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Update of consolidated common and regional pathways in NECPs and stakeholders mapping

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I EXECUTIVE SUMMARY

The report D2.5 ‘Update of consolidated common and regional pathways in NECPs and stakeholders mapping’ is un update to the deliverable report D2.1[1], which was published 18.5.2020. The D2.1 presented six pathways based on the analyses of the Integrated National Energy and Climate Plans (NECPs) of the Member States. The selected pathways were bioenergy, energy storage, energy systems integration, hydrogen, solar energy and wind energy. The additional component that the present report is bringing into the existing work, is the inclusion of the study of Long-term strategies (LTSs) of sixteen Member States, with special focus on these pathways and selected cross-cutting topics.

This deliverable derives from Task 2.1 ‘*Framework of NECPs. Measures, industrial sectors, regional clusters, expertise*’ in the Work Package 2 “Accelerating innovation and uptake by industry”. The previous NECP analysis and the LTS analysis described in this report is based on the objectives of this work package: 1) to establish a dialogue with key industrial stakeholders and facilitate transnational cooperation; 2) to analyse the proposed energy measures in the mid and long-term plans and strategies including sectoral specific as well as cross-cutting and systemic measures; 3) to define national and regional key industrial clusters due for realisation; 4) to promote a dialogue and cooperation model between regional industrial clusters, energy experts, SET Plan Implementation Working Groups, European industrial organisations, and related platforms; and finally, 5) to deliver sectorial, cross-sectorial and systemic recommendations on R&I priorities, at regional and transnational level, to support uptake of new technologies by the industry and the implementation of National Energy and Climate Plans (NECPs) and the SET Plan (Recommendations).

[1] https://supeera.eu/component/attachments/?task=download&id=697:D2 (as 20.12.2022)

LIST OF ACRONYMS

BMUB – German Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

CAES – Compressed Air Energy Storage

CCUS – Carbon Capture, utilisation and storage

CEM – Clean Energy Ministerial

CET – Clean Energy Transition

CESEC – Central and South Eastern Europe Energy Connectivity

CHP – Cogeneration Heat and Power

CO_2 – Carbon Dioxide

CSP – Concentrated Solar Power

DHS – District Heating System

DSM – Demand-side management

DSO – Distribution System Operators

DSR – Demand-side response

EC – European Commission

EE – Energy Efficiency

EERA – European Research and Energy Alliance

ESI – Energy System Integration

ETIP – European Technology and Innovation Platform

ETS – Emission Trading System

EU – European Union

GHG – Greenhouse gas

HOP – Heat only plant

IEA – International Energy Agency

IP – (SET Plan) Implementation Plan

IRENA – International Renewable Energy Agency

IWG – Implementation Working Group

JP – (EERA) Joint Programme

LTS – Long-term Strategy

LIB – Lithium-ion Battery

LOHC – Liquid organic hydrogen carriers

LULUFC – Land use, Land-use Change and Forestry

NECP – National Energy and Climate Plan

NER – Nordic Energy Research

NSEC – North Seas Energy Cooperation

MI – Mission Innovation

O&M – Operation and Maintenance

PV – Photovoltaics

PPP – Public-private partnership

RE – Renewable Energy

RED II – Renewable Energy Directive

RES – Renewable Energy Sources

R&D – Research and Development

R&D&I – Research and Development and Innovation

RTO – Research and Technology Organisation

SET Plan – Strategic Energy Technology Plan

SMS – Smart metering systems

SN – Smart networks

SUPEERA – Support to the coordination of national research and innovation programmes in areas of activities of the European Energy Research Alliance

TSO – Transmission System Operator

VRFB – Vanadium Redox Flow Battery

WTO – World Trade Organisation

II ANALYSIS OF PLANNED ENERGY MEASURES

Foreword

To reach the EU's target of climate-neutrality by 2050, the EU Member States have been required to develop their National Energy and Climate Plans (NECPs). All the EU countries were required also to develop their national long-term strategies (LTSs) on how they plan to achieve the greenhouse gas emissions (GHG)reductions needed to meet their commitments under the Paris Agreement and EU objectives and submit them to the EC by 2020. The LTSs should be consistent with the 10-year NECPs. The strategies should be updated every ten years (next update is due 01/01/2029), or every five years where necessary. The long-term strategies include total greenhouse gas emission reductions; emission reductions of individual sectors such as electricity, industry and, transport; expected progress on the transition to a low greenhouse gas emission economy, socio-economic influence of the decarbonisation measures; and links to other national objectives, policies and investment. The national long-term strategies are published on the EC website[2].

The current unprecedented geopolitical and economic situation in Europe, after Russian's invasion into Ukraine, which has led to severe energy crisis, will without a doubt have a major influence on the revisions and updates of both the NECPs and LTSs. This urgency of the situation is reflected in the EU policy agenda through the REPowerEU. The analysis of the NECPs within the SUPEERA project was performed prior the start of the war, hence the analysis of the LTSs follows the similar process what was applied to the NECPs, described in the D2.1 report.

2.1 Integrated National Energy and Climate Plans (NECPs)

According to the REGULATION (EU) 2018/1999 (11 December 2018), the integrated national energy and climate plans address all five dimensions of the Energy Union; (a) energy security; (b) internal energy market; (c) energy efficiency; (d) decarbonisation; and (e) research, innovation and competitiveness, are necessary tools for more strategic energy and climate policy planning. The Member States had to provide NECPs for the period 2021 to 2030 and set out the main pillars of the governance mechanism. The NECPs are a tool to ensure that the EU meets the energy and climate targets for 2030.

The national plans should be updated once during the ten-year period covered to allow Member States the opportunity to adapt to significantly changing circumstances. For the plans covering the period 2021 to 2030, Member States should update their plans by 30 June 2024. Objectives, targets, and contributions should only be modified to reflect an increased overall ambition in particular as regards the 2030 targets for energy and climate.

The planned schedule for the integrated National Energy and Climate Plans[3] in short:

- NECP drafts by 31.12.2018
- Final NECP by 31.12.2019
- Progress reports every 2 years

[2] https://ec.europa.eu/info/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-long-term-strategies_en#strategies (as 15.12.2022)

[3] https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-energy-and-climate-plans_en (as 8.12.2022)

- Draft update NECP by 30.6.2023
- Update NECP by 30.6.2024

The integrated national energy and climate progress reports among others shall cover e.g., information on the progress accomplished towards reaching the objectives; targets and contributions set out in the integrated national energy and climate plan; finance planning and implementing policies and measures necessary for their execution, including a review of the actual level of investments measured against initial investment assumptions.

The EC published individual assessments and summaries of the NECPs (staff working documents) in October 2020.4

As the EU climate framework is changing rapidly due the current energy crisis and stringent green transformation targets, the national plans that were originally provided, lack current information of energy forum. The energy market disruption due to Russian's invasion of Ukraine with cutting down the EU's dependence on Russian fossil fuels, has driven European countries to look for alternative energy forms in an utmost haste. As most recent, launched in May 2022, the REPowerEU – affordable, secure and sustainable energy for Europe, targets to drastically accelerate the clean energy transition and increase Europe's energy independence from unreliable suppliers and volatile fossil fuels.[5] The European Green Deal, with its ambitious goal of making Europe the first climate-neutral continent by 2050 by increasing the climate targets for 2030 (to 55% GHG emission cut instead of 40% compared to the 1990 levels), should be reflected in the updated NECPs. In addition, many strategic policies and strategies have been released since 2020, e.g., European Climate Law, the European Climate Pack Launch, the Circular Economy Action Plan, and the EU Industrial Strategy, all of them influencing the climate plans of the Member States. The NECPs will play an important role in the EU recovery package, Fit for 55 Package[6] and the REPowerEU, since the Member States' recovery plans should support the energy measures contained therein to reach the EU's climate goals.

2.2 The national Long-Term Strategies (LTS)

Even though the majority of the Member States have published their national LTS, still some countries are still to submit their own LTS (Bulgaria, Ireland, Poland and Romania) as shown in Table 1. The LTSs have been published in the EC website[7].

Table 1: List of the analysed Long-term Strategies of Member States available in 2021during the analysis (bold/green) and all published LTSs as of 29.9.2022.

Country	Status of LTS	Country	Status of LTS
Austria (AT)	German	**Italy (IT)**	**Italian**; summary in English
Belgium (BE)	**French** and Flemish	**Latvia (LV)**	Latvian and **English**
Bulgaria (BG)	-	Lithuania (LT)	Lithuanian
Croatia (HR)	Croatian	Luxembourg (LU)	French

[4] Individual assessments | Energy (europa.eu) (as 15.12.2022)
[5] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en
[6] Fit for 55 - The EU's plan for a green transition - Consilium (europa.eu) (as 21.12.2022)
[7] https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-long-term-strategies_en (as 8.12.2022)

Cyprus (CY)	English	**Malta (MT)**	**English**
Czechia (CZ)	Czech; summary in **English**	**Netherlands (NL)**	Dutch and **English**
Denmark (DK)	**English**	Poland (PL)	-
Estonia (EE)	Estonian and **English**	**Portugal (PT)**	Portuguese and **English**
Finland (FI)	**Finnish**	Romania (RM)	-
France (FR)	**French**	Slovenia (SI)	Slovenian
Germany (DE)	German and **English**	**Slovakia (SK)**	Slovakian and **English**
Greece (GR)	**Greek**	**Spain (ES)**	**Spanish**
Hungary (HU)	Hungarian and **English**	Sweden (SE)	Swedish
Ireland (IE)	-		

2.3 The methodology

The Long-term Strategies (LTSs) from the Member States available during the analysis (autumn 2021) were studied in the view of the previously performed analyses of the NECPs. That process and results are presented in detail in the Deliverable 2.1 'Consolidated common and regional pathways in NECPs and stakeholders mapping'[8]. The target was to identify the occurrence of the selected six pathways and cross-cutting topics in the LTSs, and how they are presented in the future national energy measures.

Process and structure of the analysis:

- A short introduction
- Organising information by technological **pathways** and by **sectors**
- Comparing the information of both LTSs and NECPs documents. Including complementary information from the LTSs.
- Including additional information from other documents (roadmaps / strategies where available) that could be used to formulate recommendations – the final output of the Work Package.
- Avoiding giving exact figures and/or specific targets/objectives given the distance in time, as they are already included in the assessment performed by the EC (European Commission's Summary tables).
- Including relevant information from the European Commission's Summary tables, e.g. main drivers and features
- Prioritising the objectives of the SUPEERA Work Package 2:
  - Facilitate collaboration/establish dialogue between **industry and research;**
  - **Transfer** knowledge across regions and foster transnational cooperation;
  - Deliver (cross)-sectorial and systemic **recommendations** on **R&I priorities** to support uptake of new technologies by the industry and the implementation of the **SET Plan** and **CET objectives**.
- Focusing on the foreseen R&I priorities that could help closing policy gaps

2.4 Short description of the LTS reports

The LTS documents differed from each other with no defined and homogenous content structure. Below, it can be found a short description of the analysed LTS reports in English:

[8] https://supeera.eu/component/attachments/?task=download&id=697:D2 (as 15.12.2022)

- **Czech Republic**'s executive summary of 18 pages from 2017 describes e.g. trends in greenhouse gas emissions in the country, objectives and priorities in reducing greenhouse gas emissions, projections up to 2030 and outlook until 2050. Policies and measures are presented for industry, energy sector, final energy consumption, transport, agriculture and forestry, and waste.
- **Denmark**'s LTS with 38 pages, published in December 2019, presents for example overview and process for developing the strategies including climate policies and targets; and GHG emission reductions, renewable energy and energy efficiency plans until 2050. It also describes financing, indicators and impact assessment of the socio-economic aspects.
- **Estonia**'s General Principles of Climate Policy until 2050 from April 2017 presents in 6 pages the vision and national target of climate policy, Political guidelines for the economy and sectoral policy guidelines for the mitigation of climate change in energy, industry, transportation, agriculture and forestry, and land use.
- **Finland**'s LTS with 59 pages (in Finnish), published in April 2020, presents the national targets, scenarios behind the LTS, and policies and actions. It also describes the scenarios on renewable energy and energy efficiency, and how CO_2-emission reductions in energy system, industry, transportation, land use and waste sector change according to the scenarios. Financing, needed investments, R&D&I policies and actions and socio-economic impact assessment on environment and economy are also introduced.
- **Germany**'s Climate Action Plan 2050 with 92 pages, published in November 2016, describes the principles and goals of the climate policy, the climate action as a strategy to modernise the economy, target setting and pathway until 2050, with targets and measures for the energy sector, buildings sector, mobility, industry and business, agriculture, land use and forestry; and implementation and update of the plan.
- **Hungary**'s National Clean Development Strategy 2020-2050 from September 2021, 121 pages, presents long-term vision and guiding principles; GHG emissions, policies and measures and their socioeconomic impacts with related growth opportunities, and decarbonisation pathways until 2050. Sector-specific pathways, policies and measures are shown for energy; industrial processes; agriculture; land use, land use change and forestry (LULUFC); and waste management. Adaptation policies, and cross cutting policies such as education and training, public participation and sustainable consumption and production are included. Financing of the transition and its policy instrumented cover e.g. budget planning, investment needs, and possible sources and means. Research, development and innovation cover innovative technologies and solutions, framework conditions for innovations, and economic development opportunities. Finally, the governance of implementation, monitoring and revision are presented.
- **Latvia**'s Strategy for the Achievement of Climate Neutrality by 2050 from 2019 (English translation from 2020 with 55 pages) shows the objective, indicators and directions of the long-term policy. It contains for example the current progress towards climate neutrality, most significant factors on GHG emissions in different sectors like potential innovations, energy, transport, agriculture and land use, and use of resources. Potential solutions for low carbon development are presented on e.g. research and innovations, energy efficiency, sustainable energy and resource-efficient and

environmentally friendly transport. Implementation and review of the strategy, and public participation are also described.

- **Malta**'s Low Carbon Development Strategy, published in October 2021, 122 pages, introduces process for developing strategies and abatement of greenhouse gases, in particular key policy initiatives, assumptions on energy demand, renewable energy and different energy sectors, such as energy system, transport, buildings, industry, waste, water and LULUFC. Adaptation priorities, challenges, gaps, barriers and measures are described. On financing, e.g. investment needs, sources, and policies and measures for related research, development and innovation are included. Finally, the environmental and socio-economic impact on the different energy sectors are described.
- **Netherlands**' Long-term strategy on climate mitigation from December 2019, 22 pages, has current policies for the longer term with frameworks and objectives, innovation efforts beyond 2030, and transformation of the energy system in particularly in system integration, spatial integration and sustainable energy sources. The strategy also describes long-term approach in sectors of built environment, industry, mobility, agriculture and land use; strategic challenges and policy agenda.
- **Portugal**'s Roadmap for carbon neutrality 2050, published June 2020 with 102 pages, includes for example vision and fundamental principles, transition to a competitive, circular, resilient and carbon neutral economy, and trajectories for carbon neutrality by 2050. The trajectories are shown for energy sector including power generation, mobility and transport, different industries and buildings; agriculture, forests and land use; waste and wastewater; and circular economy. The roadmap presents research, innovation and knowledge production stimulation; guaranteeing of financing conditions and increase of investment levels as well as ensuring a fair and cohesive transition. Governance, integration of objectives and engaging society are also considered.
- **Slovak Republic**'s Low-Carbon Development Strategy until 2030 with a view to 2050 from March 2020 with 93 pages, presents for instance the planned emission reductions and enhancement of removals up to 2050 with national target by 2030 and indicative milestones up to 2040 and 2050, adaptation policies and measures, energy from renewable sources, energy efficiency and analysis of energy, industrial processes, transport, and agriculture, LULUFC and waste sectors. The strategy includes current and planned financing opportunities for the planned measures, and analyses of the impact of social economic aspects of proposed policies and measures.

2.5 Consolidated common and regional pathways in the NECPs

Based on the analyses on the integrated National Energy and Climate plans, **six pathways** were selected, as they represent important technologies in the energy transition, present several examples of best practices and offer opportunities for cooperation with industry and knowledge transfer. They cover strong R&I actions within European RTOs and university forums, being also represented by EERA Joint Programmes.

- Energy systems integration
- Bioenergy
- Energy storage

- Hydrogen
- Solar power
- Wind energy

2.6 Analysis and summary of the pathways in the Long-term Strategies

The analyses of the 16 national Long-term Strategies are presented in the **ANNEX 1**. They start with a short introduction, followed by main findings on the six pathways (Bioenergy, Energy storage, Energy systems integration, Hydrogen, Solar energy and Wind energy), and selected cross-cutting topics (Social acceptance and engagement, Enabling policies, regulatory measures and financing, Regional cooperation and International cooperation).

Summary of the appearance of the six pathways in the analysed LTS is shown in the Table 2. In short, the table shows if the pathway is mentioned in the LTS, if the pathway is presented as having a strong role in future energy measures in the country (S = strong), and if certain areas are mentioned.

Bioenergy in its different forms (e.g. biomass for district heating, biofuels for transport etc.) was mentioned in 15 out of 16 LTSs. Portugal foresees that bioenergy options with CCS are not considered cost-effective, whereas biomass is seen as the most important renewable energy source in Slovakia, with the largest renewable energy potential. Bioenergy is presented as a strong future energy measure in seven countries, and in some of them, it was mentioned to be important especially for specific sectors: energy, industry and/or transportation (Estonia, Latvia).

