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THE REPUBLIC OF BULGARIA

Ministry of Environment and Water

BULGARIA’S LONG-TERM CLIMATE CHANGE MITIGATION STRATEGY BY 2050

Content

Table view

Figures

List of acronyms used:

NPP	Nuclear power station
GDP	Gross domestic product
RES	Renewable energies
EE	Energy efficiency
EEA	European economic area
EC	European commission
THE EU	European union
LULUCF	land use, land use change and forestry
IECP	Integrated Energy and Climate Plan of the Republic of Bulgaria
ME	Ministry of Energy
IPCC	Intergovernmental Panel on Climate Change
MOEW	Ministry of Environment and Water
ILO	International Labour Organisation
NG	Greenhouse gases
EU ETS	European Emissions Trading Scheme
WAM	Scenarios with complementary policies and measures
WEM	Scenarios with existing policies and measures
WAM +	Decarbonisation scenario

1. Review and strategy definition process

Bulgaria’s long-term climate change mitigation strategy to 2050 (Long-term Strategy) has been developed as part of a project to provide technical support financed by the European Union through the Structural Reform Support Programme 2020-2017 and is implemented by a consortium led by Deloitte in cooperation with the European Commission’s Structural Reform Support Service (SRSS).

The European Union (EU) sets itself high climate and energy targets for 2030 in line with the principles of the Paris Agreement on Climate Change. In relation to the post-2030 climate and energy development plans, the European Commission presented and adopted its strategic vision for a low-carbon Europe by 2050. This strategic vision outlines possible avenues for Member States to present their national long-term strategies.

The two EU climate targets of climate neutrality by 2050 and at least a 55 % reduction in Union greenhouse gas emissions by 2030 compared to 1990 levels, as well as the need for contributions from all sectors, were enshrined in Union legislation with the adoption on 5 May of the so-called European Climate Law Regulation, a framework act ensuring the involvement of all sectors in achieving the targets.

In this context, on 14 July 2021, the EC presented 15 pieces of legislation of the so-called “Fit for 55” package, presenting the Commission’s views on achieving the increased climate target of “at least 55 %”, setting the path to climate neutrality by 2050 and taking into account the need for contributions from all sectors.

Bulgaria’s climate targets are set out in Bulgaria’s Integrated Energy and Climate Plan for the period 2030-2021 (IECP) and are set out through the measures in the Recovery and Resilience Plan. The IECP aims to examine in depth possible barriers and solutions related to ambitious targets for improving energy efficiency, electricity sources and renewable energy (RES) by optimising the exchange of information and efforts at cross-industry and technical level.

The long-term strategy presents the Bulgarian position and priorities with regard to the low-carbon economy and the achievement of climate neutrality by 2050.

This document outlines the main conclusions of the assessment of Bulgaria’s potential based on energy and climate modelling, building on the IECP and including the post-2030 period.

Bulgaria’s long-term strategy sets out the different options for achieving the objectives.

Chapter 4 of the strategy presents the scenarios considered and the modelling assumptions used. Chapter 4 also contains key modelling results, a description of the reduction potential, primary and final energy consumption, final energy consumption by sector and electricity producers. Chapter 5 contains strategic measures to reduce greenhouse gas (GHG) emissions and renewable energy consumption by sector.

The results of the modelling are described in Chapter 6 and the assessment of the impacts of existing and planned policies and measures is included in Chapter 7. The macroeconomic, social and environmental impacts as well as the direct impacts of key sectors and sectors, such as the transport sector, waste management, agriculture and land use, land use change and forestry (LULUCF) are examined.

Chapter 8 of the Strategy should present the results of the stakeholder discussion on the Long Term Strategy *(to be developed)*.

The long-term strategy has been prepared in accordance with the requirements of Article 15 of Regulation

(EU) 2018/1999 of the European Parliament and of the Council of 18.06.2019 of 11 December 2018 on the Governance of the Energy Union and Climate Action, amending Regulations (EC) No 663/2009 and (EC) No 715/2009 of the European Parliament and of the Council, Directives 94/22/EC, 98/70/EC, 2009/31/EC, 2009/73/EC, 2010/31/EU, 2012/27/EU and 2013/30/EU of the European Parliament and of the Council, Council Directives 2009/119/EC and (EU) 2015/652 and repealing Regulation (EU) No 525/2013.

2. International and European framework

Introduction to the Paris Agreement and the need for action

The Paris Agreement1, adopted in 2015, sets out three general objectives, namely to limit the average increase in global temperature to well below 2 °C and to pursue efforts to limit the average increase in global temperature to 1.5 °C, recognising that this significantly reduces the risks and impacts of climate change; increasing the ability to adapt to the adverse impacts of climate change and promoting climate resilience and low-carbon development; reorienting financial flows to be compatible with sustainable and low-carbon development.

This agreement marks a new era of global mobilisation to tackle climate change and represents a paradigm shift in the implementation of the United Nations Framework Convention on Climate Change (UNFCCC), with the explicit recognition that only the contribution of all is possible to overcome the challenge of climate change.

Limiting the global average temperature increase to 1.5 °C, in line with the most ambitious goals of the Paris Agreement, requires an unprecedented transformation of modern societies and urgent and deep emission reductions across all sectors of activity, as well as behavioural changes and the involvement of all Parties.

A European framework

On 11 December 2019, the EC presented its Communication “A European Green Deal”, which sets out a vision for: achieving EU climate neutrality by 2050 and improving environmental protection while preserving competitiveness and making economic growth independent of resource use. The Communication is of a highly horizontal nature and concerns not only environmental and climate policies, but also the whole of socio-economic life, providing for the revision of a substantial part of European legislation.

On 12 December 2019, the European Council adopted an objective of achieving climate neutrality for the Union by 2050, underlining that “All relevant EU legislation and policies must be consistent with and contribute to the climate neutrality objective”. In light of the need to raise climate ambition, as also required by the Paris Agreement, EU leaders agreed on a binding EU target to achieve a net reduction in greenhouse gas emissions at Union level of at least 55 % by 2030 compared to 1990. The EU is raising its climate ambition in such a way that:

- spur sustainable economic growth
- create jobs
- deliver health and environmental benefits for EU citizens
- to contribute to the long-term global competitiveness of the economy of

1 https://unfccc.int/sites/default/files/english_paris_agreement.pdf

The EU by promoting innovation in green technologies

On5 March 2020, the Council of the European Union adopted a long-term low greenhouse gas emission development strategy of the EU and its Member States, reflecting this climate neutrality objective and submitted this to the UNFCCC Secretariat. The EU's long-term strategy, reflecting the climate-neutrality objective, is available on the UNFCCC website: https://unfccc.int/process/the-paris-agreement/long-term-strategies

The two climate targets, as well as the need for contributions from all sectors, were enshrined in Union legislation with the adoption on 5 May of the so-called European Climate Law Regulation, a framework act ensuring the involvement of all sectors in the achievement of the targets. The final text of the Regulation foresees an EU emissions reduction target of "at least 55 %" by 2030, a reduction in the role of sinks in achieving it, a climate neutrality of the Union by 2050 and negative emissions thereafter, setting indicative carbon budgets and an additional European scientific body.

