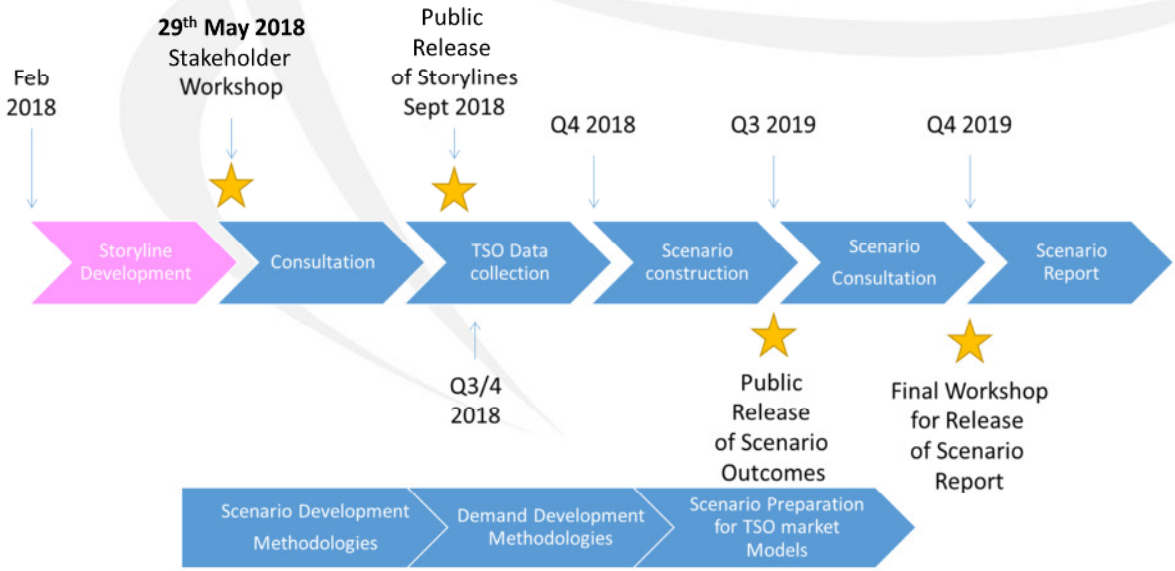

Figure 3. High level steps of gas and electricity TYNDPs 2020 Scenario Building, including more detailed scenario steps

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To whom this consultation is addressed?

This consultation is addressed to all the stakeholders interested in the European gas and electricity grid development.

Next steps

- From July to the beginning of September 2018, a joint ENTSO-E / ENTSOG online consultation process will be held. Your feedback is welcomed and considered an important part of the process.
- Based on your feedback ENTSO-E and ENTSOG will update and develop the scenarios assumptions for the electricity and gas TYNDPs 2020.
- Once this process has been completed, a workshop will be organised to review the final storylines and next steps in the quantification process.

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2. Introduction to the Storylines

Figure 4. TYNDP 2020 Storyline names

National Trends

The National Trends storyline is fairly self-explanatory. The essence of this storyline is that best available information from TSOs is collected, that fits with meeting the agreed national targets for 2020 and meeting the proposed 2030 ambitions currently proposed by the EC on an European wide basis.

TSOs have a wealth of data, information and insight that relates to each TSO's country. The data held by TSOs is based on the current short-term targets to 2020 and in the mid more certainty is coming forward in the context of 2030 with the Clean Energy Package and the negotiation on the National Development Plans proposed by Member States.

The storyline allows the TSOs to provide information on meeting the targets but also captures technology or market led developments that may be additional to the measures that are applied at a policy level. Beyond 2030, the national trends visible from the data provided will form the basis of the achievement of the long-term energy and decarbonisation goals of the EU.

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Global Ambition

The Global Ambition storyline is a world where the decarbonisation ambition is embraced by society, global policies and a drive by countries to actively promote worldwide decarbonisation. The storyline looks at a future that is led by economic development in centralised generation, economies of scale lead to significant cost reductions in emerging technologies such as offshore wind and Power-to-X. The flexibility and seasonal storage challenges are solved with the use of hydro resource and Power-to-Gas facilities, which also contributes amongst other solutions to the decarbonisation of the gas mix.