Energy storage embodies a variety of technologies. In the LTSs, it was mentioned in 12 out of 16 country strategies, in three countries with a strong role in the future (France, Hungary and Spain). In these countries, the mentioned technologies included batteries and power-to-gas applications. Particularly, their application is mentioned in specific sectors that include buildings (Belgium) and transport (Latvia).

The pathways energy systems integration (ESI), hydrogen, solar and wind energy were all mentioned in 13 out of 16 country strategies. ESI was seen as important vector in seven countries, hydrogen in eight, solar in eight and wind energy in six countries. Solar was seen as the most significant energy measure in four countries (Germany, Greece, Hungary and Italy). ESI was mentioned specifically as being important for the energy, industry and transport sectors (Estonia, Latvia). As far as the hydrogen, it was mentioned as a significant vector for the industry sector and in particular to transport (Belgium, Finland and France).

*Table 2: Summary of the pathways in the analysed Long-term strategies. S = strong role, and in **bold***, if the pathway is mentioned as the most important energy vector in the future. B= Buildings; E = Energy; I = Industry; T = Transport*

Pathway / Country	BIO	STORAGE	ESI	H2	SOLAR	WIND
Belgium	Yes (**S**)	Yes (B)	Yes (**S**)	Yes (I,T(**S**))	Yes	Yes
Czechia**	Yes	-	-	-	-	-

Denmark	Yes	Yes	Yes (**S**)	Yes (**S**)	Yes	Yes
Estonia	Yes (E,I)	-	Yes (E,I)	-	-	-
Finland	Yes (**S**)	Yes	Yes (**S**)	Yes (T)	Yes (**S**)	Yes (S)
France	Yes (**S**)	Yes (**S**)	Yes (**S**)	Yes (T)	Yes (**S**)	Yes (**S**)
Germany	Yes	Yes	Yes (**S**)	Yes	**Yes (S*)**	**Yes (S*)**
Greece	Yes (**S**)	Yes	Yes	Yes (**S**)	**Yes (S*)**	Yes (**S**)
Hungary	Yes (**S**)	Yes (**S**)	Yes (**S**)	Yes (**S**)	**Yes (S*)**	-
Italy	Yes	-	-	Yes (**S**)	**Yes (S*)**	**Yes (S*)**
Latvia	Yes (E,T)	Yes (T)	Yes (E,T)	Yes	Yes	Yes
Malta	Yes (**S**)	Yes	Yes	Yes (**S**)	Yes	Yes
Netherlands	Yes	Yes	Yes (**S**)	Yes (**S**)	Yes (**S**)	Yes (**S**)
Portugal	-	Yes	-	Yes	Yes (**S**)	Yes
Slovakia	**Yes (S*)**	-	Yes	-	-	Yes
Spain	Yes	Yes (**S**)	Yes	Yes (**S**)	Yes	Yes

** English Executive Summary of the Czechia Climate Protection Policy

Table 3 summarises the LTSs which mention the following (analysed in D2.1) cross-cutting topics: social acceptance and engagement; enabling policies and regulatory measures; financing, regional cooperation and international cooperation. In the table below, it is also mentioned, whether the cross-cutting topic is related to a specific pathway (as illustrated above).

Social acceptance and citizen engagement was explicitly mentioned in the LTSs of 12 countries, while in four of them, it was considered as an important aspect and was further elaborated (France, Germany, Netherlands and Portugal). **Enabling policies and regulatory measures** were described in almost all LTSs (14/16). Denmark and France proposed, for example, economic incentives, carbon taxation, and annual follow-up of target assessment linked to the national budget process. Clear implementation plan of the targeted measures is lacking in many of the LTSs, and only 10 out of 16 countries present any financing plans for the analysed topics. Denmark, for example, is committed to spend 580 mill. DKK in 2020 and 1 billion DKK in 2024 on research, development, and demonstration of new technologies related to energy and climate, and proposes an increase in spending to green research, development, & demonstration with 1 billion DKK in 2020. Germany has funding agreement totalling €7.3 million for 4 years to districts in the Lausitz region as part of the Joint Task for the Improvement of the Regional Economic Structure, and BMUB's Environmental Innovation Programme is funding demonstration projects that implement technology to lessen environmental impact on an industrial scale for the first time.

On **collaboration**, many countries consider the regional and international collaboration (7/16) as an important aspect. In particular, Germany emphasizes the importance of both **regional cooperation** between local authorities, business and industry and civil society associations, and **international cooperation** to secure increased financing, especially with the international financial institutions (incl. the World Bank), to make a considerable increase in their contributions to international climate finance while ensuring projects use incentives to promote positive effects on climate action and development. The Netherlands states that the international dimension of climate policy will become ever more important, and an ambitious long-term strategy must go hand in hand with international cooperation, for example formation of international alliances in the domain of green hydrogen.

Table 3: Summary of cross-cutting topics in the analysed Long-term strategies. S = the topic is emphasized in the LTS. ESI = Energy systems integration; T = Transport and H2 = Hydrogen

Cross-cutting topic / Country	Social accept. & engagement	Policies & Regulation	Financing	Regional coop	Internat. coop
Belgium	Yes	Yes	-	Yes	-
Czechia*	Yes	-	Yes	-	Yes
Denmark	Yes	Yes (S)	Yes (S)	Yes	Yes
Estonia	Yes	Yes	-	-	-
Finland	Yes	-	-	-	-
France	Yes (S)	Yes (S)	Yes	Yes	Yes
Germany	Yes (S)	Yes (ESI)	Yes (S)	Yes (S)	Yes (S)
Greece	-	Yes	Yes	-	-
Hungary	Yes	Yes	Yes	-	-
Italy	Yes	Yes	-	-	-
Latvia	-	Yes	Yes	Yes	Yes
Malta	-	Yes	-	-	-
Netherlands	Yes (S)	Yes (esp. T)	Yes	Yes	Yes
Portugal	Yes (S)	Yes	Yes	Yes (S)	Yes
Slovakia	Yes	Yes	-	-	-
Spain	-	Yes (H2)	Yes	-	-

* English Executive Summary of the Czechia Climate Protection Policy

2.7 The National Energy and Climate Plans (NECPs) in the Long-term Strategies

Some of the Member State's LTSs have a strong reference to their NECPs, while some of them do not mention their NECP at all. The status of analysed LTSs is presented in the following Table 4, and below the table, a short description how the NECPs are mentioned in some of the Member States' LTS, which present the linkage between the two plans.

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Table 4: The NECP in the long-term strategies

Mentioned briefly	Yes / LTS - NECP relation	Not mentioned
Belgium	Denmark	Czechia*
Hungary	Italy	Estonia
Latvia	Malta	Finland
	Netherlands	France
	Portugal	Germany
	Slovakia	
	Spain	
	Greece	

- **Denmark**'s LTS refers to the NECP, as the detailed information about projection models, assumptions etc. used for the latest frozen policy scenario (the WEM scenario) is available in summary in Denmark's Integrated National Energy and Climate Plan (NECP).
- In **Greece'**s LTS, the NECP is considered as the basis document where the short-term energy targets are analysed. In LTS, all energy modelling scenarios are taking as a reference the NECP and are based upon the assumptions made therein, consider the achievement of 2030 targets as the starting point for the design of 2050 ones.
- In **Italy**'s LTS, the Reference Scenario is based on NECP, presenting the decarbonisation process for 2021-2030.
- **Malta**'s Long-term strategy refers to NECP several times. For example, it is stated that the ambition of the policies and measures set out in the strategy are targeted at meeting the EU 2030 and 2050 targets and align with those already set out in the NECP. It is also mentioned that technological advances may result in additional opportunities for Malta to reduce its emissions becoming available in the period 2031-2050, which are not further explored in the NECP.
- **Netherlands**' LTS states that the government's climate policy has been elaborated in the Integrated National Energy and Climate Plan (NECP) was submitted in Brussels at the same time as the long-term strategy, and many elements in the regulation of the strategy refer to NECP.

- **Portugal** presents in the LTS, that the elaboration of it (RNC2050) was carried out in parallel with the preparatory work for the National Energy and Climate Plan (PNEC), which will be the main energy and climate policy instrument for the decade 2021-2030, setting new national targets for the reduction of GHG emissions, renewable energy and energy efficiency in line with the objective of carbon neutrality.
- **Slovakia**'s LTS refers to the NECP several times, as for example more detailed information on individual data in the sectors are described in the NECP, and details on the current way of financing decarbonisation measures until 2030.
- **Spain**'s LTS has one chapter dedicated to their NECP. The strategy explains that the National Integrated Energy and Climate Plan 2021-2030 (PNIEC) presents a roadmap for the next decade, designed in coherence with the neutrality of emissions in 2050 and from an efficient cost point of view. The Long-term strategy is based on compliance with the objectives, policies and measures included in the updated draft of the plan and, accordingly, it uses the same energy prospective model to carry out the NECP and the LTS (TIMES-Sinergia). Additionally, both documents are based on the same criteria of technological neutrality.

2.8 SUPEERA workshops

Workshops were planned to be a cornerstone of this work package to facilitate a dialogue for transnational collaboration with industry. Due to the covid-19 pandemic, this activity was strongly hindered in 2020-2021. As an alternative, three webinars were organised. There are described in the deliverable D2.1. In 2022, it was possible to organise workshops in hybrid modality (physical and online participation). Altogether, six SUPEERA workshops on "*Bringing research and industry closer - accelerating innovation & uptake by industry*" will be organised by the end of the project (June 2023) to support the dialogue between research and industry and develop the framework for collaboration model. Four of them have been organised in 2022, while the remaining two will take place in early 2023. The workshops include:

- **Workshop 1** – Energy systems integration and Wind energy, 20.4.2022, Delft, the Netherlands (hybrid format)
- **Workshop 2** – Energy storage and Hydrogen, 10.5.2022, Padova, Italy
- **Workshop 3** – Energy storage and Concentrated solar power, 15.11.2022, Almeria, Spain (hybrid format)
- **Workshop 4** – Biodiversity and Offshore renewables, 15.12.2022, Copenhagen, Denmark (hybrid format)
- **Workshop 5** – Bioenergy and Hydrogen, 1.2.2023 (to be confirmed)
- **Workshop 6** – Solar energy and energy storage, 21.03.2023 (to be confirmed)

The detailed description of the workshops and the results from the discussions that took place will be included to the Deliverable 2.3 'Definition of operational transnational collaboration model', to be published in February 2023.

CONCLUSIONS

Sixteen national Long-term Strategies were analysed focusing on the previously defined six technological pathways and selected cross-cutting topics. The analysis focused on the identification of the best practices, gaps and challenges to support the subsequent activity on formulating the transnational collaboration model between research community and industry, to ultimately facilitate accelerating innovation and uptake by industry.

- Pathways: Bioenergy, Energy storage, Energy systems integration, Hydrogen, Solar energy and Wind energy
- Cross-cutting topics: Social acceptance and engagement, Enabling policies, Regulatory measures and financing, Regional cooperation and International cooperation

At the time of analysis in 2021, 16 LTSs were published in different European languages, that were possible to be studied by the SUPEERA team. Currently, in December 2022, 23 Members States have published their LTS, while four countries that the publication of their LTS is pending are Bulgaria, Ireland, Poland and Romania.

It was found that the LTS were lacking homogeneity in among them in terms of content, and the description of energy measures for 2030-2050 were presented in varying manners. Based on the analysis, regarding the R&D&I priorities and research-industry interaction, there were only a few indications on the research/development/innovation strategies to support the advancement of the pathways or the analysed cross-sectoral issues. In the LTSs of Germany, Denmark, Greece, the Netherlands and Spain, this was addressed in some extent. Industry-research cooperation was not particularly mentioned within the analysed areas, but Latvia stated to continue the development of public-private partnerships (PPP). Financing to support the research and innovation in certain areas was indicated in some of LTSs, even though many countries acknowledged the high investment needs for novel technological solutions, which were sometimes expected from the industry. Funding actions were mentioned e.g. in the LTSs of Germany, Denmark, Latvia, the Netherlands and Spain, while many countries foresaw the importance of regional and international collaboration.

Deliverable 2.4 '*Recommendations'* will gather the analysed information from the integrated national energy and climate plans, long-term strategies and the collaboration model (currently under development), to present recommendations for research and innovation priorities and transnational collaboration between research and industry, with specific focus on systemic and cross-sectoral best practices, gaps and barriers, embodying also the lessons learnt from the organised workshops. These recommendations will be published in April 2023.

ANNEX 1. The analyses of the Long-term Strategies (LTS)

Analysed LTSs from the following Member States:

- Belgium
- Czech Republic
- Denmark
- Estonia
- Finland
- France
- Germany
- Greece
- Hungary
- Italy
- Latvia
- Malta
- the Netherlands
- Portugal
- Slovakia
- Spain

Belgium

Main findings

- Belgium is divided into three regions, which have different climate targets:
    - The Walloon region aims at achieving carbon neutrality by 2050, via a reduction of GHG emissions of 95% compared to 1990 levels, and via the deployment of technical carbon sinks (CCUS);
    - The Brussels-Capital region aims at achieving carbon neutrality by 2050;
    - The Flemish region targets a reduction of 85% of its non-ETS emissions by 2050 compared to 2005 levels, and full climate neutrality in the long-term.
- The Belgian LTS does not define a clear goal nor includes any scenarios at federal level. Nevertheless, each region is overall building its strategy on a WAM 2030 scenario, attributes a significant role to energy efficiency, to demand flexibility, and to the import of climate neutral electricity, and considers the use of natural and technical (CCUS) sinks to reach carbon neutrality.
- While the Belgian regions list several climate and energy policies to address their objectives (standards, incentives, financial support, etc.), the Belgian federal level is offering to support the regions through its taxation and standardisation powers, in order to contribute via incentives to the transition, as well as through the financing of new energy infrastructures.
- The European Commission has identified several gaps in the content of the Belgian LTS, namely: there are no emission reduction targets for the ETS and LULUCF sectors, nor a socio-economic impact assessment, nor a strategy for research, development and innovation. The estimated likely share of renewables in energy consumption, as well as some specific information per sector, are missing.

Pathways	Findings in the LTS
Bioenergy	Within the Walloon and Flemish strategies, bioenergy is still to play a role in producing electricity, whenever biomass' combustion is its only potential outcome. **Industry** The Flanders region aims at resorting to biomass for electricity production in industry, as well as using biomass for its chemical industry. It emphasises the potential synergies between its agriculture and industry sectors, towards a more circular economy. It also intends to build on the import of biomass to cover its industry's needs. **Transport** Both the Walloon and Flemish strategies are betting on alternative, climate neutral fuels, not yet on the market, to decarbonise maritime transport and aviation. **Buildings** Overall, the three Belgian regions envisage covering their buildings sector's energy needs with solar energy, heat energy, as well as bioenergy and cogeneration.
Energy storage	**Buildings** Batteries are considered, in the Flemish strategy, as both a solution for mobility and for storage in the buildings sector.

Energy systems integration	Electrification is recognized as playing a key role in the Belgian path towards climate neutrality, especially in the transport, buildings and industry sectors. Each region emphasises the need for more energy system integration, and on the need to switch from a centralized, demand-based system, towards a decentralised, more flexible and offer-based system, building on higher storage capacities as well. Flanders foresees that shorter, local value-chains will also contribute to ensure, in the agricultural and industrial sectors, to less demand in the transport sector. Flanders also emphasises the potential of the creation of clusters, which should bring new industrial synergies to maximise the use of residual energy. **Power** Flanders underlines the need for R&D to ensure renewable energies integration to the power system. **Transport** Flanders emphasises the need for multimodal hubs, in individual transport as well as goods transport. Hubs should contribute to the spreading of the use of climate neutral solutions in the entire transport sector, as well as further the synergies between different transport solutions and their complete connections and efficiency (mobility/logistics as a service). **Buildings** In the buildings sector, energy systems integration is identified as playing a key role in increasing energy efficiency, and the share of renewable energy in the sector's energy consumption. Flanders notably stresses the role of the digitalisation of energy in the buildings sector to increase flexibility and efficiency. It will act on creating standards to incentivise the renovation of buildings. If renovation is too expensive or technically complex, Flanders recommends destroying and rebuilding.
Hydrogen	**Industry** Green hydrogen is mentioned as a potential energy vector to ensure the energy transition in the industry sector – as a complementary tool for more energy efficiency as well as more flexibility on the industry demand. **Transport** Hydrogen is mentioned as a key tool to reach carbon neutrality for goods transport. Both the Walloon and Flanders' strategies target a switch from road to rail or sea in that perspective. Hydrogen is also mentioned when it comes to individual transport solutions and vehicles. Yet, the Walloons strategy is stressing the risk of a single-bullet strategy when it comes to electrifying individual transport, especially since the supply in batteries could be an issue and as such, represent a vulnerability.
Solar energy **Wind energy**	Since the promotion of renewable energy sources is within the regions' power scope, there is no target at the national level for their implementation. Nevertheless, at the regional level, while the long-term Walloon strategy is based on a 100% renewable energy target by 2050, Flanders aims at producing energy locally, and in a renewable way as much as possible, encompassing wind, solar, and climate neutral fuels related technologies.