An extraordinary meeting of the European Council took place on 24-25 May this year. Due to the traditionally divergent positions of Member States on how to achieve reductions and in particular maintaining GDP as the main criterion for burden-sharing, the President of the European Council preferred not to adopt substantive conclusions. Leaders only confirmed the December 2020 guidelines; invited the Commission to swiftly present its legislative package together with an in-depth analysis of the environmental, economic and social impacts at Member State level and stated that they would return to the topic, "at an appropriate time" after the proposals were submitted. This is a precedent, as so far the main elements for achieving the Union's climate objectives have been determined unanimously by the European Council. In practice, it was not the adoption of detailed guidelines by leaders on the architecture of the new framework that gave the EC considerable leeway in the preparation of draft legislative acts and left highly sensitive issues related to the so-called facilitative framework to be dealt with under the ordinary legislative procedure.

In this context, on 14 July 2021, the EC presented 15 pieces of legislation of the so-called "Fit for 55" package, presenting the Commission's views on achieving the increased climate target of "at least 55 %", setting the path to climate neutrality by 2050 and taking into account the need for contributions from all sectors.

National framework – mitigation and adaptation

In 2018, Bulgaria's greenhouse gas emissions amounted to 57 816 Gg CO_2, without taking into account the LULUCF sector. Compared to the 1988 base year, emissions decreased by 50.5 %. There is also a 6.3 % reduction in 2018 compared to the previous 2017 emissions. Net emissions together with LULUCF are 49 355 Gg$_{CO}$2-eq, with emissions reduced by 49.4 % compared to base year 1988.

The main reasons for the declining trend in greenhouse gas emissions in Bulgaria are the structural economic changes stemming from the radical transition from a centrally planned to a market economy. This leads to a decline in thermal power generation (and an increase in hydro and nuclear energy shares), structural changes in industry (including a fall in production in energy-intensive businesses and improvements in energy efficiency), the introduction of energy efficiency measures in the residential sector and a shift from solid and liquid fuels to natural gas in energy consumption. This has also led to a decrease in greenhouse gas emissions in the agricultural sector due to the decrease in livestock and sheep population and fertiliser use.

Bulgaria also shows a steady decline in the population over the period 1990-2018, which translates into a decline in the population of 22.1 %.2

National Strategy for Adaptation to Climate Change and Action Plan to 2030 of the Republic of Bulgaria

The National Strategy for Adaptation to Climate Change and the Action Plan of the Republic of Bulgaria provide a framework for action to adapt to climate change (ACA) and priority lines up to 2030, identifying and confirming the need for action for the MIC, both for the whole economy and at sectoral level. The sectors included are: Agriculture, Biodiversity and Ecosystems, Energy, Forests, Human Health, Transport, Tourism, Urban Environment and Water.

The basis for the development of the Adaptation Strategy and Action Plan is that Bulgaria is located in one of the regions that are particularly vulnerable to climate change (mainly through temperature increases and intense rainfall) and the increasing frequency of climate-change-related extreme events such as droughts and floods. Risks caused by climate change events can lead to loss of life or cause significant damage affecting economic growth and prosperity, both nationally and across borders. There is a consensus in the scientific community that climate change is likely to increase the frequency and magnitude of extreme weather events and the average annual air temperature in the country is expected to increase in the coming decades and change rainfall patterns.

All sectors of the economy are expected to be affected by the projected changes. These changes will further affect society and its citizens, as well as the economy as a whole. The effects of climate change do not affect all people and territories equally due to different levels of exposure, existing vulnerabilities and adaptive coping options. The risk is greater for the sectors of society and business, which are less prepared and more vulnerable.

For all sectors, there are significant uncertainties in the assessment of the nature and extent of vulnerability to climate change. However, when assessing climate risks and vulnerabilities in all sectors in the country, the overall theme is the potential impacts of both the increasing frequency of climate change-related extreme events and gradual changes in temperature and rainfall types on infrastructure, production, health and ecosystems, with related consequences for economic growth and livelihoods.

It needs to be understood that these risks and vulnerabilities also exist in terms of complex relationships and interdependencies between economic sectors. In particular, specific risks may lead to cascading effects across sectors. There is also a spatial dimension of these relationships, as the impacts and impacts of climate change affect different parts of the country in different ways. Understanding the spatial distribution of climate change risks is therefore important when developing appropriate and effective local adaptation strategies.

In general, awareness of climate change is increasingly improving in Bulgaria, but awareness of specific adaptation problems among both the public and other stakeholders remains more limited. There is a high level of general awareness at political level about the potential future impacts of climate change. However, there is considerable uncertainty as to how this can occur across sectors. Policy-making has so far mainly concerned the definition and implementation of mitigation measures, rather than adaptation.

The legal framework and policies for the ACR in Bulgaria must be understood in the context of its commitments related to international conventions and EU legislation. A number of key strategies and programmes provide the basis for climate change legislation at national level as a whole (in particular the

2Bulgaria’s Fourth Biennial Report to the United Nations Framework Convention on Climate Change.

Third National Climate Action Plan), but so far the emphasis has been on mitigation and there are no clear adaptation strategies developed at national or sectoral level in Bulgaria. The AIC institutional framework is an element of the overall institutional climate change framework enshrined in the Climate Change Mitigation Act (CSA).

The analyses of strengths, weaknesses, opportunities and threats and of political, economic, social and technological aspects (PEST) undertaken for the purposes of this strategy address the relevant issues in the Bulgarian context and provide a basis for defining the overall strategic objectives for the IQA for the country. Those headings read as follows:

- **Inclusion and integration of the ACA.** This includes improving adaptation policies and integrating adaptation considerations into existing national and sectoral plans and programmes.
- Institutional capacity**building for ACC.** This includes building expertise, training, knowledge base, monitoring and research to ensure and support adaptation actions.
- **Raising awareness of ACA.** This includes raising public education and awareness of AC-related issues and the need for adaptation actions to be implemented in Bulgaria in order to achieve public support and participation in adaptation policies and actions.
- **Building resilience to climate change.** This includes strengthening the management of infrastructure and material assets and protecting natural resources, covering water system infrastructure, energy supply infrastructure, as well as the protection and enhancement of ecosystem services (including those provided by forest resources).