European Focus

The European Focus storyline follows the proposals for the European energy transition. The Storyline provides a central view from the European Commission on technology and policy. In addition, this envisaged pathway achieves the targets and ambitions for the near and mid-term horizons. The long-term strategy is closely linked to the EU roadmap that achieves at least 80 % GHG reduction by 2050.

Distributed Energy

Distributed Energy is a storyline that embraces a de-centralised approach to the energy transition. The theme for the scenario means the energy consumer is actively participating in the energy market and helping to drive the system's decarbonisation. The consumer evolves from not just consuming energy, becoming a more integrated part of the system, which is enabled by small household, community lead and regional energy schemes that deliver value to the end user in terms of security of supply and society's decarbonisation ambition is to achieve 95 % GHG reduction in 2050.

Delayed Transition

The Delayed Transition storyline represents a world where the decarbonisation is a future objective and efforts are being made to reach the European targets, but where the progress of the energy transition is delayed or stagnant. This is caused by a potential combination of factors, such as the failure of policies, resistance to change within the energy sector, limited engagement from society or less progression in the development of decarbonisation technologies that would help enable the transition.

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3. Our Storylines in more detail

3.1 The information we are providing…

Following the initial stakeholder workshop held on 29th May, the ENTSOs have listened to feedback on the information provided. Firstly, the scenarios have been named following the preliminary use of the Greek alphabet. Secondly, the parameters table has been significantly simplified and updated to reflect the process that will be used to shape and quantify the TYNDP 2020 scenarios.

After the high level introduction of the storyline themes in section 2, this part of the consultation document is intended to provide stakeholders with more information on the guiding factors of the storylines, without going into the complexity of the many elements that building the scenario data, which will be part of the quantification processes due later in the scenario development.

Central Matrix

The Central Matrix is an **EU-wide high level view of 2050**, showing how the primary energy mix and key final energy use sectors are assumed to change from today. As is observed currently, country level or regional differences will be present, driven by factors such as policy or resource constraints.

The Matrix is intended to provide a way to identify some of the key differences between scenarios that will be used to create differentiated pathways. However, there are some key elements to understand in addition to the fact they represent an overall EU Level view:

- 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 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.

The use of the primary energy mix is an essential new feature of the TYNDP 2020 process, designed to enable the ENTSOs to gauge the overall shift in the energy sector required to ensure the decarbonisation pathways specified by the scenarios are met.

Final energy use sectors have been grouped into key categories (high/low temperature heat[1], transport, power and lighting), with indicators for the expected development of the total demand of energy use, and then the resulting effect on the electricity and gas demand in these sectors.

[1] High temperature heat: usage for industrial processes (material transformations, chemical reactions, process steam, etc) which can be in excess of 1000°C, with the dominant range in Europe above 500°C.

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Due to this approach, it is important to understand the step between the primary energy mix and final energy usage, and the effect this has on some of the categories.

For example:

- The transport overall energy demand is expected to decrease as traditional internal combustion engines become more efficient, switch fuels or are replaced by electric motors. This can lead to positive indicators for both gas and electricity demand, whilst the total demand decreases, due to the displacement of oil in this sector
- Biomethane is produced from anaerobic digestion or gasification feedstock which are categorised under biomass
- Gas produced from Power-to-Gas has the primary energy source is coming from solar and wind
- Imported energy is represented in the primary energy mix as these are produced from primary energy outside the EU

GHG Emissions

The decarbonisation of Europe is driving the energy transition. Depending on the type of technological developments, policies and societal engagement observed, the level, speed and method of transition will differ. How this manifests within the scenarios is shown within the GHG Emission charts (Figures 6 & 7).

The targets for each of the time horizons will act as the primary driver for the scenario building process, with the assumptions specified by the scenario storyline enabling the change, thus providing differentiated data sets.

Figure 7 helps to visualise some of the differences between scenarios, for example when looking at the Matrix, Global Ambition and Distributed Energy have many similarities. This includes their level of decarbonisation ambition, however due to the difference in centralised versus decentralised technology assumptions, the divergence between these scenarios is clear.

Storyline Descriptions

The storyline descriptions are designed to build further on the themes of the scenarios and provide some insight into the technologies used within various sectors and overall trends observed within that energy future.

Low temperature heat: usage for space heating and hot water.