Cross-cutting topics	Findings in the LTS
Social acceptance	The Belgian LTS emphasises the need for a just transition, engaging citizens, for education and training, and for support to the most vulnerable. Also, its strategy relies significantly on incentives on the demand side to increase energy efficiency

and engagement	and changes in energy consumption-related behaviours. Moreover, it underlines the need for research on new business cases and models, towards a more circular economy.
Enabling policies, regulatory measures and financing	An estimation of €25-50 billion between 2020-2030 is to be needed at the federal level. Half of that need is attributed to the buildings sector. The federal political level is offering to support the transition through a number of measures, consistent with its powers: establishing a long-term vision on energy supply, building new hydrogen and alternative fuels infrastructures, defining a long-term framework for intermittent energy sources integration, and ensuring an active role for citizens in the transition. Notably in the transport sector, the Brussels region aims at forbidding diesel cars from 2030, GPL cars from 2035, and to reach carbon neutrality in the transport sector as soon as 2050. Flanders is to implement several policy tools, such as standards, nudging, awareness campaigns, support to RD&I, demonstrators, ambassadors, education, training, infrastructures, local democracy, and overall, to adopt climate mainstreaming in all policy decisions and public funding, while avoiding carbon leakage, protecting industrial competitiveness and ensure just taxation.
Regional cooperation	The three Belgian regions emphasize their need to import a significant share of their electricity needs, since there is not enough local energy capacities to cover their consumption.
International cooperation	The three Belgian regions are committed to take into account their climate impact even through indirect GHG emissions. In that perspective, they mean to produce and consume locally as much as possible, to avoid carbon leakage, and to develop breakthrough technologies that can benefit to the largest.

Czech Republic

Source: Executive summary of Climate Protection Policy of the Czech Republic, 2017

Pathways	Findings in the LTS
Bioenergy	Biomass has been mentioned in the summary.
Energy storage	-
Energy systems integration	-
Hydrogen	-
Solar energy	-
Wind energy	-

Main findings

The Czech Republic's approach to climate change can be divided into a policy aimed at reducing emissions of greenhouse gases and into a policy of adaptation and strengthening resilience to the adverse impacts of climate change. The Policy defines policies and measures for the gradual reduction of greenhouse gas emissions in the specific areas, i.e. especially in the **energy sector**, final energy consumption, **industry, transport**, agriculture and forestry, waste management, **science and research** and voluntary instruments, with respect to the economically exploitable potential. The Policy proposes efficient and effective measures, including their contribution to reducing greenhouse gas emissions by 2030, and describes the pathways that lead to the transition to a low-emission economy by 2050. The main objective of the Policy is to determine an appropriate mix of cost-effective policies and measures in key sectors that will lead to achieving the greenhouse gas reduction targets.

The implementation of the Climate Protection Policy of the Czech Republic will be evaluated by the end of 2021 and updated by the end of 2023.

Eight scenarios have been defined, that can be divided into three categories:

- Scenarios of energy sector development, regardless of climate change (reference scenario A)
- Scenarios not meeting the goal of achieving a minimum 80% emissions reduction between the years 1990–2050 (scenarios marked B)
- Scenarios meeting the goal of achieving a minimum 80% emissions reduction between the years 1990–2050 (scenarios marked C)

Category B includes 4 scenarios: 1) SEP (State Energy Policy) extrapolation scenario, 2) nuclear scenario 3) green scenario, and 4) an economic recession scenario.

Category C includes 3 scenarios: 1) The import of electricity and biomass, 2) the development of CCS technology, and 3) development of RES, nuclear energy and energy savings.

SUPEERA Pathways in the Czech's LTS

BIOENERGY

Action Plan for Biomass was applied in 2012-20. One scenario includes import of biomass.

ENERGY STORAGE / ENERGY SYSTEMS INTEGRATION / HYDROGEN /SOLAR ENERGY / WIND ENERGY

-

Sectors

Transportation

A gradual increase in the share of alternative propulsion and fuels in road transport is envisaged and further electrification of railways, a gradual shift of freight transportation from road to rail or water transport.

Energy efficiency

At the state level, the attainment of the objectives in energy efficiency is addressed by the National Action Plan for Energy Efficiency (NAP EE), which defines the planned measures aimed at increasing energy efficiency and the expected or achieved energy savings, including savings in the supply, transmission or transport and energy distribution as well as in the final energy use.

Cross-cutting topics	Findings in the LTS
Social acceptance and engagement	At the state level, emissions reduction is addressed by the SEP (State Energy Policy) which reflects the state objectives in the energy economy in line with the needs of economic and **social development**, including the climate and environment protection.
Enabling policies, regulatory measures and financing	Achieving the level of the global average of the amount of climate finance is a long-term objective of the Czech Republic for the period up to 2030.
International cooperation	Broad international cooperation is crucial among countries in order to effectively achieve global climate targets, including the involvement of private entities, municipalities and individuals. The Czech Development Agency finances projects in some developing countries.

Denmark

Pathways	Findings in the LTS
Bioenergy	***Forecasts:*** The share of bioenergy decreases from 21% in 2017 to 23% in 2030 and then falls to 21% in 2040. The share of waste (bio-degradable) is 3% in 2017 and in 2030, and it decreases from 3% in 2030 to 2% in 2040. ***Biomass Combined heat & power (CHP) and Heat only plant (HOP):*** Research is ongoing in many areas relevant for biomass units, e.g. for reducing the cost of fuel, improving combustion process for reduction of emissions and improving control ability against fuel variations. New technologies are being developed and demonstrated in three plants until now, like combining gasification of biomass (bio-SNG) and gas combustion. Production of ***liquid fuels*** is already in commercial phase, but several technologies are also developed. ***Commercial technologies*** with large scale deployment include for example vegetable oil and used cooking oil (bio-oil FAME) and first generation ethanol (from corn and wheat). ***Pioneer phase technologies*** with limited applications to date are e.g. biomass gasification for diesel and jet fuel produced from wood or straw, biomass gasification for methanol production (from wood or straw), cellulosic ethanol (from straw) and fast pyrolysis of biomass to produce a bio-oil (pyrolysis oils). ***Techologies in the research, development*** and deployment stage include hydrothermal liquefaction of biomass to produce a bio-oil and catalytic hydropyrolysis of biomass to produce either bio-oil or a drop-in fuels.
Energy storage	***Lithium-ion Battery (LIB):*** Currently, a wide range of government and industry-sponsored LIB *material, cell, and system level research* is taking place. Some of the most promising post Li-ion technologies include lithium-sulphur batteries that use sulphur as an active material, and also lithium air batteries have received considerable attention. Several ***non-lithium-based battery*** chemistries are being investigated, e.g. aluminum-sulphur batteries. Although LIB systems for electricity storage are now commercially available, the R&D is still in its relatively early phase and is expected to contribute to future cost reductions and efficiency improvements. ***Vanadium Redox Flow Battery (VRB):*** VRB are under rapid development. There is significant potential for R&D to reduce cost of all battery components. There is a significant potential for cost reduction of flow batteries by using ***alternative reaction chemistries***, i.e., other redox couples than vanadium. Grid scale redox flow batteries could potentially be based on, e.g., zinc-bromide, bromide-polysulphide, iron-chromium, and zinc-chloride. ***Na-S/$NiCl_2$ Battery:*** It is not possible to quantify the full potential for improvements through R&D at the given time. The potential is however, estimated to be substantial in terms of both technical and financial specifications. All critical components of the battery are undergoing active research. New solid electrolytes to replace BASE are also being considered. An alternative research route is to use the Na-S chemistry in a flow battery. Research is also going into slightly changed chemistries which would change the battery characteristics significantly. Due to the similarity between Na-S and Na-$NiCl_2$ batteries, synergies in research and development efforts can be expected. ***Compressed Air Energy Storage (CAES):*** Research and development efforts for CAES are directed towards improving the relatively low round cycle efficiency by intermediately storing the heat generated in the compression

	phase and reuse it during the expansion phase (ACAES). Within a time perspective of 10-15 years it thus seems fair to anticipate that ACAES will be commercially available. This development is expected to improve the power-to-power efficiency to around 70 % and bring A-CAES into a much more attractive efficiency class. ***Flywheels:*** The DK technology data refers only to the 2013 European Association for Energy Storage (EASE) R&D needs for flywheels.
Energy systems integration	***Energy Security to be ensured via***: cooperation with nearby countries to keep interconnectivity high; increased flexibility; systematized monitoring of supply adequacy in different sectors; emergency plans; and increased reliance on renewables. ***Internal energy market to be supported with:*** an uphold and increase interconnectivity through projects coordinated with neighbouring countries (includes a list of PCI projects and reinvestments in existing interconnectors). DK's current focus on the functioning and integration of electricity markets, with a focus on developing cross-border markets for balancing products; expected improvements on the DK1-DE interconnector and the Swedish interconnectors; and a focus on the increase of flexibility in the energy system and the development of better functioning markets to facilitate new actors and technologies. In the future, with larger deployment of the technology and a move towards more commercial phase, the price of power conversion system (PCS) can be expected to drop, which is also the case for the module cost. ***Energy distribution grid:*** Some of the ongoing research and development activities to respond to the changing electric power system in Europe are: *i)* development of a common European framework for market operation and planning; *ii)* implementation of Smart grids with a significant level of customer flexibility; and *iii) e*nergy storage – both decentralized and at utility scale, which is currently at a very low level in DK.
Hydrogen	***Gas (in tanks):*** In general, pressurized tanks manufacturing companies are investing in optimizing their products to achieve lightweight and low-cost bulk transportation high pressure gaseous hydrogen vessels. However, radical improvements are not foreseen for the short-term future as they are dependent mainly on the materials used which are unchanged for many years. For the pressurized hydrogen storage as a system, there is currently research on manufacturing specialized hydrogen compressors to optimize the compression characteristics and increase the mass flow rate for hydrogen. ***Gas (in caverns):*** The issue relating to permeability is of utmost importance. Investigation into undesirable reactions leading to hydrogen embrittlement and loss of wall integrity are in progress. Progress in the field of compression technology is also being investigated. Tightness during underground storage along with selection of geological structure to facilitate it needs to be further investigated. Research in the field of market mobility and cost of hydrogen production will also determine the potential of large scale storage using salt caverns. ***Liquid:*** One of the challenges with LOHC (liquid organic hydrogen carriers) technology is the limited market wing to an early phase. Further, decentralized hydrogenation needs to be optimized. Catalyst costs can also be a challenge and needs to be further investigated. Different combinations of LOHC compounds can lead to cost effective and large-scale solutions. Additionally, heat generated during hydrogenation needs to be recycled and

	used for system energy optimization. Research in this field can facilitate heat integration to decrease the losses along with blending LOHCs in the existing feedstock. ***Hydrogen production:*** For AECs (alkaline electrolysis cell), research is being carried out to improve the temperature stability of the diaphragm by experimenting with various polymer substitutes and improving the AEC catalyst. Solid membranes (AEMECs - anion exchange membrane electrolysis cell) have also been researched. For PEMEC (proton exchange membrane electrolysis cell), stack cost is the major hurdle to commercialization of large-scale system. The cost of catalysts and bipolar plates are under investigation in terms of research on lab scale. Further, scarcity of elements is considered while finding alternative materials for substitution. ***Combination of electrolysis technologies*** has also been suggested for research. Electrolyser plants are now being subjected to MW scale for AECs and PEMECs, while SOECs so far only have found usage in kW scale. Reduction in price, availability of material, regulation ability as well as efficiency enhancement are being addressed to facilitate large-scale implementation of electrolysers for hydrogen production. ***Hydrogen pipe transport:*** Transmission and distribution pipes for both H2, NH3, DME and non-corrosive liquid hydrocarbons is a well-known technology (TRL=8-9). Improvements and associated cost reduction are targeted for hydrogen compression, material of constructiony, operating pressure, design code and Installation. ***Projects:*** In 2019, 128 million DKK was granted to two projects that will establish large scale production and storage of green hydrogen. Both projects have an ambition to demonstrate production and consumption of green hydrogen on near market based conditions.
Solar energy	***Forecasts:*** The share of solar energy increases from 1% in 2017 to 4% in 2030 to 6% in 2040. ***Photovoltaics:*** A trend in research and development (R&D) activities reflects a change of focus from manufacturing and scale-up issues (2005-2010) and cost reduction topics (2010-2013) to implementation of high efficiency solutions and documentation of lifetime/durability issues (since 2013). In the coming years, as PV plants are expected to play a key role in power generation, a higher focus on increasing the system value of PV generation is expected. Some R&D takes place in DK; the priorities are: *i)* silicon feedstock for high-efficiency cells; *ii)* new PV cells (e.g. photo-electro-chemical, polymer cells and nanostructured cells); *iii)* advanced power electronics for intelligent operation of PV systems; *iv)* both building integration and building application of PV modules (BIPV17 and BAPV18), design and aesthetics; *v)* system technology; incl. integration in the overall electricity system; and *vi)* reinforced international cooperation with IEA, IRENA, the EU and the Nordic countries concerning PV and "Smart Grid" development.
Wind energy	***Forecasts:*** The share of offshore wind power increases from 3% in 2017 to 12% in 2030 to 10% in 2040. The share of onshore wind power increases from 5% in 2017 to 8% in 2030 to 10% in 2040. As part of the Energy Agreement from 2018 three new off-shore wind farms will be deployed by 2030. ***Onshore R&D perspectives are:*** *i)* reduced investment costs resulting from improved design methods and load reduction technologies; *ii)* more efficient methods to determine wind resources, incl. external design conditions, e.g. normal and extreme wind conditions; *iii)* improved aerodynamic

	performance; *iv)* reduced operational and maintenance costs resulting from improvements in wind turbine component reliability; *v)* development in ancillary services and interactions with the energy systems; *vi)* improved tools for wind power forecasting and participation in balancing and intraday markets *vii)* improved power quality (rapid change of power in time can be a challenge for the grid); *viii)* noise reduction (new technology can save the losses by noise reduced mode and possible utilize good sites better, where the noise set the limit of number of turbines); *ix)* Public acceptance; *x) r*epowering strategies, like when it is feasible to repower for society and for investors – subsidy schemes must support optimal solutions; and *xi) s*torage can improve value of wind power much, but is expensive at present. ***Offshore R&D perspectives are:*** *i) f*urther upscaling of wind turbines; *ii)* new foundation types suitable for genuine industrialization; *iii)* development of 66kV electrical wind farm systems as alternative to present 33 kV; *iv)* development of compact offshore substations, including high-voltage direct current (HVDC) converter stations and cables (HVDC equipment is available today); *v)* improvement of design methods in planning and operation phase, e.g. reduction of wake losses, O&M costs by e.g. improved control strategies, more optimized tower/foundation structure by integrated design; *vi)* logistic issues, e.g. more dedicated vessels in installation and maintenance phase; *vii)* improved methods for handling of different sea bed conditions, lowering foundation costs; and *viii)* improved monitoring in operational phase for lowering availability losses and securing optimal operation.
Cross-cutting topics	**Findings in the LTS**
Social acceptance and engagement	Climate Act includes a citizens' initiative in relation to the Government's forthcoming Climate Action Plan in 2020.
Enabling policies, regulatory measures and financing	***Introduce binding targets*** (Danish Climate Act) that state: *i)* A goal to reduce greenhouse gases by 70% by 2030, relative to 1990 levels and to reach net zero by 2050 at the latest; *ii)* Danish Council on Climate Change assists the Government in making decisions on reduction targets and methods, *iii)* An annual follow-up target assessment is performed, and that this follow-up is linked to the national budget process. ***Transport sector transition that covers:*** *i)* a stop of sales of all new diesel and petrol cars as of 2030 and enhanced low emissions zones; *ii)* reach a political agreement with industry and car owners; *iii)* Government will negotiate an infrastructure agreement, which will consider climate and environmental issues to a much higher degree, incl. investments in public transport, cycling etc.; and *iv)* implementing initiatives to ensure more sustainable aviation. ***Secure climate contributions from agriculture via actions to:*** *i)* provide farmers incentive to transition to more sustainable production; and *ii)* implement a pilot scheme for multifunctional land distribution for major land reform. ***Adopt a climate action plan*** that ensures that national targets are met. ***Create greater biodiversity and more woodlands via the*** biodiversity package which includes clear targets for the proportion of the area of DK to be laid out as nature zones (including untouched woodlands and national nature parks) as well as specific initiatives to ensure that targets are reached ***Strengthen green calculation models with*** climate and green transition considerations to be integrated in the Ministry of Finance's calculation

	models, and the effort to develop greener calculation models will be secured and enhanced. ***Increase organic foods targets and strengthen initiatives against food waste*** starting with an aim to double organic farming acreage and the export & consumption of organic foods and then implement initiatives against food waste. **National Adaption Plan** includes 64 new initiatives within five general areas of initiative: 1) an improved framework for climate adaptation; 2) more consultation and a new knowledge base; 3) strengthened collaboration and coordination; 4) green transition; and 5) international climate adaptation. A few national sectors (such as transport, roads and coastal protection) have dedicated adaptation plans. All municipalities have adopted local adaptation action plans in line with the national adaptation plan ***ETS targets are to:*** achieve 55% renewables share in 2030; use renewables are to cover all final electricity consumption or more by 2030; and phase out of coal in electricity production by 2030. ***Non-ETS targets are to:*** limit Denmark's non-ETS greenhouse gas emissions in 2030 at least by 39 percent relative to Denmark's emissions in 2005; and ensure that Denmark's non-ETS greenhouse gas emissions in each year 2021-2029 do not exceed a specific linear trajectory. ***LULUCF (emissions and removals)*** during 2021-2025 and 2026-2030 will be accounted for where they occur in: afforested land, deforested land, managed cropland, managed grassland and managed forest land and as of 2026 also managed wetlands. This will ensure that emissions do not exceed removals under the accounting rules, calculated as the sum of total emissions and removals on DK's EU territory in the land accounting categories above combined and in accordance with LULUCF Regulation. **Financing:** Committed to spend 580 mill. DKK in 2020 and 1 billion DKK in 2024 on research, development, and demonstration of new technologies related to energy and climate (large share for EUDP programme, which funds projects in line with SET objectives); Proposed increase in spending to green research, development, & demonstration - 1 billion DKK in 2020 (expect a large part will go to climate-related research and innovation, including in clean energy); Intensify export promotion activities in the energy sector, both in scale and volume, to total of 174 million DKK 2019-2024.
Regional cooperation	***Include stakeholders*** on an ongoing basis, including independent experts, popular movements and interest organisations, for example, by promoting a strategy for circular economy, transitioning to a more energy-efficient society, smarter waste sorting, and transitioning public sector procurements so they support the green transition to a higher degree.
International cooperation	***Climate action plan includes*** investigating the potential for Denmark to prepare a common strategy with the North Sea nations for a significant expansion and exploitation of the offshore wind potential. ***Assume the responsibility for more ambitious targets in the EU and enhance green diplomacy by pushing for:*** *i)* increasing EU targets in 2030/2050; *ii)* expansion of EU self-reliance (with other ambitious nations); *iii)* stronger green diplomacy and DK international commitment; and *iv)* new development policy strategy with climate assistance as a central element.