A set of strategic objectives for each sector has also been developed to address their specific adaptation needs. They address the general aspects of the main strategic objectives mentioned above. A set of operational objectives and proposed adaptation activities linked to sector-specific strategic objectives have also been developed.

Monitoring and evaluation of the Action Plan is carried out, including the collection and analysis of data on the measures implemented. Reporting on national adaptation actions takes place every 2 years starting in 2021. Progress in the implementation of the measures will be assessed in a medium and one final official report to be prepared and submitted to the Council of Ministers in 2025 and 2031 respectively.

The implementation of short-term measures with the highest priority has been assessed in the initial report, which was developed in 2021. 3 The report reports progress towards increasing adaptive capacity and addressing barriers to adaptation in relation to the priorities set for improving knowledge management, education and communication on adaptation.

National recovery and resilience plan for Bulgaria

The**green transition** is one of the EU’s main ambitions to address the global challenge of limiting the adverse effects of climate change.

The green transition is at the forefront of the Bulgarian Recovery and Resilience Plan, concentrating 53,66 **%** of the total estimated expenditure, with a minimum of 37 % of the regulation

[3] https://www.moew.government.bg/bg/purvi-mejdinen-otchet-na-nacionalna-strategiya-za-adaptaciya-kum-izmenenie-na-klimata-i-plan-za-dejstvie/

in Directorate G. In doing so, Bulgaria contributes to meeting the EU-wide targets for progressive decarbonisation. The focus is on three main strands:

(A) enabling the accelerated deployment of renewable energy sources and hydrogen;

(B) enhanced action to increase the energy efficiency of the economy;

(B) sustainable mobility.

The share of energy from renewable sources in gross final energy consumption amounted to 21.6 % in 2019, with the country still performing better than the EU (18.9 % EU average in 2019), also significantly exceeding the national*Europe 2020*target (16 % for 2020). However, striving to achieve climate neutrality by 2050 implies significant additional efforts to increase the share of renewable energy in gross final energy consumption.

Parallel efforts to increase energy efficiency are equally necessary given the high levels of energy intensity of the economy, which exceed 3.5 times the energy cost per unit of GDP on average in the EU, as well as the extremely unfavourable energy performance of the building stock in the country with predominantly energy consumption classes E, F and G. The efforts to renovate the building stock will be essential to support economic recovery by creating jobs in the building sector, saving energy, healthier living conditions and reducing energy poverty.

The carbon intensity of the transport sector in the country is 3.5 times higher than the EU average, reaching 2.8 kg of greenhouse gases for EUR 1 in gross value added in 2019. The sector is one of the main emitters of greenhouse gases and accounts for 26 % of their total. Therefore, in the context of efforts to decarbonise the economy, there is a need to intensify investments in sustainable transport to reduce the sector's carbon footprint.

	OBJECTIVE
- Share of energy from renewable sources in gross final consumption of energy in 2024	
- Cumulative decrease to energy intensity to economy 2021-2024	
- Cumulative decrease to carbon intensity to economy 2021-2024	

The main objective of the Low Carbon Economy component is to reduce the carbon footprint and energy intensity of the economy and to facilitate the green transition by taking measures to increase the energy efficiency of residential, public and business buildings, as well as by promoting renewable energy production. The modernisation of the country's electricity grid planning, management and maintenance activities and the completion of the ongoing reform of the electricity market towards full liberalisation will be key. Research and pilot development of low carbon energy solutions at this stage in Bulgaria is another decarbonisation priority area for Bulgaria.

The planned reforms and/or investments in this part of the Recovery and Resilience Plan are:

- Establishment of a National Decarbonisation Fund;
- Facilitating and increasing the efficiency of investments in energy efficiency multi-apartment buildings;
- Developing a definition and criteria for "energy poverty" for households in the Act for energy for the purposes of market liberalisation and financing of energy efficiency projects;

- Energy efficiency in buildings;
- Programme for financing single renewable energy measures in single apartment buildings and multi-apartment buildings not connected to heat transmission and gas networks;
- Energy-efficient municipal outdoor artificial lighting systems;
- Financing mechanism for energy efficiency and renewable projects together with energy bills;
- Single Window;
- Stimulating electricity generation from RES and supporting the process of decarbonisation and reduction of administrative burden in the connection and operation of RES;
- Support for producers of energy from renewable sources. Development, facilitating and accelerating international trade in guarantees of origin;
- Digital transformation and evolution of information systems and systems electricity System Operator time in a low-carbon economy;
- Unleashing the potential of hydrogen technologies and the production and supply of hydrogen;
- Design, construction and commissioning of infrastructure for the transport of hydrogen and low carbon gaseous fuels for power stations and other consumers in coal regions in the Republic of Bulgaria;
- Support scheme for pilot projects for the production of green hydrogen and biogas;
- Liberalisation of the electricity market;
- Setting up an Energy Transition Commission to develop Climate Roadmap neutrality;
- Establishment of a state-owned enterprise "Coal Regions Conversion";
- Scheme to support the decarbonisation process by building highly efficient low carbon fuel power plants replacing coal capacity in coal regions;
- A scheme to support the construction of a minimum of 1.7 GW of RES and batteries;
- Exploration and development of a pilot project for cogeneration of heat and electricity from geothermal sources.

The indicative estimates of expenditure needed to implement the objectives of the component amount to a total of BGN 8 420.7 million, of which BGN 4 368.0 million to the Recovery and Resilience Facility and BGN 4 052.7 million to national co-financing.

3. Principles

The long-term strategy aims at achieving climate neutrality by 2050, but this depends on many uncertain development factors, in particular future technology costs, as the current ones are still commercially and industrially immature, and on the ability to achieve ambitious targets for improving energy efficiency, electricity sources and renewable energy (RES). Given these uncertainties, it is difficult to propose a single strategic plan with an optimised distribution of efforts between sectors and technologies.

The long-term strategy starts with the IECP without committing to a specific strategy to achieve the long-term objectives, and instead sets out the paths for the development of the energy system beyond 2030 in order to meet the significant emission reduction targets.