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3.2 Central Matrix

Factor		2050 Scenario Overview				
Scenario		National Trends	Global Ambition	European Focus	Distributed Energy	Delayed Transition
Category	Criteria					
Primary mix	Coal	---	---	---	---	--
	Oil	--	---	--	---	-
	Nuclear	--	--	--	---	-
	Hydro	o	o	o	o	o
	Geothermal	o	+	o	++	o
	Biomass	+	+++	+	++	+
	Imported Green Gas	++	+++	+	+	+
	Natural gas	-	--	-	--	o
	Wind onshore	++	+++	++	+++	+
	Wind offshore	++	+++	++	++	+
	Solar	++	++	++	+++	+
	Imported Green Liquid Fuel	+	+	+	+	+
High temperature Heat	Total demand (all energy)	o	-	o	-	o
	Electricity Demand	+	+	+	++	+
	Gas Demand	+	++	+	o	+
Low temperature Heat	Total demand (all energy)	-	--	-	--	o
	Electricity Demand	+	++	+	+++	+
	Gas Demand	-	-	-	--	o
Transport	Total demand	-	--	--	--	-
	Electricity Demand	+	++	++	+++	+
	Gas Demand	+	++	++	+	+
Power and Lighting	Electricity Demand	o	-	o	-	o

Legend

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

Figure 5. Central Matrix

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3.3 GHG Emissions Reduction

As the GHG reduction indicator is one of the most important political drivers for defining future national and/or pan-European climate ambitions this parameter is introduced into the overall scenario building process at an early stage. Clear GHG emissions reduction targets have been set by the European Union for 2020 and 2030 as part of the pathway towards a low carbon society in 2050 by reducing GHG emissions by 80-95 % compared to 1990 levels. The 2020 Climate and Energy Package forms basis for 20 % cut in GHG emissions by 2020 and the 2030 Climate and Energy Framework sets the target for 40 % reduction by 2030.

The ENTSOs propose five Storylines, of which four meet above mentioned targets. Furthermore, **Global Ambition** and **Distributed Energy** show higher ambitions by reaching 95 % emissions reduction by 2050. **National Trends** and **European Focus** show lower ambitions with 80 % CO_2 reduction but are still compliant with European targets. It is these targets which are shared between both scenarios, even if they will meet these levels of decarbonisation in different ways. Only **Delayed Transition** does not accomplish the objectives by reaching 69 % emissions reduction and also slightly missing the 2030 targets, as seen in Figure 6.