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Estonia

General Principles of Climate Policy until 2050

Pathways	Findings in the LTS
Bioenergy	Strategy on bioenergy. Particularly mentioned in the energy & industry and agriculture sectors
Energy storage	Not mentioned specifically
Energy systems integration	Strategy on energy systems integration. Particularly mentioned in the energy & industry sectors
Hydrogen	Not mentioned specifically
Solar energy	Not mentioned specifically
Wind energy	Not mentioned specifically

Political guidelines for the economy as a whole

- Development of technologies, products and services reducing GHG. Export of those for resolution of global problems
- Green growth areas with great export capacity and economical/ecological potential to be identified and prioritised
- Increase awareness of the society on mitigation of climate change/adaptation in order to shape climate-friendly attitudes and choices of consumers
- Development of resource-efficient circular economy, continuation with reduction of waste production and more efficient waste separate collection, reduction of use of primary raw material and increase of use of secondary raw material

Sectoral policy guidelines for the mitigation of climate change

Sector	SUPEERA Pathways in LTS
Energy & Industry	**ESI:** • placement of the **industrial sector** (incl. directly related business and service sector companies), **near energy production** units enhanced and **connection between major consumers and manufacturers with the EL grid** encouraged via supportive legal environment. • Economic and energy efficiency of the system as a whole when renovating the existing building stock and planning and constructing new buildings. • When planning, building, managing and reconstructing **grids** within energy systems, the **economical and energy efficiency of the complete system** will be considered with the aim of achieving maximum energy and resource efficiency. **Legislation** will be used for facilitating efficient and sustainable operation of energy and heat networks on the basis of free market principles, and all market participants who have joined the network can freely buy and sell energy in the network without discriminating limitations. Smart network technologies and consumption control technologies will be developed and their implementation will be facilitated in the context of increasing market volatility and increasing the variability of energy sources.

	Regulatory measures for reduction GHG emissions: • Participation in the **European Union Emissions Trading System** and improving its efficiency will be continued until there are more cost-efficient ways for achieving the desired results. **The implementation of novel tax policy instruments** for the reduction of greenhouse gas emissions **in sectors and installations which do not belong to the EU's Emissions Trading System** will be considered under the condition that it is purposeful, cost-efficient, and economically reasoned. **BIO**: • A wide use of **domestic bio** and other kinds of renewable energy resources will be facilitated during the production of **electricity and heat** as well as the production of **fuel for transport**. • the development of renewable energy production technologies and knowledge-based, ecological and sustainable upcycling of biomass will be facilitated
Transportation	**Enabling policies**: • The percentage of **sustainable transport fuels** will be increased mainly through targeted tax policies and the public sector acting as a role model • the development of a tax policy guided from the overall effect of transportation and the reduction of greenhouse gas emissions will be considered without an increase in the overall tax burden **Social acceptance and engagement**: • Consumer awareness will be increased by the example of the public sector
Agriculture	**BIO**: The production of bioenergy will be steadily enhanced and such energy will be mainly used instead of non-renewable fuels with more energy intensive manufacturing processes. Greater efficiency and the upcycling of resources will be facilitated in the production of bioenergy. Low-quality timber and side products of the timber industry will be used for manufacturing timber-based fuels. The combined use of manure from intensive animal farming and grassland resources that have not been exploited so far will be preferred for the production of biogas.

Sectoral political guidelines for adapting to the effects of climate change

The operation of the economy and the infrastructure of the energy sector and other sectors in the occurrence of any climate event will be ensured in a way that ensures the availability of vital services to people.

Finland

Pathways	Findings in the LTS
Bioenergy	Bioenergy is seen as prominent renewable energy source.
Energy storage	Batteries and energy storage are recognized as potential technological solutions.
Energy systems integration	Flexibility of energy system is important with renewable energy sources.
Hydrogen	Hydrogen's role is seen especially on transportation.
Solar energy	Solar power will increase strongly.
Wind energy	Wind power will continue to increase.

Main findings

Finland's Long-term Strategy (LTS) is based on **three scenarios**, one as reference and two alternative paths that would allow Finland to reach its 2035 national carbon neutral target and greenhouse gas emissions decrease until year 2050.

- **With Existing Measures (WEM)** as reference describes the achieved development with present policy measures
- **Continuing Growth Scenario** assumes accelerated deployment of new technologies, which will require very strict reduction targets from all sectors
- **Savings Scenario**, assumes circular economy and significant energy efficiency gains, and which includes utilisation of carbon dioxide capture and storage (CCS)

Execution of the climate targets requires significant investments on research, development and demonstration of climate-friendly solutions. It is estimated that industry will invest on R&D minimum of 100 billion € 2020-2050 of which remarkable share will be allocated on climate solutions. Special focus will be on energy intensive energy processes, transportation and development of flexible energy system. Technological solutions can be e.g. digital energy systems, batteries, energy storage and power-to-x solutions.

The LTS does not describe on which sectors the emission reductions will be targeted. The LTS is not legally binding document for Finland or Finland's energy and climate policy preparation. SET Plan was not mentioned in the Finland's LTS, even though Finland has been active in the SET Plan activities, as mentioned in the NECP.

SUPEERA Pathways in Finland's LTS

BIOENERGY

From the renewable energy source use of wood-based bioenergy will grow most. Wider use of side fractions, such and biogas and energy plants, and waste is foreseen.

ENERGY STORAGE

Flexible production can be enabled with e.g. power-to-X applications, where produced hydrogen or hydrocarbons can be stored easier that electricity.

ENERGY SYSTEMS INTEGRATION

To ensure the flexible capacity with wind and solar energy production, investments on storage capacity, smart grids and transmission connections of electricity would be needed.

HYDROGEN

Hydrogen was seen in strong role in decarbonization of the transportation (hydrogen-fuelled vehicles).

SOLAR and WIND ENERGY

In both low emission scenarios wind and solar energy rise into remarkable position in energy production. Increase of wind power production will continue until 2035. After that solar power will rise as renewable energy source with the wind energy.

Sectors

Industry

In the scenarios, main drop of emissions is achieved in fuel combustion mainly due to the hydrogen technology, CCS applications, electrification and carbon neutral renewable and synthetic fuels.

Cross-cutting topics	Findings in the LTS
Social acceptance and engagement	As summary, the scenarios estimate that economical well-being will grow even the society changes into low carbon or carbon neutral.
Enabling policies, regulatory measures and financing	Research, development and innovation policy actions and measures will be implemented so that they alloy wide spectrum of climate solutions for needs of industry and energy supply.

France

Main findings

- The French Long-term Strategy aims at achieving carbon neutrality by 2050, via the deployment of sectoral and progressive 5-year periods thresholds of GHG emissions, called "carbon budgets". It is based on a reference scenario up to 2050 with additional measures (WAM), among which are the deployment of new technologies such as CCUS, power-to-gas, energy storage and hydrogen technologies, and takes into account the contributions received in the course of a stakeholder engagement process.
- To achieve carbon neutrality, the French Long-term Strategy sets out a number of targets and actions, such as: shifting from fossil towards low-carbon energy (mainly biofuels, low-carbon heat and electricity), reducing energy consumption within all economic sectors, reducing non-energy related emissions in agriculture and industry via a more integrated, innovative approach, doubling the number of natural and technical carbon sinks, and in the meantime, increasing public awareness and engagement.

Pathways	Findings in the LTS
Bioenergy	Building on a substantial increase of the biomass production, and as such, on a substantial contribution from the agricultural and LULUCF sectors, biofuels and waste heat are identified as key enablers to ensure the decarbonisation of the transport (especially aviation and maritime) and the energy sectors.
Energy storage	Energy storage and energy systems integration should also significantly contribute to decarbonise the French energy sector itself, since they can allow for more energy efficiency (by the optimisation of resources, the deployment of storage capacities) and sobriety (raising public awareness and deploying smart devices for energy). Overall, the French LTS also calls for a more integrated, long-term approach when it comes to energy choices and resources mobilisation, in order to ensure their optimisation.
Energy systems integration	
Hydrogen	Towards the decarbonisation of the transport sector, and especially aviation and maritime, policies will facilitate the shift from fossil to low-carbon energy sources and fuels (batteries, biofuels, hydrogen, electricity, etc.)
Solar energy	Overall, by 2030, France will aim at deploying 33% of renewable energy in gross final energy consumption. More specifically, in the industry sector, electrification via low carbon sources is also identified as key to decarbonise.
Wind energy	

Cross-cutting topics	Findings in the LTS
Social acceptance and engagement	The French LTS emphasizes the need for education, training, and awareness raising among stakeholders actions (such as the development of education tools, the opening of data on energy consumption, GHG emissions and climate-friendly jobs) to strengthen social acceptance and engagement.

	Moreover, in order to build the French LTS, a public consultation was organised between 2017 and 2018 on both climate and energy policies.
Enabling policies, regulatory measures and financing	Investments needed in the building, transport and energy sectors are estimated to exceed € 3 trillion over the period 2019-2050. Proposed regulatory measures are: economic incentives, carbon taxation, and overall, adopting a global approach through all policy sectors for the fight against climate change.
Regional cooperation	Both European and international regulatory and financial frameworks are mentioned as playing a key role in GHG emissions reduction, especially in carbon taxation and standard harmonisation.
International cooperation	

Germany

Pathways	Findings in the LTS
Bioenergy	By 2050, biomass will contribute to energy provision to a limited extent, largely based on *obtaining energy from waste and* slurry, fermentation products and *residues*, in local applications to provide thermal energy for industry, commerce, trade, and services and the heat sector. For biogenic resources energy recovery should only occur at the end of a *cascade of uses*. The global increase in demand for agricultural commodities for a wide range of uses limits the potential for sustainable use of bioenergy. By contrast, the use of bioenergy from residues and waste materials will make a major contribution to supplying energy to multiple sectors, so full advantage must be taken of the available potential over the long run. *No increase in the amount of land used* to grow renewable raw materials beyond current levels is anticipated, even during a transition period, due to restrictions on land use and sustainability considerations. ***Solid:*** Care must be taken to ensure that they are from legal and sustainable sources with carbon sink functions borne in mind. Important for decarbonising the heat sector in future, especially in older buildings that are difficult to retrofit. ***Liquid:*** Since aviation and maritime transport will continue to rely on liquid fuels for the foreseeable future, options for *blending biogenic fuels* and those based on renewable electricity are being considered. The role of waste and residue-based biofuels should also be explored in this context. Biobased vehicle fuels are also being considered, provided sustainable production can be guaranteed. ***Gaseous:*** More manure from livestock farming is to be used to produce biogas. The government will determine the extent to which the use of livestock manure to generate energy can be *funded* beyond current levels.
Energy storage	Examples are given: combine low-temperature systems with renewable energy sources, concepts for storing energy in a way that is useful for the system, or methods of producing, distributing and using sustainable fuels based on power-to-gas or power-to-liquid technologies. Further, note that *battery cell manufacturing capacity is needed in Europe* that can compete in the global market and will drive forward research and development in battery and storage technologies.
Energy systems integration	Energy demand must be significantly and permanently reduced in all sectors ("*efficiency first*"), secondly renewable energy must be directly used in all sectors where feasible and makes economic sense, and thirdly electricity from renewable sources must be used efficiently. ***Sector coupling:*** The electricity sector will be increasingly "coupled" with the buildings, transport, and industry. Research and development of new options for using waste heat (e.g. power generation) will receive support, and option for avoiding waste heat are also receiving more attention. The use of highly efficient heating networks, especially those of the 4th generation (low-temperature district heating networks), based to a high degree on renewables, will also play an important role. Further, networking trends are making inroads into buildings too. ***Energy systems integration:*** With its new Electricity Market Act, the German government has created a regulatory framework to balance generation and consumption flexibly and efficiently. To balance supply and demand, the energy supply of the future will be digital. *Digitalisation* applies to all stages of the energy value chain. New efficiency potential is being identified as increasingly large volumes of data are analysed. Modern technologies can be used to create

	smart connections between electricity grids and electricity generation and consumers.
Hydrogen	***Today:*** A number of demonstration facilities for producing hydrogen by electrolysis and producing synthetic methane were set up and their operation is now being analysed. An initial pilot plant to produce electricity-based liquid fuels (power-to-liquid) also went into operation in 2014. The first steps to increase the use of methane in maritime and inland shipping have also been taken. ***Future:*** Achieve cost parity with biofuels, which depends above all on intensifying research into materials and surface engineering aspects of electrolysis. Use of synthetic vehicle fuels based on renewable energy. Replace fossil fuels with CO_2-free or CO_2-neutral fuels. However, as potential of sustainable biomass is limited, the conversion of renewable electricity into hydrogen and possibly in further processes to synthetic methane and synthetic liquid fuels could make sense. The hydrogen produced in this way will be used in fuel cells, the synthetic hydrocarbons primarily in ships and aircraft.
Wind and solar energy	Renewables accounted for 32% of electricity demand in 2015, the majority coming from wind 13.3%, and photovoltaics 6.5%. Their share in overall electricity production is rising significantly. Because these technologies currently hold a great deal of cost-effective potential, they are being massively expanded in line with the government's goals. They dominate and characterise the system.
Cross-cutting topics	**Findings in the LTS**
Social acceptance and engagement	Climate Action Plan 2050 must include social justice, affordability and economic efficiency, participation and a vibrant democracy as fundamental criteria. ***Active participation:*** Promotion of the innovative ability of an open society through targeted support for diverse initiatives and stakeholders. Voluntary measures can be supplemented by targeted regulation. The government will continue to develop a culture of participation, thereby initiating and strengthening learning and innovation processes. The government will fund studies under real-life conditions to test sustainable lifestyles, forms of work and economic approaches. The Climate Action Plan will be reviewed and updated as part of a ***public dialogue process***. Dialogue will also include formulation of guiding principles and transformation pathways for climate neutrality. ***Lead by example:*** *i)* systematically record energy consumption, the share of renewable energy sources and CO_2 emissions for federal properties and mobility, explain changes from the prior year and tighten measures where necessary; *ii)* initiate an exchange of best practices among the various levels of the public sector; *iii)* review and update Energy efficiency refurbishments, sustainable mobility management, programme of sustainability measures; *iv)* continue the Alliance for Sustainable procurement across the federation, Länder, and local authorities; *v)* continue the government's Green IT initiative. ***Knowledge & training:*** *i)* integrate training and education about climate action into its current and future funding lines; *ii)* do educational work in the area of international development policies to promote critical engagement with development and climate policy issues and encourage personal commitment, *iii) continue to fund projects* that contribute to increasing the level of awareness and to the implementation of knowledge relevant to climate issues in all occupations recognised as requiring official qualifications, implement planning and production processes in day-to-day work, encourage the acquisition of additional qualifications needed to implement climate action measures at work (particularly those that enhance recognised job profiles instead of creating new