Thus, the starting point until 2030 becomes PECP, suggesting that fundamental changes should happen in the period 2030-2040.

4. Scenario analysis

Three different scenarios have been identified based on a large amount of data and plausible assumptions, possible trajectories and GHG emission reduction targets for action areas set out in the target definition:

- Scenario with existing policies and measures (WEM),
- Scenario with Additional Policies and Measures (WAM), ○ and WAM +.

The available (and acceptable) technological solutions in Bulgaria's national context are to avoid a single choice of technology so that the measures can be applied flexibly in line with technological progress and the structure of final energy consumption by sector after 2030.

The following elements have been identified as 'successful under all conditions' and are therefore included in all scenarios:

1. Improving energy efficiency in all sectors, with a focus on large-scale energy renovation of residential and public buildings, as well as industry, mainly through increased use of heating as well as improved choice of equipment;

2. Development of renewable energy in all sectors, with a focus on the electricity sector, including zero carbon dioxide emissions from solid fuel combustion;

3. Electrification of transport and heating with parallel reduction of the carbon footprint of electricity;

4. Development of domestic fuels from biomass and gas through advanced technologies.

A quantitative assessment of 'successful under all conditions' scenarios shows that even if they are fully financially and technically depleted, their potential will significantly reduce GHG emissions by 2050, but will not be sufficient to fully achieve the 2 °C or even 1.5 °C GHG reduction targets. Therefore, additional policies will be needed depending on the transformations and technologies that are not yet sufficiently advanced today. Analysing and comparing these alternatives is the main focus of the Long-term Strategy. The baseline policies are common to all scenarios.

Scenarios that envisage reaching the 2050 GHG reduction targets and represent long-term strategic scenarios fall into two categories depending on the size of the reduction target set: 2 °C or even 1.5 °C. Moreover, each category further includes different scenarios that are embedded in the main strategic priority for transformations and technologies that are complementary to the key policy priorities.

The following long-term strategic scenarios have been adapted to quantify possible scenarios for the Bulgarian long-term strategic scenarios:

- Improving energy efficiency and electricity for 2 °C and 1.5 °C/Electricity and Energy Efficiency Improvement for 2 °C and 1.5 °C (ElecEE);

- New energy carriers for 2 °C and 1.5 °C/New energy carriers for 2 °C and 1.5 °C (NC).

All long-term strategic scenarios must include technologies, transformations and policies that are innovative and disruptive conventional practices.

The main policies are common to all scenarios. The scenarios mimic the trajectory of what is needed to achieve the 2050 climate targets without the development and implementation of innovative policies and technologies in the period 2030-2050.

The ElecEE scenarios would not include end-use fuels with climate neutral impact (synthetic), but envisage savings and sources of electricity going beyond conventional practices (e.g. zero-energy buildings, circular economy, vehicle sharing, use of electricity in high temperature industrial processes, etc.).

Scenario options that meet the 1.5 °C objective must be designed to minimise greenhouse gas emissions in all sectors. Measures to this end should be designed to the greatest extent possible, including by using carbon capture and storage technologies, but only to a limited extent for sector-specific emissions. Conversely, the scenarios serving the 2 °C objective do not include carbon capture and storage technologies and remain a selective volume of greenhouse gas emissions in those areas wherefurther reductions are difficult or costly.

The mathematical model achieves economic and technical optimisation of the distribution of emission reductions by sector, depending on the assumptions for technologies and policies in each scenario.

4.1. Description of the (B) EST model

(B) EST is the English acronym of (Bulgarian) Energy System Tool, a tool for long-term evaluation and energy planning in Bulgaria. The (B) EST instrument was developed by E3Modelling and adapted to the needs of Bulgaria in a project under Contract No SRSS/SC2019/032 funded by the European Union through the Structural Reform Support Programme 2020-2017 and implemented by a consortium led by Deloitte in cooperation with the European Commission's Structural Reform Support Service (SRSS).

The instrument is designed as a one-off country-specific forecast model and focuses on energy system planning, investments in electricity generation, energy price forecasting (including the elimination of energy subsidies) and climate change mitigation policies including energy efficiency policies. The model includes energy-related CO_2 emissions, environmentally-oriented policy instruments and abatement technologies. The model is designed for medium- and long-term forecasts and produces analytical quantitative results in the form of detailed energy balances up to 2050. The model simulates:

- The consumption of energy by sector and by energy product, guided by the development of activity, income and energy prices,
- Energy production from energy carriers determined by energy consumption and prices,
- Energy prices as a result of a clear market equilibrium, and
- Investments in the consumption and production sectors dependent on costs, technological progress and the dynamic turnover of energy capital in different sectors.

4.2. Assumptions for 2 °C and 1.5 °C scenarios

EU Emissions Trading System (ETS) prices

EU ETS prices are based on those of the EU's long-term 'Clean Planet for All' strategy. The NECP scenario trajectory is in line with the current ETS Directive and the linear reduction factor of 2.2 %. The 2 °C and 1.5 °C scenarios have significantly higher price trajectories in the EU ETS, as these scenarios need to be consistent with achieving 80 % and above 90 % reduction in greenhouse gas emissions at EU level.

Transport

The following **CO_2 standards** have been applied to **passenger cars** under the different categories of scenarios. The scenarios implement standards for CO_2 **and for light and heavy-duty vehicles**, improving current regulations to increase the uptake of low- and zero-emission cars.

Table 1: Applied CO_2 standards for cars by scenario

	2015	2020	2025	2030	2035	2040	2045	2050
NECP	0.0	156.5	126.3	100.4	88.7	88.7	88.7	88.7
2 °C scenarios	0.0	156.5	126.3	100.4	73.0	46.7	28.7	21.8
1.5 °C scenarios	0.0	156.5	126.3	100.4	66.0	27.8	5.0	0.0[3]

In addition, the following measures have been implemented in the transport sector:

- Modal transition (mostly rail);
- Incentives for shared cars, leading to higher employment rates per car compared to the NECP scenario;
- Introduction of advanced advanced biofuels.

The incentives are currently the same in all scenarios, but this can be changed: e.g. ElecEE scenarios may have greater incentives, or NC scenarios may have smaller ones.

Exports of electricity

The NECP scenario maintained constant exports of around 8 TWh over the projection horizon. This assumption is justified by the continued generation of nuclear baseload capacity and the moderate increase in electricity consumption over the forecast horizon.