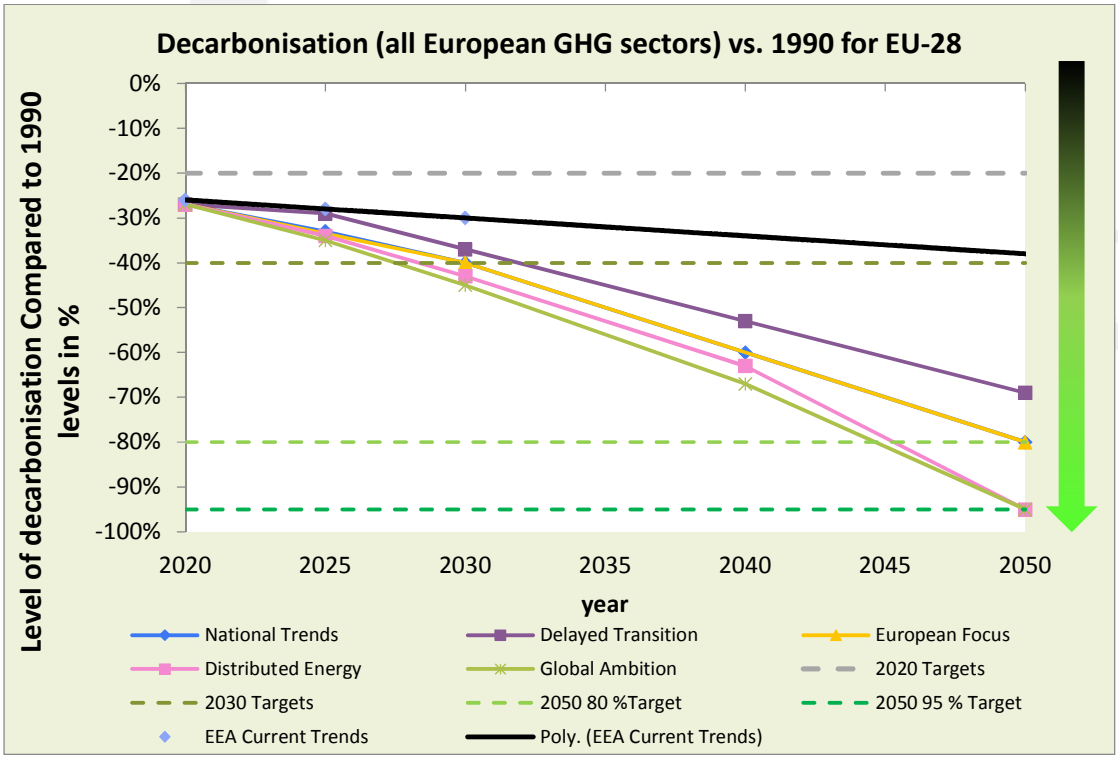

Figure 6: Different Decarbonisation Pathways[2]

[2] Current trends based on EEA projections (https://www.eea.europa.eu/publications/trends-and-projections-in-europe-2017) and then extrapolated.

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Although all storylines are heading towards a decarbonised future for the EU, they all differ substantially in their energy transition approach. For instance, one emerging theme is that the European energy transition could be driven either by a centralised or decentralised pathway, and this general lever is considered in the graph below.

As an example, **Global Ambition** looks at a future that is led by large development in centralised generation including offshore wind and Power-to-X. In contrast to that, **Distributed Energy** is a storyline that embraces a de-centralised approach to the energy transition, with rooftop solar installations linked with batteries, community or regional uses of biomass and geothermal resources.

It is important to understand that these levers are not absolute, and are intended to give a strong indication of the future development anticipated in the scenarios. For example, decentralised technologies will still exist in a centralised scenario, but to a lesser extent.

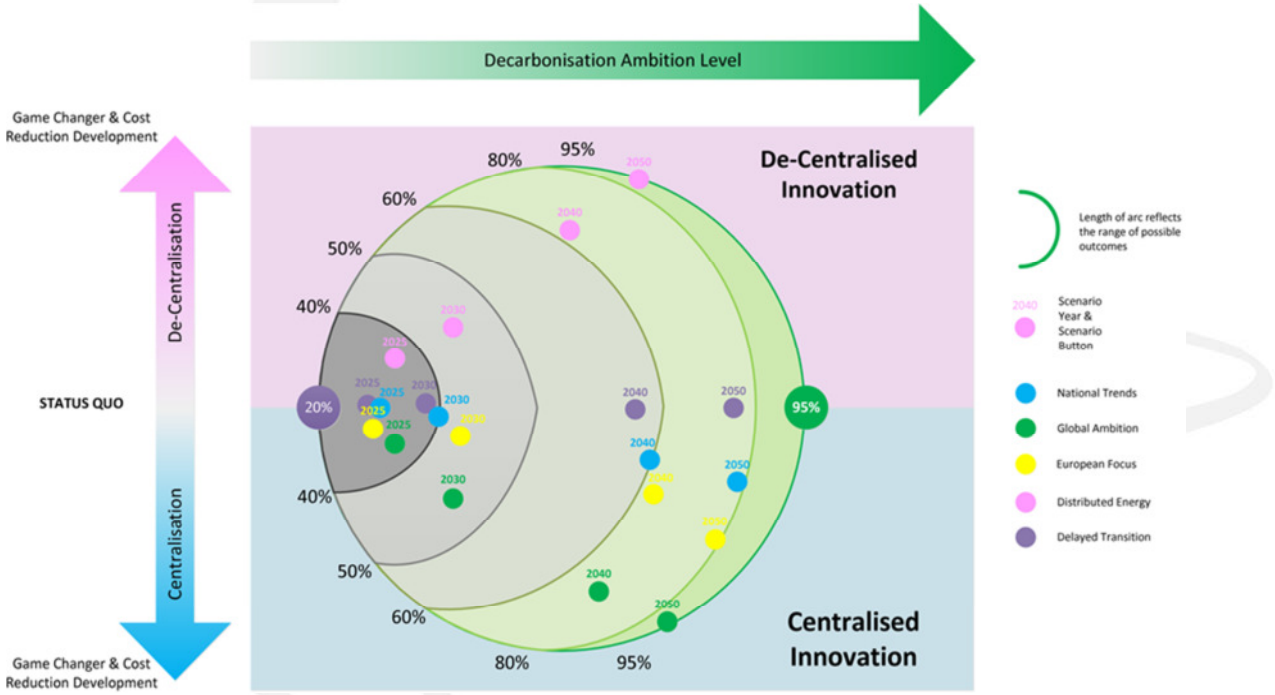

Figure 7: Decarbonisation & (De-)Centralisation

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4. Storyline description

National Trends [Alpha (α)]