	ones), and support measures to promote climate action in the area of career counselling; *iv)* continue to pursue measures that have proven successful, update where applicable and use them as a blueprint for new activities; and *v)* take advantage of multistakeholder initiatives by business and civil society to support the implementation of environmental and social welfare standards along global supply chains (e.g. Sustainable Cocoa Forum and Partnership for Sustainable Textiles). ***Innovative research and development projects serve as models*** for increasing the awareness of all members of society and helping to change behaviour over the Long-term (e.g. Efficiency House Plus). Those that are successful must be permanently established and expanded.
Enabling policies, regulatory measures and financing	***Climate Action Plan 2050*** key elements are: *i)* Long-term targets, *ii)* guiding principles and transformative pathways, *iii)* 2030 targets/milestones, *iv)* strategic measures, *v)* a learning process with regular updates, and *vi)* a technology-neutral and innovation-friendly approach. Emissions targets, compared to 1990 numbers, are split into areas of action (*Energy sector*: 61-62%, *Buildings*: 66-67%, *Transport*: 40-42%, *Industry*: 49-51%, Agriculture: 31-34%, and Other: 87%) to reach the overall goal of 55-56% reduction by 2030 and 80-95% reduction by 2050. Work will also occur towards ensuring that the individual sectors take responsibility for meeting the reduction targets. For future updates, a scientific platform of selected institutions doing research in the natural and social sciences will prepare scientific experts' reports and assessments for the revision of the programmes of measures. ***Other goals:*** *i)* 20% of the total land used for agriculture be organically farmed; *ii)* halve food waste and losses by 2030; *iii)* increase the amount of forested land in Germany via widespread use of certification of legal, sustainable forestry practices; *iv)* continuous improvement in resource efficiency - specified in the German Resource Efficiency Programme (currently ProgRess II). ***General funding framework:*** *i)* use energy and climate policy to guarantee affordability and a fair distribution of costs; *ii)* renewables and energy efficiency will in future be the standard for investment; *iii)* no longer providing support to build new coal-fired power stations or retrofit those that have already been mothballed (modernisation is only permitted in exceptional cases); *iv)* With 2017 Renewable Energy Sources Act, payment levels will be ascertained on the basis of a tendering process; *v)* all energy-consuming sectors make an appropriate contribution to financing; *vi)* a greater proportion of research funds must be allocated to areas such as renewable energy technologies, grids, storage systems, technologies needed for sector coupling (including power-to-gas and power-to-liquid) and technologies and measures to increase energy efficiency - also will focus on applying research outcomes in practice. To determine what shape the research and development programme will take, the government will soon undertake an ***industry-specific dialogue process*** with affected industries. Support for launching mature technologies on the market will build on that. ***Specific funding agreements:*** *i)* allocate funding totalling €7.3 million in the next 4 years to districts in the Lausitz region as part of the Joint Task for the Improvement of the Regional Economic Structure; *ii)* The Federal Ministry of Education and Research is funding innovative R&D projects in the area of CO_2 use as part of the CO_2 Plus, innovative resource efficiency via r+Impuls *iii)* The BMUB's Environmental Innovation Programme is already funding demonstration projects that implement technology to lessen environmental impact on an industrial scale for the first time; *iv)* the Local Authorities Guideline offers

	financial support for a wide range of climate action measures and has funded some 8,000 projects in 3,000 local authorities since 2008; *v)* increasingly focus the use of National Climate Initiative (NKI) funds on enabling particularly energy-intensive sectors and companies to introduce new technologies that are available on the market and new business models to reduce production's resource and energy demand and strengthen the circular economy. To accelerate the dissemination of best practices, these measures will be backed by public relations work aimed at specific target groups.
Regional cooperation	***Climate Action Plan:*** The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety set up a comprehensive ex ante dialogue and participation process to give representatives of the Länder and local authorities, business and industry and civil society associations, and the public the opportunity to play an active role in developing the Climate Action Plan 2050 and make suggestions for specific measures. Dialogue will continue with the affected sectors and their businesses, the trade unions their workforces belong to, associations and civil society. This process will be refined in a way that is scientifically sound, has democratic legitimation and includes broad and continual participation of the scientific and academic community. ***Research & development actions:*** DE will *work with industry to develop a research and development programme* oriented to reducing industrial process emissions that affect climate. It is tailored to specific sectors and goal oriented. ***Knowledge & training actions:*** DE will work with stakeholders in the field of vocational and university training and continuing professional development, as well as the relevant associations and institutions, to develop long-lasting mechanisms to accelerate the dissemination and use of new technical knowledge. One area of emphasis will be training for employees of small and medium-sized enterprises. NKI includes funding for target groups such as local authorities, educational institutions, companies, and consumers, as well as strategic projects to provide information, advice and support to those groups and help them build capacity.
International cooperation	***Development and financing actions are to:*** *i)* double international climate finance by 2020 based on the 2014 level; *ii)* get the international financial institutions (incl. the World Bank), to make a considerable increase in their contributions to international climate finance while ensuring projects use incentives to promote positive effects on climate action and development; *iii)* expand the Technology Mechanism of the United Nations Framework Convention on Climate Change (UNFCCC); *iv)* work at the national, European and international levels to ensure that environmentally harmful subsidies are eliminated with due regard for the interests of consumers and other aspects of the national economy; *v)* support the work of the Financial Stability board; and *vi)* support measures that will allow climate action and sustainable development to be achieved together. Initiatives are currently concentrated in the areas of energy (incl. the energy transition in Africa through the Africa Renewable Energy Initiative), climate risk insurance, forests (African Forest Landscape Restoration Initiative), marine and coastal protection (10-point action plan for marine protection and sustainable fisheries), transport (particularly funding for sustainable mobility systems in urban areas), and adaptation to climate change (National adaptation plan Global Network). ***Carbon markets actions are to:*** *i)* contribute intensively to redefining the mechanisms of the carbon market; *ii)* work at the European level to make the

	ETS (EU Emissions Trading System) more effective – with most efficient and climate-friendly technologies to be used as a benchmark (top 10% of plants must be granted an exemption from further requirements to reduce CO_2); and *iii)* contribute to reasonable rules on what is known as "direct and indirect carbon leakage". ***In relation to products,*** Trade in sustainable products and services should be preferred. Germany will work to achieve this within the EU and WTO -incl. product repair (also by independent workshops) and product lifetime transparency. ***Environment actions are:*** *i)* reinforcement of international cooperation in conserving, restoring and sustainably managing forests (for climate action, species protection, raw materials supply); *ii)* effective protection of grassland with a ban on ploughing grassland on carbon-rich soils will be a particular priority; and *iii)* examination the possibility of consistent, permanent funding for paludiculture.

Greece

Pathways	Findings in the LTS
Bioenergy	Bioenergy will play an important role in a decarbonised energy system, from biomass utilisation for thermal applications to biomethane production, which could be fed into the natural gas network.
Energy storage	Various energy storage technologies will enable short and long-term energy storage for providing flexibility to the grid and utilising the excess renewable energy.
Energy systems integration	Synergies between transport, power generation and heat sector will enable more efficient utilisation of energy resources.
Hydrogen	Hydrogen will be a key energy carrier that will be utilised across several sectors, from industry and transportation to energy production and storage.
Solar energy	Solar photovoltaics and solar thermal applications are considered as the most important renewable energy source for the future Greek energy system.
Wind energy	Onshore and offshore wind energy will be the backbone of the renewable energy generation.

General remarks about the LTS

The LTS report does not provide any information on specific measures or trajectories on reaching 2030 and 2050 goals, but it illustrates via different modelling scenarios several potential pathways that are considered for the Greek energy system. Each scenario includes a different mix of technology and policy measures, suggesting a potential pathway to decarbonisation goals. This information cannot be deemed as a part of a concrete national strategy but as a set of potential pathways to be followed depending on progress towards the national goals and other variable factors (e.g. technology costs, EU policies etc.) that will determine the future steps and measures to be taken. Therefore, the information included in the analysis below does not correspond to concrete measures or pathways but rather on pathways that have high potential on achieving Greece's climate and energy goals.

The LTS was submitted to the EC back in 2020, which does not reflect the latest governmental plans. For instance, Greece is updating the regulatory framework for offshore wind and there are already several investment schemes submitting plans for offshore wind parks. Offshore wind is poorly mentioned in the LTS.

Policy axes towards climate neutrality strategy 2050

- Improving energy efficiency
- Electricity of transport and heat
- Renewable energy sources
- Net mobility in the transport sector
- Industrial competitiveness and climate neutrality
- Network infrastructure and market integration policies
- Bio-economy

Innovative policies considered in the different scenarios include:

- Extreme interventions to improve energy efficiency.

- Large-scale circular economy.
- Electrification in all sectors and uses or means of transport where the relevant chronologies are today immature.
- Behaviours and organizational interventions that reduce car activity and trucks.
- Development of **chemical storage of electricity through hydrogen**.
- **Coupling of sectors** through the production and disposal of **climate-neutral hydrogen** and the direct use of hydrogen in certain applications in **industry, in transport and gas distribution**.
- Application of **carbon dioxide capture**, use and storage, in underground formations and chemicals.

ENERGY SYSTEMS INTEGRATION

Hydrogen is considered as a key energy carrier for connecting different energy intensive sectors, such as industry, transportation and the power sector. Energy storage technologies, such as batteries (including electric vehicles), pump-hydro and hydrogen will provide flexibility to the energy system as needed, in order to overcome temporal variability of renewables.

Green hydrogen and synthetic methane could replace fossil fuels currently utilised in heat engines for supporting power system balancing. Electric vehicles and hydrogen fuel cell powered ones will replace ICE (Internal Combustion Engine) vehicles in both private and public transport sectors, while carbon capture storage technologies could be applied at a wide range of carbon emitting industries, especially thermal plants run on lignite, biomass, biogas and natural gas.

HYDROGEN

Power generation

Hydrogen is considered as a key energy carrier for connecting different energy intensive sectors, such as industry, transportation and the power sector. The majority of future green hydrogen production is envisaged to utilise the excess renewable energy generated at times when the electricity demand is low.

Green hydrogen and synthetic methane could replace fossil fuels currently utilised in heat engines for supporting power system balancing, which in the light of increased share of renewables in the energy system, these services are becoming more and more important. Green hydrogen could also complement other energy flexibility technologies such as battery energy storage and pumped hydro.

Green hydrogen (and synthetic methane) could be blended with natural gas in the existing natural gas network or stored physically or chemically.

Industrial sector

Carbon from carbon capture systems in the industrial processes such as the cement industry could be used in conjunction with renewable hydrogen for the production of petrochemical products as a way to trap carbon into products instead of releasing it to the atmosphere.

Transportation

Electric vehicles and hydrogen fuel cell powered ones will replace ICE vehicles in both private and public transport sectors. However, hydrogen fuel cells will have a considerably higher share in public transport vehicles compared to those of the private transport sector which will be dominated mainly by electric vehicles. The optimistic scenario also indicates the possibility of using synthetic fuels (including hydrogen) blended with natural gas for the road freight transport sector.

SOLAR ENERGY

Solar energy, together with wind is considered as the main renewable energy technology to be utilised at its greatest extend towards the decarbonisation of the energy system. This includes centralised generation plants but also decentralised, making use of roof space of buildings with commercial, industrial and residential applications.

Solar thermal systems for hot water provision in the residential sector are quite common in Greece. The LTS underlines that they are well featured in all future scenarios for covering residential demand for domestic hot water, without excluding that part of this demand could be covered by electric heat pumps.

ENERGY STORAGE

Energy storage technologies, such as batteries (including electric vehicles) pump-hydro and green hydrogen will provide flexibility to the grid (ancillary services) as needed due to the variability of renewable generation. Chemical storage of green hydrogen will enable long-term storage capabilities that can be used in thermal plants and replace fossil fuels for power generation for spinning reserves. Pumped hydro will be utilised at an extent and based on the existing infrastructure for energy storage between a day and a week's time, while electric batteries will contribute to daily and short-term energy storage needs.

WIND ENERGY

Onshore wind energy together with solar will be the main sources of renewable energy production in a decarbonised power system. Regarding offshore wind energy, it will provide a substantial amount of renewable energy, but it will be quite limited compared to onshore installations. However, based on recent developments Greece is finalising its legislative framework and seeks to form PPPs (public–private partnerships) for the development of 1.5 GW offshore wind energy by 2030.

BIOENERGY

Biomass residues from the agricultural and farming sectors along with municipal waste and forest biomass, could be utilised in thermal plants for electricity production, and together with other forms of renewable energy contribute to satisfy a part of the heating demand in public, residential and service buildings.

Biomethane as a product to upgrade biogas could be fed into the natural gas network with the possibility of ultimately replacing it in the long run. Additionally, regulatory measures for the mandatory mix of biomethane to the natural gas network would enable investments in the biogas production sector with Long-term perspectives.

Biomethane production is mainly envisioned to be produced by the utilisation of primary biomass sources, for instance agricultural bioproducts, municipal solid and liquid waste through mainly biomass gasification and anaerobic digestion processes. Synthetic methane could also be produced by utilising carbon from CCS and hydrogen.

LTS underlines also the need for policies to support the production of raw material of biomass and energy farming at industrial scale.

Industrial sector

Biomass and biogas could be both utilised in energy intensive industries, while biomass residues from industry could supplement the bioenergy feedstock.

Transportation

Biomass could also be used partially (due to limited primary sources) in the transportation sector, especially in those modes of transport where other renewable-based alternatives are less feasible.

Lignocellulosic biomass could be produced and utilised in some modes of transport, while biodiesel could replace current fossil-based diesel fuels in the road freight transportation.

Hungary

Pathways	Findings in the LTS
Bioenergy	Hungary plans to increase the sustainable use of bioenergy and reduce its consumption of natural gas starting in the 2040s.
Energy storage	It will be necessary to significantly increase the electricity storage capacity of the country due to the planned high level of electrification which will be based mostly on energy generate from RES.
Energy systems integration	Electrification will be pursued in all areas of the economy, based on domestic nuclear and renewable energy sources.
Hydrogen	By 2040s, hydrogen will already play an important role in both climate neutrality scenarios to replace the use of natural gas especially in the transport and industrial sectors.
Solar energy	Solar power is considered the most potential source for renewable energy generation in the future.
Wind energy	Wind energy is not mentioned.

Main findings

The LTS presents **three main scenarios** for GHG emissions up to 2050:

- **Business-as-usual (BAU) scenario**: emission trajectory follows current trends, assuming that all existing sectoral policy strategies and measures remain in effect, and that there will be no new interventions.
- **Late action (LA) climate neutrality scenario**: This scenario aims to reduce emissions in the energy sector at a delayed and slower pace until 2045, and then with an increased effort until 2050.
- **Early action (EA) climate neutrality scenario**: the EA approach envisages achieving climate neutrality by 2050 while considering the short- and medium-term benefits of job creation, GDP growth and the advantage of first mover.

The **most important points** include:

- The energy sector – including the energy supply and the energy consumption of the industry and transport sectors and others (such as tertiary or residential sectors) – will play the most significant role in reducing emissions;
- In all scenarios, remaining emissions in 2050 will be compensated by natural and technical sinks;
- CCS and hydrogen technologies will gain ground after 2030;
- The 2050 climate neutrality target cannot be reached without the utilization of nuclear energy;
- Hungary will pursue the increase of renewable energy to decrease energy imports and enhance energy security. Most renewables will come from solar power, biomass, and biofuels.

BIOENERGY

Hungary plans to increase the sustainable use of bioenergy. Starting in the 2040s, it will reduce the consumption of natural gas, which will completely disappear in some sectors. Natural gas will be partially replaced by hydrogen, mainly in the transport and industrial sectors.

The high uptake of biomass-based electricity generation with CCUS technology will further increase the share of renewable energy. In many subsectors – industry, transport, and others, such as carbon leakage and agricultural energy use – full decarbonization cannot be achieved without CCUS. The CCUS technologies typically will only enter the energy system in the 2030s, and possibly the 2040s.

Transport

Over time the decarbonisation of transport will be achieved through expanding the application of second generation/advanced biofuels and hydrogen, as well as the more efficient usage of fuels and the gradual decrease in using liquefied petroleum gas (LPG) on the market.

As a result of electrification in the transport sector, the consumption of oil-based fuels will decrease drastically.

ENERGY STORAGE

Due to the high degree of electrification, which will occur in all areas of the energy sector and will be mostly based on RES with variable power generation capacity, it will be necessary to significantly increase the electricity storage capacity of the country – mostly through primary battery technology (especially from 2040s onward).

Hungary will need to promote the use of technologies that can store large amounts of energy for a longer period (especially power-to-gas (P2G) technologies).

Buildings

The household subsector has the greatest potential for energy savings. This will be due to the substantially lower energy consumption of new appliances (first and foremost heat pumps), cost-effective renovations to be carried out mainly under the energy efficiency obligation scheme as well as the favorable energy consumption indicators of newly built dwellings.

ENERGY SYSTEMS INTEGRATION

The decarbonisation of the energy sector and large-scale electrification are the main means to reduce emissions. Electrification will be pursued in all areas of the economy, based on domestic nuclear and renewable energy sources.

Hungary will seek to improve energy efficiency in all fields of the national economy and to establish a circular economy. To this end, the Circular Economy Platform was already established in 2018 and a Working Group was created to support it.

The stakeholder consultation stream called “Climate Breakfasts” held in 2020 with representatives of civil society organizations and the industries confirmed the importance of digitization, electrification in the long-term process of industrial decarbonization and the need to increase energy efficiency. Stakeholders considered particularly important to introduce incentives for R&D to ensure the competitiveness of domestic actors in the development, production and export of new, energy-efficient and renewable energy-based technologies.

Transport

Consultations with industry representatives have confirmed that decarbonization can be promoted in the automotive industry through fuel switching and the introduction of hydrogen. Hungary is considering the future purchase of "clean" electric vehicles (battery-powered vehicles and hydrogen fuel cell buses) for public transport, as well as the appropriate development of the charging station network and infrastructure.