In decarbonisation scenarios, electricity consumption is rising due to increasing electrification in the consumption and transformation sectors in the new energy carrier (NC) scenarios. In decarbonisation scenarios (apart from NC_var scenarios), electricity exports decreased after 2035 and approached 0 in 2050 when nuclear capacity was fully decommissioned at the end of its life. Only the NC_var scenarios, in which nuclear energy continues in 2050, support exports of 8 TWh over the projection horizon.

Carbon capture and storage for the production of electricity

Currently, the scenarios include the capture and storage of CO_2 (CCS) for electricity generation in all decarbonisation scenarios to limit the increase in renewable energy. However, scenarios include both CCGT CCS and CCS for biomass (BECCS-Bioenergy with Carbon Capture and Storage) to take into account any negative emissions.

Process emissions

For all decarbonisation scenarios (i.e. all scenarios except the NECP and WEM scenarios) there is an option

[3] The model does not use a value of 0 to avoid computational and digital problems

to reduce process CO_2 emissions through Carbon Capture and Storage (CCS). While combustion emissions are reduced through fuel switching and energy efficiency, process emissions still remain. Currently, according to scientific literature, the following options for reducing process emissions are available:

- **Reduction of industrial activity**: this would happen in the context of a circular economy. *This option is currently not included in any strategy scenario.*
- **Use of hydrogen as a fuel/raw material**: innovative strategies using hydrogen instead of fossil fuels are being developed for some processes: e.g. direct reduction for iron production. They are still in the pre-prototype phase. *This option is currently not included in any strategy scenario.*
- **CCS/CCU: carbon**sequestration has a generic application and can be used for waste combustion gases or process processes. As carbon sequestration can be applied in a wide variety of industrial sectors, this is currently considered as one of the most promising technologies for reducing process emissions, even though it is currently not mature. A key driver for improving CCS is the carbon price in the EU ETS, as all industries with high levels of process emissions are part of the EU ETS. In the model, the option is available for iron and steel production, chemical as well as cement industry. The option will be available after 2035 and is used in all scenarios. The CCS option is activated based on economic optimisation.

Non-carbon emissions

The scenarios include the following approaches/options for non-carbon emissions:

- The approach used to reduce emissions is based on EPA MACCurve4, as also described in the PECP.
- The carbon price in the EETS applies to all sectors in the EETS.
- Non-EETS sectors shall be subject to reductions based on non-EETS values equivalent to the EETS carbon value after 2035.
- Like previous scenarios, any changes resulting from energy system factors apply automatically to non-carbon emissions.

The results show that a large part of the remaining emissions in the system come from the Agriculture sector.

More options

Change in factors relevant to agriculture driven by changed agricultural policies:

- Numbers of animals;
- Use of nitrogen fertilisers.

4.3. Improving energy efficiency and electricity for 2 °C and 1.5 °C/Electricity and Energy Efficiency Improvement for 2 °C and 1.5 °C (ElecEE)

These scenarios present the maximum energy efficiency and electrification options for energy end-users.

The scenarios shall have the following characteristics:

- ‘Maximum’ energy efficiency;
- ‘Maximum’ electrification for end-users;
- High development of renewable energy recovery;
- Excluding e-fuels in end-use sectors;

4 https://www.epa.gov/global-mitigation-non-co2-greenhouse-gases/global-non-co2-greenhouse-gas-emission-projections

- Small amounts of hydrogen for production storage purposes, mainly to balance the development of renewable energy;
- Circular economy as a form of efficiency (further recycling): reduction of core industrial activity;
- Modal changes in transport, shared cars;
- Bioenergy carriers where electrification is not possible as no liquid e-fuels are assumed in this scenario.

The underlying idea of these scenarios is that energy efficiency is maximised in consumption sectors and other consumption is electrified as far as possible. A challenge for these scenarios is the high need for investment in end-use sectors for energy efficiency, electrification, even for activities where biomass is currently not technologically developed and biofuels need to be developed to the extent necessary to secure sectors/consumption where electrification is not possible (e.g. aviation, maritime transport, etc.).

In order to increase energy efficiency, heat recovery in industry should be improved and other consumption sectors renewed. The factors that will improve energy efficiency are the following:

- Energy efficiency value: it is a modelling tool that simulates generalised energy efficiency incentives, mainly aimed at renovating buildings;
- Improved deployment of high-performance equipment leading to a wider spread of high-performance equipment, both in the domestic and industrial sectors;
- Improved levels of equipment development leading to a greater upgrade of high-performance equipment.

High levels of efficiency lead to significant improvements in energy efficiency.

4.4. New energy carriers (NC)

This scenario foresees the development of new energy carriers to be used for both storage and final consumption.

Scenario characteristics:

- 'Maximum' energy efficiency;
- 'High' electrification for final consumption;
- Very high development of renewable energy;
- E-fuels in end-use sectors: blending hydrogen and e-CH_4 into gas pipelines, liquid e-fuels for transport;
- Hydrogen for storage in production, mainly to balance the development of renewable energy;
- Bioenergy carriers.

While energy efficiency and electrification needs are more moderate in this scenario, the use of e-fuels requires further significantly higher use of electricity. This will place a significant burden on electricity production and will therefore require very large amounts of renewable energy.

This scenario foresees the deployment of hydrogen in the gas grid up to 10.8 % of the energy ratio in 2050 in 2 °C scenarios and up to 17.9 % in 1.5 °C scenarios. The latter would require a (partial) upgrade of the gas network to accept these high shares.[5]

E-methane blending is considered to be 44 % in the 2 °C and 62.5 % scenarios in the 1.5 °C scenarios: leaving only limited fossil gas in the grid.

4.5. Optional option: New energy carriers, nuclear energy and CO_2capture and storage/New energy carriers, nuclear and CCS (NC_var)

Options for new energy carriers require a significant amount of electricity generation: in this scenario, the decommissioning of Units 5 and 6 of the Kozloduy Nuclear Power Plant is not foreseen in 2047 and 2049 and their lifetime is extended beyond 2050.

This life extension in the current version is done at no extra cost; this needs to be taken into account when comparing the scenarios.

4.6. Summary of scenario options

The[5] proportion of hydrogen blending in the gas network depends on the state of the network.

Table 2: View scenario options

	NECP	ElecEE2C	ElecEE1.5C	NC2C	NC1.5C
Additional energy efficiency policies	NO	Very High	Extremely high	High	High
Electrification of final consumption (static and mobile)	NO	Very High	Extremely high	High	High
Bioenergy carriers	NO	Very High	Extremely high	High	High
New climate-neutral energy carriers	NO	NO	NO	High	Very High

All long-term strategic scenarios (i.e. ElecEE2C, ElecEE1.5C, NC2C, NC1.5C) include technologies, transformations and policies that are innovative in nature and correspond to a change in conventional practices.