1) Macro-Economic Trends

The National Trends scenario follows the trends developing in the climate policies on a national level. A centralised and top-down climate policy driven by the European Union is largely eschewed in favour of independent national solutions. The economic climate in storyline National Trends is one of moderate growth. As a result, there is stable rather than rapid development in many sectors and societal ambition to contribute to climate action is tempered by affordability. National Climate Plans supported by subsidies and the EU ETS scheme push towards the decarbonisation of Europe.

2) Transport

Overall uptake of electric and hybrid vehicles grows moderately, influenced by the economic climate, with consumers still conscious of the cost. Internal combustion engines using gas and oil with high shares of green gases and biofuels see low growth at an EU level, with a focus on heavy good vehicles and shipping. However, total energy demand in the transport sector decreases, mainly caused by the shift towards electrical vehicles and higher efficiencies in internal combustion engines.

3) Residential and Commercial

Driven by the economic climate, energy efficiency improvements in the residential and commercial sectors occur at a moderate rate resulting in overall lower heat demand. This leads to a variety of heating solutions being deployed, based on regional climatic specificities and building stock conditions. Electric heat pumps are common in new efficient buildings, but there is still a high share of gas fuelled appliances as part of hybrid solutions such as hybrid heat pumps. Overall the gas demand in the residential sector slightly decreases, whereas electricity demand for power and lighting remains stable.

4) Industrial

Total industrial energy demand is relatively stable as energy efficiency measures balance with the moderate economic growth, leading to increased production. Post 2030, both electricity and gas demand in the industrial sector are marginally increased replacing coal and oil. Due to the current political view of CCS/CCU in most of European countries, it does not play a notable role in this scenario.

5) Electricity

The power sector sees high growth of solar and wind generation, however national policies dictate on a country level which technology is favoured. Generation is typically more centralised. Decentralisation is limited to those in society who can afford to invest in self-generation solutions. Electricity storage sees low growth with limited large-scale battery solutions available. Gas fired power generation replaces coal and to a certain level nuclear due to national regulations rather than price in the short-term and provides the necessary flexibility to balance renewables in the long-term.

6) Gas Supply

Natural gas supplies via pipeline and LNG are still dominant sources of supply. Power-to-Gas sees limited development and is used more for energy storage than a key supply of gas. Biomethane growth is reliant on national policy support and available feedstocks. Storage capacity remains as a key component of the energy system. The storyline takes into account large imports of green gases using the existing gas infrastructure leading to a high decarbonisation of the gas mix.

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Global Ambition [Beta (β)]

1) Macroeconomic Trends

The Global Ambition storyline assumes moderate economic growth based on sustainability. The storyline looks at a future that is led by economic development in centralised generation, economies of scale lead to significant cost reductions in emerging technologies. Global climate efforts and global methods regarding CO_2 reductions such as a global emission trading are in place. The EU is on track towards its ambitious 2050 decarbonisation targets.

2) Transport

Wide adoption of zero-emission vehicles is a key component of decarbonisation in storyline Global Ambition. It sees a high penetration of electric vehicles in passenger transport across whole Europe. Green gas and hydrogen are the main fuels in the heavy good transport and shipping. Both segments utilize some liquid biofuels, especially as means to decarbonize older vehicles. Efficiency gains from fuel switching combined with development of communication technology reduces total energy demand for transport.

3) Residential and Commercial

Energy efficiency improvements occur at a high rate in residential and commercial sectors, driven by global decarbonisation efforts and technology improvements. Fossil fuels are replaced by electricity and green gases. Hybrid heat pumps are the end user heating appliance with the highest penetration due to their ability to use both electricity and gas to provide heat and therefore allow an efficient use of the existing electricity and gas infrastructure. Although the gas mix can be seen as mainly carbon neutral, solely gas fueled end user appliances run low due to their lower efficiency.