Industry

The decarbonization of the industry sector cannot be based on curbing production but investments improving efficiency and technological development. To effectively reduce process emissions, dramatic changes are needed in the future in those industrial sub-sectors that account for a significant share of GHG emissions, namely petrochemicals, iron and steel, ammonia and cement. Emissions of nitrogen oxides (mainly N2O) from industrial processes can be reduced relatively quickly as early as 2030s, although further reductions thereafter are limited. It will be possible to accelerate the reduction of CO_2 emissions in the longer term. in addition to the development of production/manufacturing processes and the increase of material efficiency, the use of CCUS

technologies and alternative raw materials for the replacement of fossil-based energy sources used as certain raw materials may also be necessary in the future.

HYDROGEN

In the future, Hungary will rely on the increased use of hydrogen and upscaling of the related hydrogen technologies. Part of the hydrogen will be produced will be produced using electrolysis technology and increasingly from renewable sources, which will help reducing the use of natural gas. By 2040s, hydrogen will already play an important role in both climate neutrality scenarios to replace the use of natural gas especially in the transport and industrial sectors.

Already in 2020, during the consultation stream "Climate Breakfasts", stakeholders highlighted the role of hydrogen as an important factor in industrial decarbonization.

SOLAR ENERGY

Solar power is considered the source with the highest potential for renewable energy generation that the country will rely on in the future.

Hungary may consider the introduction of subsides to finance household-sized solar collector and PV investments.

Buildings

In both decarbonisation scenarios Hungary will implement solar power programmes to increase the energy efficiency of households.

WIND ENERGY

Wind energy is not mentioned.

Cross-cutting topics	Findings in the LTS
Social acceptance and engagement	Efforts to raise public awareness to shape consumption patterns and promoting the transition to a circular economy are expected to have a significant positive impact. Hungary will support a change in the consumption patterns. In the future, it would be important to calculate and make available products and services' carbon footprint and services, so conscious consumers could make informed choices. The consultation stream called "Climate Breakfasts" held in 2020 with representatives of civil society organizations and the industries drew attention to the need to place particular emphasis on the conservation of biodiversity and the promotion of organic farming in sustainable agricultural practices.
Enabling policies, regulatory measures and financing	Research, development, and innovation will be one of the main pillars for achieving energy and climate goals. Through the research development and further improvement of new technologies and processes, as well as their market introduction, a degree of cost reduction can be achieved to greatly help the spread of clean technologies. The education and (re)training of professionals capable of developing and/or applying new technologies and processes is also crucial to reach climate neutrality. Prioritizing public transport over private transport will further reduce the primary energy demand of the transport sector. Interventions would be needed to reduce energy consumption in the energy sector. Such a regulatory tool could be the energy efficiency

	obligation scheme to be introduced, investments, or operating subsidies, but these could include direct (e.g., prohibitive) instruments as well. There is a need to fully integrate climate change as a precondition into industrial development policies. Acceleration and expansions of investment will be needed to: • Boost energy efficiency, especially in the residential (e.g., modernization of the heating systems) and commercial sectors • Electrify the economy, especially in the transport, residential, and commercial sectors. • Development of CCUS technology, as well as in the increasing the utilization of renewable energy sources and energy storage systems. • The LULUCF sector will require significant investments to enhance net CO_2 capture (sink capacities) after 2030. This will be especially needed for measures that improve forest adaptation, reduce logging in the medium term, and increase afforestation efforts in the Long-term.

Italy

Pathways	Findings in the LTS
Bioenergy	The contribution of bioenergy should be significant, especially through the maximum development of biogas and its upgrade to biomethane, which can be used in thermal end-uses but also in the generation sector.
Energy storage	
Energy systems integration	
Hydrogen	Italy will be highly reliant on the use of hydrogen in multiple sectors.
Solar energy	As of today, solar and wind energy are the most viable energy sources to increase energy supply and the production from RES.
Wind energy	See above

Main findings

Three "potential levers" are identified to achieve climate neutrality by 2050:

- **Reduction of energy demand**, especially of transport and civil sectors, e.g.:
  1. Deep buildings renovations.
  2. Sharing private mobility.
- **Change in the energy mix** by:
  1. Favouring RES, in particular:
     1. biomethane and hydrogen;
     2. Develop offshore wind and increase solar power;
     3. Develop unexploited resources, e.g. ocean and electrochemical.
  2. Electrification of end-uses, e.g., increase the number of electric cars and heat pumps;
  3. Develop circular economy;
  4. Hydrogen production (to be used as it is or transformed into other fuels).
- **Increase CO_2 sequestration** by:
  1. LULUCF: sustainable management of forests via increased efforts in terms of fire-fighting and sustainable soil management policies in combination with restoration and afforestation to bring back the "carbon sinks" to their historical maximum;
  2. Livestock farming: better management of livestock and development of CCS solution;
  3. CCS-CCU: mostly foreseen for the industry sector, like steel production.

BIOENERGY

The contribution of bioenergy should be significant, especially through the maximum development of biogas and its upgrade to biomethane, which can be used in thermal end-uses but also in the generation sector.

More efficient cooling systems for biomass plants will be introduced.

Industry

The use of renewable synthetic or bio-based gases and e-fuels will be promoted to reduce the emissions of the industrial sector – thus significantly changing the mix of fuels and carriers used.

Transport

CO_2 capture from bioenergy can be used to produce alternative fuels such as synthetic methane or methanol.

To reduce the impact of the transport sector, Italy the following possible technologies have been identified:

- Diesel vehicles: internal combustion engines fuelled by biodiesel;

- Gas vehicles: internal combustion engines fuelled by liquefied biomethane;
- Maritime transport: Direct Methanol Fuel Cell (DMFC) ships, i.e., ships with an electric engine in which electricity is produced on board by methanol fuel cells. Biodiesel and liquified biomethane will be used as fuels.

ENERGY STORAGE

A high capacity of grid-based and distributed electrochemical storage systems must be installed in the future. These will have multiple uses, i.e., shifting excess from RES production to times of the day when it can be consumed directly for end-use and by Power-2-X plants; providing large amounts of power for flexibility and fast backup services.

E-fuels production plants, together with power-to-heat plants and Direct Air Capture (DAC) systems, would become functional to the stability of the electricity system by introducing flexible storage and consumption capacities.

Other flexible ways of using electricity in the energy system could be realised by the development of seasonal heat storage systems, including for district heating networks. These systems will be able to store heat produced by surplus PV production in the summer season for supply in the winter period (Power-to-Heat).

The use of air coolers, additional pumps or cooling towers will be promoted. Moreover, open-cycle cooling systems will be replaced by closed-cycle systems.

Industry

The electrification of heating in the industry sector is foreseen through the following systems and technologies:

- Low-temperature heat production (100-150°C) - Industrial electric heat pumps: The technology is suitable for low-temperature thermal uses (<100°C), but there are models that can also serve thermal uses up to around 150°C by combining the heat pumps with a heat booster that can raise the temperature.
- Medium temperature heat production (100-500°C): Mechanical vapour recompression, electric boilers, infrared drying, microwave ovens.
- High-temperature heat production (>500°C up to 1100-1600°C for the main processes of steel, cement, glass, ceramics, steam cracking): Induction melting furnaces, plasma technology, infrared, ultraviolet, microwave, electric heaters.

Transport

The electricity system will benefit from new forms of demand management capable of restoring flexibility. For example, batteries in electric vehicles will be an important element which can be used to provide services to the grid (Vehicle-to-grid).

To reduce the impact of the transport sector, Italy is considering the introduction of battery electric trucks.

Buildings

Increasing the energy efficiency of existing buildings is the subject of the recent 'Strategia di lungo termine di riqualificazione del parco immobiliare nazionale' (STREPIN). Italy will have to renovate most existing buildings and introduce structural measures and institutional incentives. In terms of the materials used, the criterion of sustainability will be important through the cascading use of wood and waste from its processing for the structural and energy improvement of buildings. Among the policies under consideration to increase the efficiency of renovation measures and reduce energy consumption there are strengthening urban and peri-urban green policies, containing heat islands, and reducing radiation. Moreover, it will be required to increase heating generation via electricity (i.e., through heat pumps) to reduce the use of natural gas and oil products.

ENERGY SYSTEMS INTEGRATION

The progressive replacement of gas with hydrogen will require an upgrading and an overall reconfiguration of the network, for example, with portions dedicated exclusively to the transport of hydrogen itself and peripheral sections of the distribution that could be closed (because served by local systems).

The reconversion of the gas infrastructures into hydrogen for both distribution and transport will be carried out gradually. Hence a first phase of gas-hydrogen mixture is foreseen, before achieving the complete conversion to hydrogen only. Operationally, this translates into the promotion of enhanced cooperation between electricity transmission and gas transport system operators, with joint planning, experimentation and study of infrastructure adaptation needs.

More in general, to cope with the future effects of climate change, Italy plans to:

- promote the development of microgrid;
- burying part of the grid underground;
- replace open-cycle cooling systems by closed-cycle ones;
- provide incentives for climate proofing of new buildings;

Transport

Highways: electrification of motorway sections with suspended electric cable and pantograph.

HYDROGEN

A significant share of electricity (i.e., 25- 30%), will be used to produce hydrogen – particularly in the overgeneration phase. Therefore, it will be essential to manage this vector in such ways that are:

- technologically effective: share mixable in the network with gas/biomethane, direct use in transport and industry, possibility of storage;
- economically efficient: production cycle costs, transport, storage, reuse.

Transport

Hydrogen generated from renewable sources in combination with captured CO_2 of "bio" origin will allow the production of biomethane and fuels similar to conventional ones but with zero greenhouse gas emissions (e-fuels), thus favouring the reuse of existing infrastructures and vehicles.

Italy will invest in e-hydrogen fuel cell, i.e. vehicles with an electric motor in which electrical energy is produced on board by hydrogen fuel cells (FCEV: fuel cell electric vehicles). Moreover, to reduce the impact of the transport sector, Italy has identified the following possible technologies to be introduced in the future:

- Diesel vehicles: internal combustion engines fuelled by:
- synthetic diesel obtained from gasification/pyrolysis of biomass or from H2 and CO_2;
- synthetic methanol upgrade diesel obtained from H2 and CO_2.
- Gas vehicles: internal combustion engines fuelled by:
- liquefied synthetic methane from H2 and CO_2.
- Petrol vehicles: internal combustion engines fuelled by:
- synthetic methanol obtained from H2 and CO_2.
- Maritime transport:
    1. Ships with hydrogen fuel cells;
    2. Fuel: synthetic methanol obtained from H2 and CO_2 and synthetic liquefied methane obtained from H2 and $CO_2$2.

Industry

Italy plans to change the industrial energy mix to decarbonise the sector. In steel production, the blast furnace could be eliminated and replaced by a process of direct reduction of iron ore (DRI-direct reduced iron) in which methane (DRI-CH4) or hydrogen (DRI-H2) can be used as reducing agents. In this case, the subsequent transformation of iron into steel could take place in electric arc furnaces.

The DRI-H2 process with subsequent electric arc furnace is an option for the complete decarbonisation of integrated steel production.

SOLAR ENERGY

Current knowledge suggests that photovoltaics and wind energy are the main options for increasing electricity production from renewables. By 2050, photovoltaic installed capacity would reach values in the order of about 10-15 times the current level.

However, the planned values of RES may pose serious sustainability problems, in terms of land consumption and environmental impacts. Therefore, this massive deployment of solar (and wind turbines) plants should be coupled with other environmental objectives such as limits on land consumption and landscape protection.

Solar thermal will be used to heat buildings, even though, in order to decarbonise the energy system, the technology competes with photovoltaics, not only in terms of cost, but also in terms of occupying roof space.

WIND ENERGY

As of today, wind energy – together with solar – is the most viable source to increase energy supply and the reliance on RES. By 2050, wind power, both on-shore and off-shore, could reach 40-50 GW.

Cross-cutting topics	Findings in the LTS
Social acceptance and engagement	The following are acknowledged as enabling factors to reduce the energy demand: • Citizens' willingness to carry out deep building renovations; • Citizens' willingness to share private mobility;
Enabling policies, regulatory measures and financing	• Transformation of "CIPE", Interministerial Committee for Economic Planning, into "CIPESS" Interministerial Committee for Economic Planning and Sustainable Development. • Revision of the energy taxation • Strategia di lungo termine di riqualificazione del parco immobiliare nazionale (STREPIN) to increase energy efficiency of buildings.

Latvia

General Principles of Climate Policy until 2050

Pathways	Findings in the LTS
Bioenergy	Solutions on bioenergy. Particularly mentioned in the energy, transport and agricultural sectors
Energy storage	Solutions focusing on electrification of the transportation sector.
Energy systems integration	Solutions on ESI. Particularly mentioned in the energy and transportation sectors
Hydrogen	Mentioned to a limited extent and related to energy and transport sectors
Solar energy	Shortly mentioned as important RES
Wind energy	Shortly mentioned as important RES

In the Long-term Strategy of Latvia, the most essential factors of occurrence of GHG emissions which are specific to Latvia have been identified and the potential solutions for the implementation of low carbon development (LCD) have been offered. In the following, the described text assumes **the situation in Latvia in 2050** after the implementation of the foreseen actions of the LTS.

Main findings

- The use of RES in the energy sector has been primarily promoted by supporting the obtaining of solar and wind energy.

BIOENERGY

Energy

Sufficiently extensive use of liquid biological heating fuel in energy generation and use of bio-oils in equipment in the agricultural and forestry sectors is ensured from residues of felling areas, wood residues and straw. First-generation biofuel is not being manufactured.

Transport

The use of biofuels (non first-generation) is particularly used for aviation. Part of the water transport uses biofuels in pure form or mixed with fossil fuels.

Land Management and agriculture

Agriculture and forestry are yet significant contributors to bioenergy. Biomass is primarily obtained to be sold on the local market. Biogas from the processing of manure and other organic waste is obtained in households where it is economically feasible.

ENERGY STORAGE

Transport

Road transport is mainly electrified and charging infrastructure is widely accessible. Rail transport, small-scale aviation and domestic aerial transport are also electrified. Water transport is partly electrified.

ENERGY SYSTEM INTEGRATION

Energy

New technologies and methods for heat supply systems which ensure the use of innovative technologies and solutions for efficient operation of the heat supply system have been introduced in the centralised and local heat supply system. Private residences are mainly self-sufficient in terms of energy because decentralised zero-emission heat supply and electricity supply solutions are being used.

The EU countries form a joint energy network which allows to optimise the generation, supply, and use of energy, as well as increases the security and stability of energy.

The consumption of electricity has increased, and it is mainly related to the electrification of the transport system, the use of electricity in heat supply, and the increase of the living standard of inhabitants, i.e., an increased number of electric appliances.

Transport

The infrastructure for the charging of electric vehicles is available on TEN-T62 roads and in cities, allowing for the convenient and fast charging of electric vehicles. Fast charging stations are widely accessible. Ports are electrified, thus reducing emissions from ships standing in ports. Such infrastructure has been integrated into the European transport system.

HYDROGEN

Energy

Hydrogen as energy carrier which has been manufactured using electricity obtained from different types of RES, different solutions for the storage of hydrogen, has an increasingly important role.

Transport

The use of hydrogen for transportation purposes has taken place. Water transport is partly driven by hydrogen.

SOLAR ENERGY

Energy

Taking into consideration the high-capacity technologies of variable RES (solar and wind energy) installed, electricity accumulation technologies are commercially developed and introduced.

WIND ENERGY

Energy

Taking into consideration the high-capacity technologies of variable RES (solar and wind energy) installed, electricity accumulation technologies are commercially developed and introduced. construction of wind parks or switching from fossil energy resources to RES in heat supply enterprises of the large cities, is particularly important.

Cross-cutting topics	Findings in the LTS
Solutions for local governments	• The tax system completely conforms to the principle "polluter pays" and state administration and local government authorities have renewed their fleet with environment-friendly vehicles • Local governments are taking an active part in different local and international initiatives “local governments learn from local governments

	• State administration (each ministry within the scope of its competence) has improved and developed policy planning documents and laws and regulations of each sector of national economy so that they conform to the objectives declared in the Strategy • Local governments promote the development of green employment • Legal acts and regulatory framework should include all other instruments to be used in the implementation of the Strategy • The tax system as a whole should be restructured by 2050 so that the promotion of climate change mitigation and adaptation to climate change would become an integral part of objectives of the taxes of the relevant categories. Subsidies, reliefs, tax refunds should also be used to achieve the climate neutrality. Subsidies to fossil heating fuels should be denounced completely, focusing on and shifting towards support to RES. • Create a national energy efficiency fund which will provide long-term and low-interest loans. • Continue the development of public-private partnerships (PPP). • Development of green obligations (funding for projects against climate change)
Research and innovations	• A policy promoting sustainable and low carbon tech and introducing the most efficient tech available on the market has been introduced • Principles of low carbon development are integrated into all State-funded studies • Investments for the development of research and innovation, for the development of new and improved technologies and processes are being successfully attracted • High level of commercialisation and competitiveness of research results • Improvements in resource efficiency provide an opportunity for growth through eco-innovations and green working places • Well-developed research human capital, culture of shared use of the infrastructure and cooperation • Extensive and accessible base of applicable knowledge promoting reduction of GHG emissions and ensuring CO_2 removals is created
Comprehensive energy efficiency	• The principle of "energy efficiency first" is introduced and implemented comprehensively • Construction of all new buildings conforms to the requirements for zero energy consumption buildings • Manufacturing processes are energy efficient • Only energy-efficient and resource-efficient products and equipment are available to the society

Malta

Pathways	Findings in the LTS
Bioenergy	Malta aims to capture the vast majority (80%) of municipal biowaste from residential and commercial sectors to produce biogas. Biofuels and synthetic fuels are considered as potential energy sources only after 2030.
Energy storage	Short-term energy storage could be used to balance intermittent renewable energy generation, especially if backup supply is not met by the interconnector. Large-scale battery storage systems are not considered.
Energy systems integration	Energy system integration is mostly depicted in the potential and long-term (beyond 2030) scenario of producing synthetic fuels and switching from ICE to EVs in the transportation sector.
Hydrogen	Hydrogen will be imported and could play a central role as a fuel in CCGT plants. It could be used for both electricity production and as a fuel.
Solar energy	Both on-shore and off-shore PV applications are considered, while solar heaters for DHW supply will be a priority against rooftop PVs.
Wind energy	Offshore floating wind farms might be considered, provided that siting challenges could be overcome.