4.7. Opportunities for decarbonisation by sector

Table 3: Overview of scenario selection

Select Scenario	Description/Explanations	ElecEE	NC	NC_var
(additional) nuclear energy	Beyond the 2 000 MW investment accepted in NECP (NECP)	No	No	Yes
Capture and Storage of CO2 (CCS) for electricity production				
Lignite	*Do we allow investments in lignite with CCS? (in NECP we have an investment block for new investments in lignite)*	*No*	*No*	*No*
Gas	*Do we apply CCS to gas plants?*	*Yes*	*Yes*	*Yes*
CCS for process emissions	There are very few possibilities to reduce process emissions. Options include: • CCS • Clinker imports • Circular measures economy that is declining	Yes	Yes	Yes

	primary production			
Chemicals		*Yes*	*Yes*	*Yes*
Cement		*Yes*	*Yes*	*Yes*
BECCS (CCS for biomass)	CCS in biomass allows negative emissions in the energy system	Yes	Yes	Yes
(additional) RES	It is essential to have additional RES in the system, in particular given the limitations of other options	Yes	Yes	Yes
Transport				
CO2 standards for light-duty vehicles (LDV)	*As in the European Commission's LTS scenarios*	*Yes*	*Yes*	*Yes*
Performance Standards for Heavy Duty Vehicles (HDV)	*As in the European Commission's LTS scenarios*	*Yes*	*Yes*	*Yes*
Electrification of urban transport	*Low carbon zones in urban areas*	*Yes*	*Yes*	*Yes*
Car sharing	*Higher occupancy rates of passenger cars*	*Yes*	*Yes*	*Yes*
Improved infrastructure availability (refuelling)	*E.g. Reducing the range of anxiety*	*Yes*	*Yes*	*Yes*
Increased availability of different EVs (and PHEVs) and the services needed for these technologies	*More models and availability of maintenance services*	*Yes*	*Yes*	*Yes*
Learning through work	*Lower investment costs in vehicles with new technologies (clean electric, hybrid plug, hydrogen)*	*Yes*	*Yes*	*Yes*
Modal change	*Modal shift to track-based transport for both passengers and freight:* • *low carbon areas* • *taxation of issuing vehicles?* • *higher supposedly*	*Yes*	*Less intensive*	*Less intensive*

	comfort of public transport			
Advanced biofuels	*Mainly for blending in road transport (HDV) and long-distance transport, as well as in aviation*	*Yes*	*Less intensive*	*Less intensive*
E-fuels				
E-liquid fuels	*For which sectors?*	*No*	*Road freight transport other difficult to electrify sectors*	*Road freight transport other difficult to electrify sectors*
E-gas	*For blending with pipeline gas?*		*Yes*	*Yes*
H_2	*In which sectors? What purpose should hydrogen be used for*	*For the storage and balancing of electricity*	*To store and balance electricity For the industry Housing and tertiary sector (not very effective in our conditions)*	*To store and balance electricity For the industry Housing and tertiary sector (not very effective in our conditions)*
Consumption sectors (industry, households and tertiary)				
Increased availability of new technologies and necessary services	*More models and availability of maintenance services*	*Yes*	*Yes*	*Yes*
Conditions for activation	*Positive market assumptions and active participation in advanced technology consumption*	*Yes*	*Yes*	*Yes*
Energy efficiency	*Increase the value of efficiency*	*Yes*	*Less intensive*	*Yes*
Renewables	*Increased renewable value*	*Yes*	*Less intensive*	*Yes*

4.8. Key results

A. Reduction of emissions

The scenarios achieve between almost 80 % GHG emission reductions for the 2^0C scenarios and between 83 % and 84 % for the 1.5 °C scenarios compared to 1990 levels.

Table 4: Change in greenhouse gas emissions as a percentage from 2005 levels in the chosen scenarios

	2015	2020	2025	2030	2035	2040	2045	2050
NECP2019v2 Scenario	— 42.64	— 43.56	— 43.95	— 49.00	— 57.56	— 66.03	— 66.73	— 64.01
NC2Cb Scenario	— 42.64	— 43.53	— 43.78	— 49.33	— 68.63	— 74.14	— 78.65	— 78.33
EE2Cb Scenario	— 42.64	— 43.69	— 43.90	— 49.09	— 69.49	— 75.90	— 79.58	— 79.38
NC_var2Cb Scenario	— 42.64	— 43.58	— 43.78	— 49.28	— 69.03	— 73.44	— 78.18	— 78.65
NC1p5Cb Scenario	— 42.63	— 43.61	— 43.94	— 49.37	— 74.51	— 80.28	— 83.66	— 83.65
EE1p5Cb Scenario	— 42.64	— 43.60	— 43.83	— 49.09	— 71.77	— 80.89	— 84.35	— 84.11
NC_var1p5Cb Scenario	— 42.63	— 43.63	— 44.00	— 49.37	— 75.39	— 80.17	— 83.47	— 83.75

In terms of CO2 emissionsfrom energy, the scenarios achieve between 82 % and 84 % reductions for the 2 °C scenarios and just over 94 % for the 1.5 °C scenarios compared to 2005 levels.

Table 5: Change in CO2 emissionsfrom energy combustion as a percentage from 2005 levels

	2015	2020	2025	2030	2035	2040	2045	2050
NECP2019v2 Scenario	— 9.26	— 10.40	— 13.06	— 25.70	— 45.12	— 64.38	— 67.31	— 62.79
NC2Cb Scenario	— 9.26	— 10.35	— 12.71	— 26.41	— 62.49	— 75.38	— 87.47	— 89.19
EE2Cb Scenario	— 9.26	— 10.69	— 12.97	— 25.89	— 64.07	— 78.88	— 88.89	— 90.69
NC_var2Cb Scenario	— 9.26	— 10.46	— 12.69	— 26.30	— 63.35	— 73.96	— 86.74	— 89.36
NC1p5Cb Scenario	— 9.24	— 10.51	— 13.04	— 26.50	— 69.28	— 82.67	— 92.37	— 94.22
EE1p5Cb Scenario	— 9.26	— 10.50	— 12.80	— 25.89	— 68.63	— 83.14	— 92.47	— 94.57
NC_var1p5Cb Scenario	— 9.24	— 10.57	— 13.18	— 26.50	— 71.23	— 82.43	— 91.94	— 94.44