4) Industrial

Fossil fuels are replaced by green gasses and electrification in industrial use. Combined with energy efficiency and high demand flexibility, overall energy demand is reduced. Carbon capture and storage (CCS) technologies are applied especially in processes where fossil fuels cannot be substituted with electricity or gas. Using CCS, the sector contributes with low or even net-negative emissions.

5) Electricity

Low carbon technologies are competitive without subsidies. Thus, in storyline Global Ambition, wind and solar are the leading sources of power generation, and they can be deployed where the economics are best. Electricity generation remains mainly centralised with a high penetration of wind farms in the Northern Europe and large scale solar power plants in Southern Europe. New nuclear and CCS units are not built to a large extent due to challenges with cost and acceptability, whereas decommissioning of existing nuclear units follows national policies. Gas fired power generation replaces coal due to an effective global emission trading in the short and mid-term, and provides the necessary flexibility to balance renewables in the long-term. In the long-term, Power-to-Gas and batteries are the main technologies balancing renewables. Gas is also used in CHP units in existing district heating networks.

6) Gas Supply

Carbon-neutral gases substitute natural gas as time progresses. Biomethane growth is high using feedstocks produced in Europe. Furthermore, large scale Power-to-Gas is used to produce hydrogen and synthetic methane, which are fed to the existing gas infrastructure. Imports of carbon-neutral gases grow significantly, including “blue hydrogen”, from steam methane reforming natural gas in combination with CCS/U. Gas storage capacity remains as a key component of the energy system.

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European Focus [Gamma (γ)]

1) Macro-Economic Trends

The economic climate in storyline European Focus is one of higher growth, which sees increased penetration of new or further developed technologies in many sectors, with greater choice and affordability of these climate friendly options available to society. In addition to European policies, there is a global emissions scheme driving decarbonisation.

2) Transport

There is significant progress of the decarbonisation of the transport sector through the application of a variety of different technologies. Electrification of private transport observes very high levels of growth, but equally renewable liquid fuels, gas and hydrogen vehicles all contribute greatly, especially for heavy goods vehicles, shipping and aviation.

3) Residential and Commercial

Similar to the transportation sector, there is considerable development of a number of heating technologies across the residential and commercial sector, aided by higher levels of energy efficiency, which leads to an overall reduction in the total demand for heat. Electric and gas heat pumps, hybrid solutions, more efficient boilers and micro CHP all contribute to the transformation of this sector, being deployed based on regional climatic conditions and the specific application. The demand for electricity is increasing as the result of this change. A strong prosumer trend is not yet in sight, so that demand flexibility uptake is limited.

4) Industrial

Industrial demand for both electricity and gas is relatively stable as energy efficiency measures balance with the favourable economic growth. Along with energy efficiency, the development of renewable sources for both electricity and gas allows these processes to decarbonise, with demand flexibility in the industrial sector observing only moderate growth.

5) Electricity

There is high growth of solar and wind generation, dictated by commercial conditions and the best renewable energy resource locations. Generation is typically more centralised, however those in society who can afford in invest in self-generation solutions, coupled with the higher volume of electric vehicles. As stand-alone large scale battery storage systems are uncommon, gas fired power generation provides adequacy and supports the system as coal is phased out, and provides the necessary flexibility to balance renewables in the long-term. Nuclear is dependent on national political decisions.

6) Gas Supply

Until the mid 2030s natural gas serves as main gaseous energy carrier. After this period, there is a transformation towards synthetic gases, which develop as a source of carbon neutral gas for the energy system. These gases also offer long term energy storage, and offer a synergy between systems as there is a need to shift energy seasonally. Biomethane growth is high and widespread utilising a variety of technology. Storage capacity remains as a key component of the energy system.

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Distributed Energy [Delta (δ)]

1) Macro-Economic Trends

The economic climate in Distributed Energy is one of high growth, which sees increased penetration of new or further developed technologies in many sectors. People are engaged in climate action in general, leading to societal trends of decarbonisation along with strong climate policies. Society is motivated to make environmentally conscious and socially responsible investments. A greater number of prosumers investing in a range of smart or flexible low carbon energy solutions driven by a favourable market design. In this scenario decentralised energy sources are strongly developed. Biomass (as well in from of Biomethane) and Geothermal sources for the (low temperature) heat demand are utilised extensively.