Main findings

The Maltese energy system is interconnected with the European power system via a KV cable through Sicily.

Although achievement of a 100% RE mix is not possible for Malta at this point in time, technologies will evolve significantly by 2050, giving a plausible low-cost renewable solution to help Malta meet its power supply requirements along with significantly reducing carbon emissions.

Apart for a strong focus on energy efficiency measures, the main renewable energy sources that are expected to play a major role towards energy system decarbonisation is solar energy, while relying at a great extend to current and future interconnection infrastructures.

The Maltese government has created and RDI policy framework to enable Malta's pathways towards low carbon economy. This is consisted of national strategy and policy instruments and measures.

BIOENERGY

Malta aims to capture the vast majority (80%) of municipal biowaste from residential and commercial sectors to produce biogas. Biofuels and synthetic fuels are considered as potential energy sources only after 2030.

ENERGY STORAGE

Short-term energy storage is considered as an alternative to the current CCGT (combined cycle gas turbine) plants to balance intermittent renewable energy generation, especially if backup supply is not met by the interconnector. However, large-scale battery storage systems are not part of the Maltese long-term strategy.

ENERGY SYSTEMS INTEGRATION

Energy system integration is mostly depicted in the potential and long-term (beyond 2030) scenario of producing synthetic fuels and switching from ICE to EVs in the transportation sector.

HYDROGEN

Hydrogen is considered as one of the three energy related measures (together with offshore floating wind and an additional interconnector) that will play a major role in delivering a low carbon energy system for Malta by 2050. Apart from hydrogen's role to operate CCGT power plants, it is also envisaged as a potential source of energy to be used for both electricity and fuel. However, hydrogen will be imported via a potential pipeline and not produced by excess renewable energy.

SOLAR ENERGY

The Maltese low carbon development strategy foresees a continuous uptake of solar PV, both on-shore and off-shore applications, with similar trends applying also for solar heaters at residential buildings for DHW supply. Though, technical limitations are expected to slow down new installations of roof PVs after 2030, which are also "competing" for rooftop space with solar thermal.

WIND ENERGY

Depending on its feasibility, offshore floating wind farms are also considered even before 2030. Though, siting challenges (e.g. Natura 2000 zones etc.) might limit the number of suitable locations.

Other important documents for review:

- MCST, Public consultation document: Towards a smart specialisation strategy 2021-2027 for Malta, 2020
- MCST, National R&I Strategy 2014-2020, 2014
- National Strategy for Research and Innovation in Energy and Water for 2021-2030

Netherlands

Pathways	Findings in the LTS
Bioenergy	Sustainable biomass is required through the transition. For mobility, production of sustainable advanced biofuels and renewable synthetic fuels should be increased.
Energy storage	Only mentioned as one of the enablers for flexible energy system.
Energy systems integration	Clear plans for the energy system integration.
Hydrogen	A significant role is seen for green hydrogen as a fuel for industry and both heavy and long-distance transport.
Solar energy	Increase the availability of solar power.
Wind energy	Increase the availability of wind power.

Main findings

In the Netherlands, the **Climate Act** has turned the focus of the Netherlands' climate policy emphatically on the Long-term. The act specifies a final target for 2050 and an interim target for 2030. The Climate Agreement contains agreements for all sectors. To implement the actions towards the targets, the first **Climate Plan** under the Climate Act contains policy initiatives to prepare for the Long-term.

The transition will be characterised by many uncertainties. Ideas may change and new solutions may appear out of the blue. Therefore, the climate policy must anticipate new developments.

The objective of the long-term strategy is to serve as a basis for further analysis, discussion and policymaking in the years ahead, both at the national and the international (European and global) level. The LTS describes which current and proposed **policies** form the main contributions to the transition in the longer term, the **key challenges** for the further transition that will require answers, solutions and instruments in the coming years and summarises the **policy implications and follow-up steps**.

Energy savings and renewable energy are considered to be means at the Netherlands' disposal during the transition, to achieve the reduction target.

An **Integrated Knowledge and Innovation Agenda (IKIA)** lists the social as well as technological innovation priorities for all sectors. The IKIA specifies the most important knowledge and innovation challenges for the short term (development, demonstration and rollout) and the Long-term (research and development), elaborated into multi-year, mission-driven innovation programmes (**MMIPs**).

SUPEERA Pathways in the Netherland's LTS

BIOENERGY

Sustainable biomass will be required for the transition to a climate-neutral and circular society, and the Netherland's government believes that a genuine contribution can only be made by biomass that is truly **sustainable**. Therefore, it is working on a uniform sustainability framework to guarantee that all biomass used in the Netherlands is sustainable. The Netherlands wants to ensure that use will be restricted in due course and that it will be applied as high-grade as possible. In time, sustainable biomass will be used only in sectors where no cost-efficient alternative is available, such as aviation and shipping.

ENERGY STORAGE

Storage is mentioned as one enabler for integrated sufficient flexibility.

ENERGY SYSTEMS INTEGRATION

The aim is for a system integration to take place of various sources of energy, resulting in a more efficient use of infrastructure and generation capacity and a greater resilience of the energy system at the decentralised level against outages at the central level. The production of **renewable fuels** and the **capture and reuse of CO_2** can also contribute to further integration of the energy system. A governmental vision on the Organisation of the Market for the Energy Transition to make choices, mainly regarding the structure, regulation and funding of heating, **hydrogen** and CO_2 infrastructure for both public and private parties has been drawn up.

The Netherlands has integrated sufficient flexibility in its arrangements to compensate for a drop in supply or demand, such as through the availability of demand-side response, **storage** and controllable capacity. The growing importance of **solar and wind energy** will require further strengthening of this flexibility. For this reason, the government is investing in **flexibility demonstration projects** and has made this challenge a topic of study for knowledge and innovation programmes. Furthermore, the Netherlands will continue its efforts to expand its interconnection capacity with neighbouring countries

HYDROGEN

In the Long-term, the Netherlands has envisaged a significant role for **green hydrogen** as a fuel for industry and both heavy and long-distance transport, and for the built environment in areas where other CO_2-free alternatives are more expensive or more difficult to realise. Hydrogen also offers opportunities for the flexibilisation of the electricity system. As a result, the Netherlands has launched an ambitious **hydrogen programme** focused on scaling up the supply of sustainable hydrogen and developing the necessary infrastructure.

SOLAR ENERGY

The Netherlands is taking robust steps to increase the availability of solar power.

WIND ENERGY

An agreement on the North Sea is planned to determine additional wind farm zones for the period beyond 2030, with specifics regarding careful integration. The Netherlands is taking robust steps to also increase the availability of wind power.

Sectors

Built environment

Innovation programmes will be used to allow the building sector to develop concepts and products that will enable large-scale, rapid and cheaper sustainability improvements. Sustainable heating will be provided by means of heating networks, electrical heat pumps and the occasional use of green gas and **hydrogen**, provided the future supply of these latter two resources is assured.

Industry

The focus will be on cost reductions and the development of CO_2-reducing technologies through a combination of **innovation, demonstration and pilot projects**. In each of the five regional energy-intensive industry clusters, a multi-year frontrunner programme will be developed that combines efficiency improvements with more sustainable resource use and CO_2 reduction.

Mobility /Transportation

Efforts will concentrate on reducing car use by making alternative modes of transport more attractive. Another point for attention is to increase the **availability of emission-free energy sources**. As an example, the charging infrastructure for electric vehicles will be brought up to standard and legislation and subsidies will be deployed to increase the production of **hydrogen, sustainable advanced biofuels and renewable synthetic fuels**.

Cross-cutting topics	Findings in the LTS
Social acceptance and engagement	Societal challenges have been laid as one the three challenges: **Working on an attractive prospect for all concerned**
Enabling policies, regulatory measures and financing	In mobility (transportation), the charging infrastructure for electric vehicles will be brought up to standard and legislation and subsidies will be deployed to increase the production of hydrogen, sustainable advanced biofuels and renewable synthetic fuels. Several programmes and projects launched or planned for green transition.
Regional cooperation	Cooperation has been described as one the three challenges: **Stepping up cross-border cooperation**
International cooperation	While there are already many steps that can be taken nationally, the **international dimension of climate policy** will become ever more important as 2050 approaches. An ambitious long-term strategy must go hand in hand with international cooperation. An example is the formation of alliances regarding **green hydrogen**.

Portugal

Pathways	Findings in the LTS
Bioenergy	Bioenergy options with CCS are not considered cost-effective
Energy storage	Battery storage amounts to 3%-4% of total installed electricity generation capacity in early 2030s and 6% by 2050.
Energy systems integration	Not mentioned
Hydrogen	2%-4% of electricity generation is used in hydrogen by 2040. H_2 is projected to replace biofuels by 2050 in transport sector.
Solar energy	11% of industry heat demand is satisfied by solar thermal and 66%-75% of energy consumption in buildings for water heating is satisfied by solar by 2050.
Wind energy	Installed offshore wind capacity is expected to surpass 1 GW during 2040s.

Main findings

The LTS presents **three main scenarios** for GHG emissions up to 2050. For 'Roadmap for Carbon Neutrality 2050' (RNC2050), three scenarios were built:

- **Scenario Off-Track** retains the essentials of the economic structure and current trends as well as the decarbonisation policies already adopted or in force.
- **Scenario Peloton** involves socioeconomic developments compatible with carbon neutrality with the development and application of new technologies. These do not significantly change the production structures or the population's lifestyles. It foresees a modest incorporation of circular economy models and the maintenance of population concentration in the Metropolitan Areas.
- **Scenario Yellow Jersey** introduces a socioeconomic evolution compatible with carbon neutrality, characterised by a structural and transverse change in production chains. It foresees an effective incorporation of circular economy models and a greater importance of medium-sized cities.

The **most important points** include:

- Portugal is one of the countries that is most potentially affected by climate change. Accomplishing carbon neutrality in Portugal implies reducing greenhouse gas emissions by more than 85%, compared to 2005, and ensuring an agricultural and forestry carbon sequestration capacity of around 13 million tonnes.
- In line with the results of the IPCC Report on 1.5 ºC, the largest effort to reduce emissions will be placed by 2030.
- Portugal aims to produce 100% of electricity from renewables by 2050. The path towards carbon neutrality will involve significant use of endogenous renewable energy resources. Over two thirds will be come from **sun and wind**, accounting for over 80% of primary energy consumption by 2050.

BIOENERGY

In the light of current knowledge, the bioenergy options with CCS are not seen to be cost-effective for Portugal.

Transport

Decarbonisation of the transport sector will be almost total and will be based on strengthening the public transport system and replacing current fossil fuel vehicles with a mainly electric fleet. The use of hydrogen and advanced biofuels will also play an important role, especially in heavy long-distance intercity transport of passengers and freight by road. The challenges of a mostly battery-based and/or hydrogen-based mobility, include e.g. the need to greatly expand the battery charging network or to design and implement new networks, such as a network for hydrogen supply or of overhead electric contact lines on the main roads. For the shipping sector, the main solutions include energy efficiency measures, and also the use of LNG and biofuels for medium and long distances.

ENERGY STORAGE

Battery storage is foreseen to amount to 3%-4% of total installed electricity generation capacity in early 2030s and 6% by 2050. Batteries will become a cost-effective technology that is necessary for stability of the system as early as 2025 (187 MW), coupled with a renewable sun and wind capacity that will exceed 16 GW.

ENERGY SYSTEMS INTEGRATION

ESI is not directly mentioned in Portugal's LTS.

HYDROGEN

2%-4% of electricity generation is used in hydrogen by 2040. Hydrogen is projected to replace biofuels by 2050 in transport sector.

SOLAR ENERGY

Photovoltaic solar technology will be most clearly established by increasing its importance and reaching 13 GW centralised and 13 GW decentralised capacity by 2050. Along with wind energy, these two technologies have a cost-effective potential to jointly supply 50% of the electricity generated in 2030 and 70% in 2050. As these technologies pose challenges due to their variability, solutions are emerging, be they technological in terms of battery storage, and hydrogen production. or hybrid solutions, or in terms of network management, which should be endowed with greater intelligence and flexibility.

Industry

Solar thermal power for low temperature heat production in industry becomes competitive in early 2020s. 11% of industrial heat demand is satisfied by solar thermal by 2050.

Buildings

11%-12% of energy consumption in buildings is foreseen from solar energy and a significant share, 66%-75% of energy in buildings for water heating is expected from by solar energy by 2050.

WIND ENERGY

Onshore wind energy is increasing its share significantly, reaching projected 12-13 GW by 2050. Installed offshore wind capacity is expected to surpass 1GW during 2040s.

Cross-cutting topics	Findings in the LTS
Social acceptance and engagement	LTS recognises that as climate action has to be sustained over decades and its' support cannot be taken for granted, it is important that interest in and acceptance of these policies be continually promoted.

Enabling policies, regulatory measures and financing	Connection between RDI and the production system is vital for real-world prototypes, pilot projects and for knowledge transfer to production system and households. Revenues from emission auctions under the CELE regime (ETS) are allocated to the Environmental Fund, the main national instrument for financing climate action in both mitigation and adaptation dimensions. The use of CELE revenues for the purpose of combating climate change has been applied by Portugal since 2012 and should be maintained and reinforced. The National Investment Plan embodies decarbonisation of the economy as one of the structuring areas, should be highlighted for the next decade, with more than 66% of investment in areas contributing to these objectives. There are also other national funds to support decarbonisation of the economy and the energy transition in both the public and private sectors: • Innovation, Technology and Circular Economy Fund • Energy Efficiency Fund • Energy Sector Systemic Sustainability Fund • Innovation Support Fund • Blue Fund • National Building Rehabilitation Fund. A number of other financing instruments are available for a short-term horizon but which may be replicated if found effective in promoting decarbonisation: • Energy Efficiency Credit Facility • "Efficient House 2020" Program • Urban Rehabilitation and Revitalization 2020 Financial Instrument • Rehabilitate for Lease Program • Plan for the Promotion of Efficiency in Electricity Consumption.
Regional cooperation	Interconnections with the EU power grid and with other markets will also have an important role to play in the management and security of supply of the national power system.
International cooperation	Portugal supports increasing global ambition and climate action, strengthening international cooperation on climate action, in particular with the Portuguese-speaking countries; and continuing to defend Europe's leading position in combating climate change; participates in promoting and disseminating good climate action practices.

Slovakia

Pathways	Findings in the LTS
Bioenergy	Biomass is the most important RES in Slovakia, with the largest RE potential.
Energy storage	Not a focus area, only mentioned in connection to financing programmes.
Energy systems integration	New NEUTRAL scenario measure to promote the interconnection of electricity and gas sectors through Power-to-X technology and enable hydrogen blending to natural gas.
Hydrogen	Not a focus area, no plans for production.
Solar energy	Not a focus area. Once mentioned in an envisaged support scheme.
Wind energy	Onshore wind is an existing possibility.

Main findings

The LTS presents **three main scenarios** for GHG emissions up to 2050:

- **WEM** (with existing measures) as reference
- **WAM** (with additional measures)
- **NEUTRAL**, new measures to reach climate neutral 2050 target, were set after modelling exercises.

The LTS is based on **WEM scenario**, while climate neutrality target was introduced to LTS in late stage of preparation and all additional measures have not been modelled. Slovakia has a higher decarbonisation target than was modelled in the WAM scenario: to achieve climate neutrality by 2050.

- WAM includes a RES support scheme for electricity generation with envisaged RES technologies such as solar photovoltaics, onshore wind turbines, biogas/biomethane and biomass. The scenarios assume the support of 50 MW in 2021-2025, followed by support of an additional 500 MW based on auction

A high share of nuclear sources in electricity production and a high share of natural gas in the heat sector characterise Slovakian energy sector. Slovakia intends to increase the share of nuclear power.

Slovakia sees the decarbonisation of energy mainly to take place in the substitution of coal with low-emission sources, energy efficiency and modernisation measures as well as transport decarbonisation.

The high emission intensity of the Slovak economy suggests that the cost of economic adjustment for energy-intensive sectors is likely to be high, but the intensity may also indicate that the country has great potential for cost-effective emission reductions, if adequate and well-targeted policies and investments exist.

The **most important points** include:

BIOENERGY

Biomass has long been established as the most important RES in Slovakia, and the largest RE potential in the country. A slight growth in biomass use is expected during the ongoing decade, mainly for CHP and production of heat and cold.