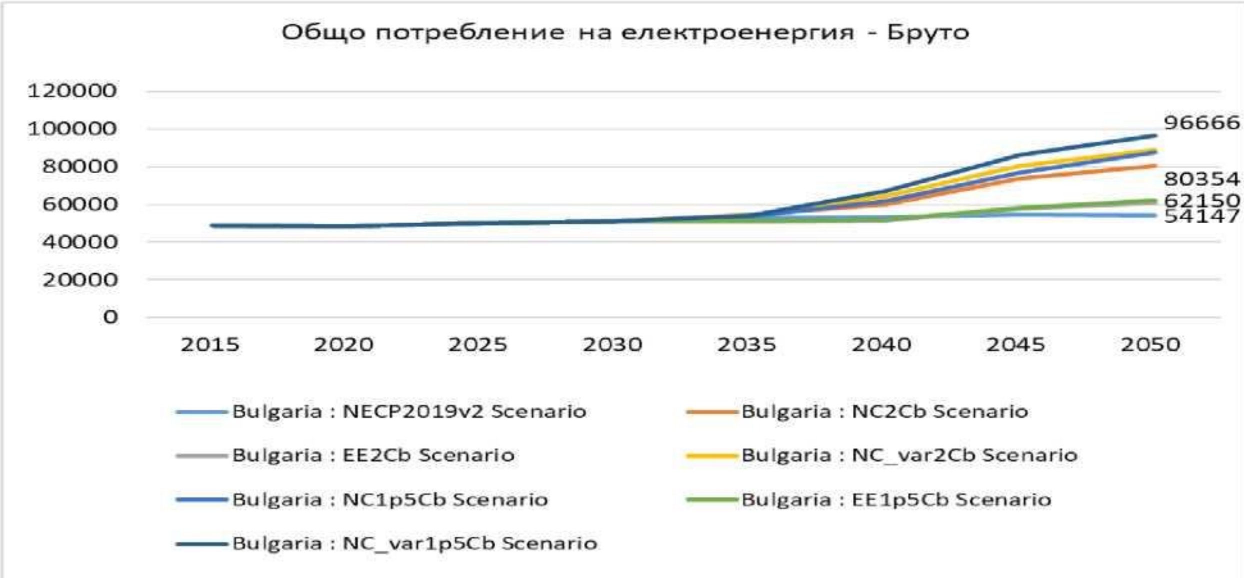
B. Gross and final consumption of electricity

The scenarios show two levels of gross electricity consumption.

The high energy efficiency and electrification scenarios show the least increase in electricity consumption compared to the NECP scenario, as although end-use sectors are largely electrified, electrical equipment is efficient and the scenario is characterised by high energy efficiency limiting the increase in total electricity consumption.

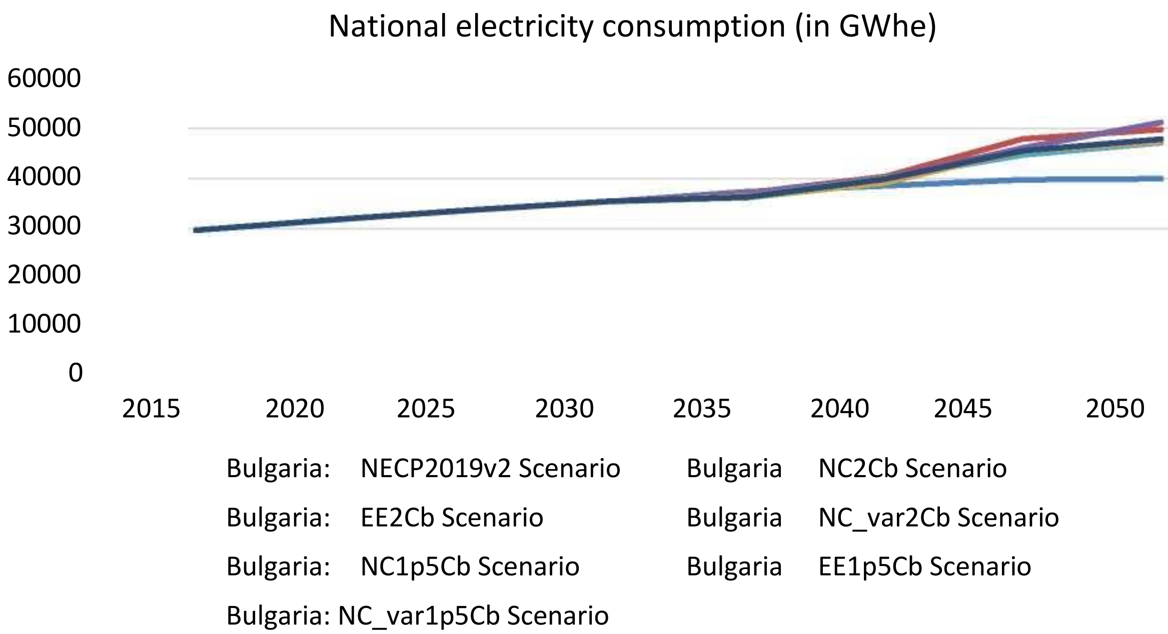
Gross final electricity consumption increases significantly in the new energy carrier (NC) scenarios, as they require large amounts of electricity for the production of e-fuels (liquid and gaseous).

Figure 1: Total gross electricity consumption in Bulgaria under the selected scenarios



Instead, final energy consumption levels are at similar levels in the scenarios, as electrification drive in ElecEE scenarios is counterbalanced by high energy efficiency, while in NC scenarios demand reduction is constrained by the 'missing' energy efficiency.