2) Transport

The overall transport demand (km/a) is slightly decreasing due to a good development of public transport and solutions like car-sharing and flexible working conditions. People try to buy locally, therefore heavy load transport is staying on a comparable level. There is significant progress of the decarbonisation of the transport sector through the application of a variety of different technologies. Very high levels of growth are observed in the electrification of private transport and are combined with smart charging systems plus offer vehicle-to-grid flexibility. Heavy goods vehicles, shipping and aviation see an increase in renewable liquid fuels, gas and hydrogen vehicles.

3) Residential and Commercial

Energy efficiency grows with very high levels of renovation and insulation of residential and commercial buildings. This leads to a strong increase in the electrification of heating through the use of heat pumps driven by the decentralised generation of electricity by photovoltaic. Hybrid solutions are used for older building and cities with limited potential for PV. Smart technology in combination with home battery storage systems provide flexibility.

4) Industrial

Industrial demand is increasingly electrified. The increasing energy efficiency reduces the overall demand slightly and keeps the gas demand stable whilst the economic conditions grow. The sector also offers increasing levels of demand flexibility. Industrial gas use is relatively stable. Fossil gas is replaced by green gas. Carbon capture and storage (CCS) technologies are applied in industry process, which are hard to be decarbonized (e.g. production of cement).

5) Electricity

Renewable energy generation growth is strong but more decentralised, with high penetration of small scale PV. The overall demand for renewable energy is very high due to the ambitious CO_2 target. Therefore, there will be as well a high generation from wind. Further innovations in small scale generation and storage technologies are seen. Gas fired power plants play only a small role to provide adequacy but they support the system in early years as coal is phased out and nuclear generation is reduced. Energy production is more flexible with intermittent generation and allows for the optimized management of the production and consumption of electricity and heat.

6) Gas Supply

Biomethane growth is high and widespread utilising a variety of technologies. There is some development of synthetic gases develop as long-term energy storage, as well as a source of carbon neutral gas for the energy system. Storage capacity remains as a key component of the energy system.

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Delayed Transition [Epsilon (ε)]

1) Macro-Economic Trends

Storyline Delayed Transition considers a future with low economic growth, which leads to restrictions in meeting the European climate targets. National subsidies are limited and not a viable alternative due to financial pressures. There is scarcity of global financing for new RES developments since there is not a strong ETS price or subsidies available, plus delays occur in many projects. Society has less money to contribute to the energy transition.

2) Transport

Oil and hybrid technologies are still used in passenger transport as gas and electric vehicle uptake is slow and subsidies are not sufficient. Heavy goods transport and shipping relies on oil and gas using internal combustion engines. However, domestic biogas and biofuels production as well as imports of carbon-neutral gases and liquid fuels increase, which allows moderate decarbonisation of the transport sector. The total energy demand is only slowly decreasing.

3) Residential and Commercial

Once again, due to its low economic growth, storyline Delayed Transition considers limited renovation and insulation rates or efficiency measures in the building stock. Hybrid heat pumps and gas condensing boilers are main technologies used in renovated or new dwellings, replacing inefficient gas or oil boilers. The heat sector will still reach considerable reduction of CO_2 emissions due to the high decarbonisation of the power sector and to a lesser extent the introduction of green gases in the gas sector.

4) Industrial

Industrial energy demand is stable due to the low economic growth combined with some energy efficiency gains. Both electricity and gas replace high emissive fossil fuels and therefore experience low growth.

5) Electricity

Solar and wind have still the highest growth in generation, however national policies place restrictions of the location of technologies and the decreased funding or delayed implementation of project holds back the potential. Electricity storage sees low growth, and battery production and capability grow slower than anticipated.

Thermal power generation continues at higher levels to compensate, with a slow policy driven coal phase out and the nuclear plant lifetimes extension to maintain adequacy.

6) Gas Supply

Development of renewable gases is restricted, with limited support for biomethane and a lack of renewable generation to support synthetic gas production. Power-to-Gas is slow to develop at scale and is mainly used for storage. Still the gas supply experiences some level of decarbonisation by the substitution of natural gas by carbon-neutral gases such as biomethane, synthetic gases or hydrogen from Power-to-Gas and imported green gases.

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