Existing measures for biomass use include Optimization of district heating systems – shift from fossil fuels to biomass and natural gas and installation of combined heat and power (CHP) units in district heating systems. Industrial CHP plants which can also participate in district heating through secondary

use of industrial steam. Other measures include improving the efficiency of district heating systems (DHS), installing innovative district heating technologies, and improving heat supply from CHP units.

Transport

Measures are taken in the transport sector for fuel suppliers to increase the share of RES in fuels to 14% in 2030 and reach a share of advanced biofuels in fuels to 3.5% in 2030.

To reduce emissions from transportation, Slovakia intends to reduce road freight transport of over 300 km, transfer 30% of road freight to railway or waterway transport, and to fully electrify the railway network and make rail freight transport more attractive to carry goods. Slovakia also intends to support bicycling and pedestrian traffic.

ENERGY STORAGE

Slovakia promotes renewable energy sources and efficient district heating systems (DHS) in the areas of heat and cold supply, smart energy systems and energy storage.

Buildings

Increasing the energy efficiency, including centrally deep renovation of buildings and efficient district heating systems are the main measures of decarbonising building energy.

ENERGY SYSTEMS INTEGRATION

Promoting the interconnection of the electricity and gas sectors through Power-to-X technology and enabling an increase in the level of hydrogen blending to natural gas.

HYDROGEN

Hydrogen blending and use of hydrogen in urban public transport and innovative industrial applications are considered.

SOLAR ENERGY

Once mentioned in an envisaged support scheme

WIND ENERGY

Slovakia is a land-locked country. Onshore wind is an existing possibility.

Cross-cutting topics	Findings in the LTS
Social acceptance and engagement	Slovakia acknowledges that a poorly controlled and insufficiently regulated low-carbon transformation risks deteriorating economic and social rights, and consequently the exercise of civil and political rights. Adequate action to mitigate social impacts is also a prerequisite for social acceptance of the Low-Carbon Strategy in the Long-term.
Enabling policies, regulatory measures and financing	Slovakia intends to: • Create conditions and remove barriers to optimal use of energy sources without GHG and to support sources and projects that replace fossil fuels and ensure the reliability of electricity or heat production and supply. • Reduce legislative, technical, administrative and financial barriers to the implementation of these resources with an emphasis on the self-consumers sector. • Offer legislative and financial support from the EU and SR for electricity production from local sources by enabling electricity supply to the distribution system. Local generation aims at reducing electricity grid losses, GHG emissions, transmission capacity construction costs.

	• Biofuels in road transport since 2010. Speeding up second-generation biofuels from non-food crops. After 2020 operators obliged to specified minimum biofuel blending. • Public transport: enabling private carriers.
Regional cooperation	No discussion
International cooperation	No discussion

Spain

Pathways	Findings in the LTS
Bioenergy	The **Biomass roadmap** (Hoja de Ruta del Biogás), which is currently under development, will boost the use of this renewable gas to contribute to decarbonization.
Energy storage	The **Energy Storage Strategy** comprehensively analyses the storage needs for the transition of the energy system, taking into account an intersectoral perspective.
Energy systems integration	The Spanish LTS indicates that the transition towards a more decentralized electricity generation system based on non-manageable renewable technologies must be accompanied by the development of a more **flexible model**. The **digital transformation** is, along with the energy transition, one of the main challenges. The implementation of digital technology is having an impact on the economy as a whole and, in particular, on the energy sector, affecting and transforming the definition of the current market model.
Hydrogen	The **Hydrogen Roadmap** sets decarbonization targets for those sectors, such as the industrial sector, mobility or the decarbonization of the electricity and energy storage sectors.
Solar energy	The evolution of the percentage of renewable energies in the cold and heat sectors experiences a strong increase in the Climate Neutrality Scenario, reaching 97% in 2050. According to the LTS, this is mainly due to the contribution of heat pumps, as well as biomass, renewable hydrogen and **solar energy.**
Wind energy	The **Roadmap for the development of Offshore Wind and Marine Energies** in Spain is currently under development (Hoja de Ruta para el desarrollo de la Eólica Marina y las Energías del Mar en España)

BIOENERGY:

One of the main lines of work that is considered in the horizon of 2050 to achieve the reduction of emissions from the agricultural sector is the **production of biogas**. With regards to residues and residual waters, the implementation of technologies will be potentiated or that there will be an advanced phase in the actuality as the **composting**, 'la digestion anaerobia y la capture de biogas'.

The renewables gases (biogas, biomethane and hydrogen) play an important role in the transition and support to vulnerable communities and sectors, being a significant contributor to the creation of employment and promotion of economic development in all areas.

The **Biomass roadmap** (Hoja de Ruta del Biogás) will try to boost the use of this renewable gas to contribute to decarbonization.

Biomass roadmap (Hoja de Ruta del biogás) (Draft July 2021)

The following action lines are indicated in the roadmap to promote the investment action, within the framework of the promotion of renewable gases established as a measure 1.8 of the National Integrated Energy and Climate Plan 2021-2030 (PNIEC 2021-2030).

Regulatory instruments

Enhancement of the renewable origin of biogas

- Implement a system of Guarantees of Origin that allows verifying the amount of energy from renewable gases from a supplier's supply structure or from the energy supplied to consumers.

Administrative simplification and elimination of regulatory barriers

- Streamline plant authorization procedures.
- Cooperate for the homogenization of administrative procedures between the different Autonomous Communities.
- Prepare an authorization processing guide.

Regulatory actions within the framework of the circular economy

Sectorial instruments

Obligations of use

- Establish annual biogas / biomethane penetration targets in the sale or consumption of natural gas.
- Develop a calculator for the reduction of greenhouse gas emissions.
- Adapt the tool for accounting for the obligations of sale or consumption of biofuels for transportation purposes (SICBIOS) to include renewable gases.
- Implement the European Strategy for the Reduction of Methane Emissions.

Sectorial measures in Circular Economy.

- Promote the use of materials derived from biogas production.
- Encourage codigestion.
- Encourage cost-benefit analysis for the development of biogas projects in livestock farms.
- Analyse the convenience of setting a minimum quota for the use of fertilizer products of organic origin in agriculture.
- Promote the integration of anaerobic processes with existing or newly built aerobic treatment plants.

End uses of biogas and biomethane

- Promote biogas utilization systems in situ.
- Promote the use of biogas for cogeneration.
- Prioritize the use of biogas in transportation.
- Promote the biogas-fed heat networks (distributed generation).
- Make the direct uses of biogas compatible with the production of renewable hydrogen from it.
- Enable the option of connection to the gas network.

Economic instruments

- Allocate existing funding programmes to biogas development.
- Fiscally consider the positive effects of biogas on the environment.

Transversal instruments

- Support biogas projects in just transition zones.
- Promote the use of biogas by the Public Administrations and bring this fuel closer to the public
- Include the study of biogas technologies in educational plans in existing degrees that have a thematic relationship.
- Promote citizen involvement in the selective separation of bio-waste (organic fraction of waste)

- Promote the creation of local energy communities in the agricultural sector.
- Promote the development of knowledge of the personnel of the involved public administrations
- Create working groups with the biogas sector and waste and agricultural associations.

Establish a working group to develop and ensure compliance of this roadmap.

ENERGY STORAGE

According to the Spanish LTS, energy storage (daily, weekly and seasonal storage) is one of the technologies that should be introduced for a flexible and safe operation of the system. **Energy storage**, together with **demand management**, as well as **intelligent networks**, **will play a fundamental role** in the decarbonisation of the electricity system, and particularly in island territories and isolated regions.

With regards to the industrial sector, energy storage is one of the great opportunities, but at the same time a greater effort will have to be devoted to achieve a double objective: to achieve a technologically viable solution, but also to develop the national industrial and business fabric able to implement and leverage this solution on a large scale. In the case of renewable hydrogen, Spain has great potential to be one of the great leaders in deployment. These efforts are included in the Energy Storage Strategy.

Energy storage strategy (Estrategia de almacenamiento energético)

The action lines defined in the strategy include the following:

- Regulatory: Establish legal requirements for storage and the role of market players, as well as eliminate bureaucratic barriers and facilitate initiatives and projects.
- Market participation: Promotion of storage in the electricity system markets, as well as the promotion of dynamic energy prices and participation in capacity mechanisms
- Business model: Promotion of storage and its value chain at all levels, from the commercialization of energy to self-consumption, promoting the figures of the aggregator and the energy communities
- Sectorial integration: Boosting renewable hydrogen, the development of power to X and the potential of thermal storage
- Citizen engagement: Boosting energy communities to generate spaces for citizen participation, and training professionals to deepen the just transition
- R&I: Long-term R & D & I support through laboratories and pilot projects, taking advantage of international and national initiatives
- Sustainability: Promote the circular economy by supporting businesses that give waste a second life and improve its traceability
- Isolated systems: Take advantage of storage as a basis for technological development in islands and isolated areas, promoting R&i and job creation
- Governance: Measures designed to favour the participation of regional and local entities, to update and establish a monitoring system from the Administration
- Prospective analysis: Study and definition of three important aspects for energy storage: its needs, the evaluation of costs and benefits, and the storage life cycle

HYDROGEN

According to the LTS, hydrogen is **one of the main magnitudes of the strategy** and it will be necessary to develop decarbonized energy vectors, such as renewable hydrogen, in order to meet the needs of the industrial and transport sectors.

Industrial sector

There is significant potential for other sources of renewable energy to contribute more significantly to the decarbonisation of the industrial sector for medium and high temperature processes. Renewable hydrogen can be one of the main energy vectors with application for these processes.

Hydrogen and "power to X" can provide alternatives of interest to **industry and heavy transport** where electrification and the use of batteries appear to have difficulty delivering good returns at a reasonable cost. These energy vectors are also relevant for dealing with daily, weekly or seasonal **storage**.

In relation to hydrogen, it is necessary to develop the electrolysis process from renewable energy sources, especially taking advantage of those moments in which there is excess generation, more specifically when that excess generation forces part of the energy generated get lost (known as "spills").

Consequently, both **research and innovation are essential** throughout the hydrogen generation, storage and use chain.

In particular, clean hydrogen is a novel technology and requires greater coordination throughout the value chain. In this regard, the European Commission has launched several initiatives, announcing the launch of the new European Alliance for Clean Hydrogen, which will bring together investors with governmental, institutional and industrial partners.

In support of this Alliance, the European Commission has presented the Hydrogen Strategy of the European Union, which defines the hydrogen objectives for the next three decades. For its part, the Spanish Government approved the Hydrogen Roadmap on October 6, 2020: a commitment to Renewable Hydrogen, in line with the European strategy. Additionally, there is a specific line identified as a value chain on hydrogen systems within the IPCEIs (Important Projects of Common European Interest) calls.

Also important is the development of the rest of renewable fuels, which can be produced from biochemical processes or from synthesis using renewable hydrogen or other renewable gases.

Transport sector

Hydrogen is one of the technologies that are expected to play a more **relevant role** in decarbonising the transport sector in 2050. Hydrogen that can be used directly in fuel cells or as an intermediate element in Power to Gas technologies and also in industrial applications that currently consume non-renewable H2.

The hydrogen-fuelled fuel cell will possibly be the alternative provided by manufacturers for electric buses and other heavy electric vehicles with greater autonomy and occupancy needs.

In this scenario, the development of renewable gases will require an increase in production efficiency, via economies of scale in the case of renewable hydrogen, and a learning line in the case of Power to Gas. In this sense, for the period 2030-2050, an industrial scale will be needed for electrolysis and the manufacture of fuel cells that makes the use of these gases competitive in heavy transport. At the same time, the deployment of the supply infrastructure must be ensured, which, due to the investments it requires, must be accompanied by technological development.

The Hydrogen Roadmap

The Hydrogen Roadmap establishes decarbonisation objectives for sectors such as the industrial sector, mobility or the decarbonisation of the electricity and energy storage sectors.

For the definition of the strategy, the following economic sectors have been analysed in the roadmap: electricity generation, transportation, industry, building, agriculture, waste and fluorinated gases. Specifically, the modelling of the energy system with the TIMES-Sinergia system has generated projections for 2050 of GHG emissions, energy efficiency, renewable energy and external energy dependence compatible with the objectives set and that allow estimating the order of magnitude of the necessary transformations.

The following action lines are suggested in the roadmap aimed at **promoting investment** in the sector:

Regulatory instruments:

Administrative **simplification and elimination of regulatory barriers** to hydrogen production:

1. Modify the classification as an industrial activity of the production of renewable hydrogen in situ at service stations.
2. Analyse the different procedures for processing the operation and execution of small-scale green hydrogen production facilities and evaluate their simplification without undermining environmental protection and ensuring sustainability criteria.
3. Promote the development of regulatory measures that simplify and facilitate the deployment of direct electricity lines dedicated to the production of renewable hydrogen within the framework of the regulations of the electricity sector, as well as of hydroducts that transport renewable hydrogen within the framework of the regulations of the hydrocarbon sector.

Creation of a system of Guarantees of Origin (GdO5). In collaboration with the European institutions, establish a system of Guarantees of Origin for renewable hydrogen that allows the provision of appropriate price signals to consumers.

Promote the competitiveness of renewable hydrogen. Consider within the framework of green taxation and, specifically, in indirect taxes, the positive effects on the environment of renewable hydrogen. Likewise, taxation must encourage renewable hydrogen compared to hydrogen, whose origin does not have traceability.

Sectorial instruments

Monitoring of hydrogen production and consumption. Establish a national statistical system on the consumption and production of hydrogen in Spain, differentiating by types of hydrogen and by consumer sectors.

Promotion of the application of renewable hydrogen in industry:

- Evaluate the viability of establishing renewable hydrogen penetration targets for the 2025-2030 period, following the path set out in the European Hydrogen Strategy, in those sectors in which electrification is not the most efficient option nor is there a viable and sustainable alternative.
- Design financial instruments to support the Spanish intensive hydrogen consuming industry to adapt its processes and infrastructures to the continuous supply of renewable hydrogen.
- Develop long-term national decarbonisation strategies based on renewable hydrogen in those sectors that are most difficult to electrify. They will be based on specific dialogue with each sector.
- Identify the current hydrogen consumption poles, promoting and encouraging the creation of "hydrogen valleys or clusters". The constitution of Industrial Hydrogen Tables will be promoted together with autonomous communities, local administrations, hydrogen consumers and promoters of renewable hydrogen production projects, fostering the development of pilot projects.

Promotion of the application of renewable hydrogen in transport (specific measures in-ground, maritime and air transportation).

Integration of energy vectors

- Establish a legal basis for Power to X (P2X) power plants and electrolysis facilities.
- Clarify the operational framework so that the electrolysers participate in the adjustment services necessary to guarantee an adequate supply of the electricity sector and the legal bases for their participation.
- Make the use of green hydrogen in engines of generation and cogeneration plants more flexible, providing a greater guarantee of supply to the electrical system.
- Review the technical, regulatory and quality aspects of the gases necessary for the injection and use of hydrogen in the natural gas network, with special emphasis on the use of certain existing facilities for the transport and/or dedicated storage of renewable hydrogen.
- Simultaneously assess the need to modify devices that use gas in industry and in electricity generation to allow safe operation with higher concentrations of renewable hydrogen
- Carry out a prospective analysis of the needs to adapt gas equipment for domestic use (boilers, heaters, etc.) to allow the gradual integration of renewable hydrogen.
- Jointly assess the implications for natural gas vehicles derived from the use of an H2-enriched mixture (HGNC).
- Analyse the feasibility of producing renewable hydrogen from waste.

Transversal instruments

- Information campaigns and sectoral professional skills
- Potential for the production and consumption of renewable hydrogen in Spain and socio-economic impact
- Contribution to the just transition, the fight against the demographic challenge and the circular economy
- Updating and renewal of the roadmap as a continuous process
- Strengthening of Spain's position in the international hydrogen market

Support for research and innovation of technologies in the renewable hydrogen value chain

WIND

The Spanish LTS mentions the Roadmap for the development of Offshore Wind and Sea Energies in Spain (Hoja de Ruta para el desarrollo de la Eólica Marina y las Energías del Mar en España (draft)), which is in a draft version, includes the following action lines and measures:

Spain as a reference location for R&I in marine renewable technologies

- Development and reinforcement of test platforms.
- Framework ´plug & play´ for the substitution of experimental prototypes in platforms of marine renewable energy trials.
- Technological development programs.

Support and promotion of the value chain

- Assessment of port infrastructure for construction, assembly or export of components associated with marine renewable installations.
- Monitoring and accompaniment of the industry and national maritime value chain to the development of offshore wind and offshore energy projects.
- Public-private and private-private collaboration hub for renewable marine development.
- Strengthening of Spain's positioning in the international context.

- Training, education and professional qualification in the renewable marine sector.
- Contribution to the just Transition.
- Circular economy: promotion of eco-design and value chain around the end of life.
- Coordination with the sector for communication and awareness campaigns among the population.

Clear and predictable framework for the deployment of marine renewable generation

- Definition and approval in the POEM (maritime spatial planning plans) of zoning for the development of offshore wind farms.
- Coordination of the access and connection framework and new management models of electrical networks
- Framework for promoting investment in offshore wind and offshore energy.
- Adequacy of the administrative framework.
- Preparation and publication of geographic viewers with information related to the wind resource

Marine and Sea Energies in Spain and to the areas established in the POEMs.

- Environmental and biodiversity on renewable energy implementation in the marine environment.

Governance

Monitoring and evaluation of the achievement of the implemented measures and establishment of new actions