Figure 2: Domestic electricity consumption in Bulgaria under the selected scenarios



C. Final energy consumption by sector

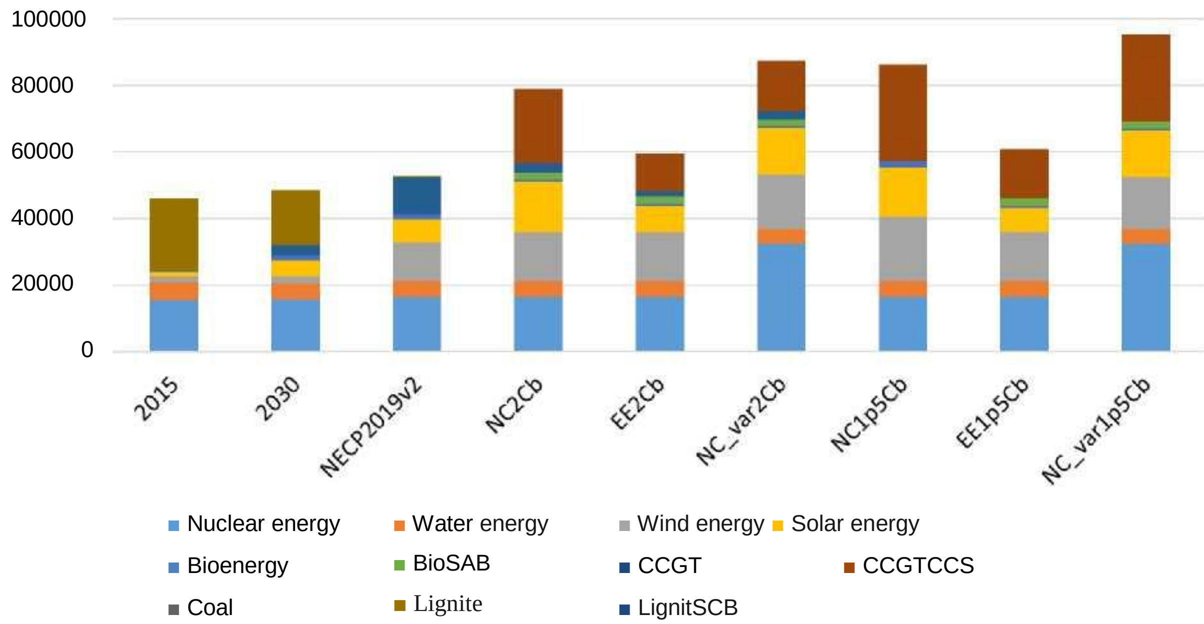
Final energy consumption is apparently lowest in ElecEE scenarios. In the 1.5 °C scenario, the consumption in the current scenarios is similar in different scenarios, due to the high levels of efficiency required in case of 1.5 °C. All decarbonisation scenarios, although the economic activity is the same, show a decrease in energy consumption compared to 2015 levels, while providing for a higher standard of living.

Production of energy

The electricity sector envisages a significant development of renewable energy (mainly wind energy), as well as the development of CCS for electricity production in all scenarios, both for biomass combustion and for gas plants.

Nuclear energy production is based only on exogenous investments provided by the Bulgarian authorities.

Figure 3: Gross electricity production by type of installation (in GWhe)



S. Measures to reduce greenhouse gas emissions

A set of measures has been developed for all climate-related areas within the scenarios set out in Chapter 4. Strategic measures will focus on emissions from energy use, buildings and transport, taking into account the possibility of industrial $CO2_{recycling}$ (carbon sequestration and re-utilisation, CCU). In addition, reduction options will be considered in the framework of maintaining and improving carbon sequestration through natural carbon sinks – forests.

A. Decarbonisation – Greenhouse gas emissions

The current linear economic model implies the exploitation of resources (extraction of fossil fuels, raw materials, soil and water) that are further transformed, used and returned to the environment as waste or emissions to the atmosphere are not considered sustainable. In this regard, Bulgaria, through its policies and measures, promotes the transition to a circular, competitive and sustainable economy in order to achieve a carbon-neutral environment.

In this context, existing and planned measures in the energy sector as well as in non-energy sectors will make a major contribution to decarbonisation. Existing and planned measures until 2030 will be extended until 2050 and will support measures supporting the transformation of the RES sector and other dimensions of the Energy Union, in particular energy efficiency, the internal market and energy security. To improve air quality, the use of green and more efficient technologies complementing the use of alternative fuels for domestic heating and transport other than solid fuels will be promoted.

Overall, the main enablers of decarbonisation are related to renewable resources, energy efficiency, electrification of transport and the development and deployment of new energy carriers (e.g. hydrogen).

<u>Transport sector</u>

The main measures aimed at reducing air pollution and greenhouse gas emissions in the transport sector are mainly linked to the development of electric mobility through the following measures and policies:

- promoting the production of electric and other environmentally friendly vehicles;
- construction of infrastructure for green vehicles;
- increasing the use/demand of new green vehicles;

- accelerating the deployment of charging infrastructure for electric and hybrid vehicles;
- promoting research and development in the field of green vehicles and road systems;
- increasing the share of biofuels;
- promoting the phasing-out of outdated private cars and their replacement by electric vehicles;
- reducing fuel consumption and increased energy efficiency in transport;
- promoting sustainable urban mobility by increasing the share of public electric transport or the deployment of intelligent transport systems;
- introduction of low emission zones;
- develop a strategy for the purchase of rolling stock (locomotives, freight wagons and passenger coaches) and align existing ones with interoperability requirements integrating the specificities of the rail system;
- rationalisation of the rail network;
- organise awareness-raising campaigns and capacity building of stakeholders to develop sustainable mobility.

Residential sector

In order to exploit the sector's high emission reduction potential, Bulgaria has developed numerous policies and measures:

- phasing out the use of solid fuel heaters;
- expansion of the central heating network;
- transition from traditional combustion stoves to natural gas-fired heating systems and district heating;
- installation of solar collectors;
- household gasification through natural gas network development;
- implementation of energy efficiency measures for buildings, including renovation of public and government buildings;
- deployment of regional district heating powered by biomass or geothermal energy;
- refurbishment of cogeneration and central heating boilers with natural gas turbines;
- increasing energy efficiency as a result of the replacement of solid fuel heating appliances.

Industrial sector

The industrial sector consists of a wide range of activities and processes, such as refining, cement, ceramics, glass, iron and steel, chemicals, etc. Emissions are mainly due to the consumption of fossil fuels by the internal processes involved.

Measures in the industrial sector therefore aim to:

- higher energy efficiency in industry and reduction of heat losses;
- increasing high-efficiency cogeneration;
- development and deployment of carbon capture and storage technologies for production emissions;
- increasing the use of natural gas in industry through new gas
  - infrastructural followed by electrification of the sector (based on the growing share of RES-E);
- use of alternative fuels;
- development of technology parks – introducing incentives to encourage the private sector to invest in R & D and innovation of widely used production methods aimed at optimal resource efficiency;
- promoting the exchange of good practices between companies with regard to the efficient use of raw materials in production;
- systems for monitoring electricity consumption in industry;
- replacement of obsolete and inefficient power generation equipment with new ones;
- energy efficiency audit and implementation of prescribed measures.

Agriculture sector

Based on the analysis of the main emission sources in the agricultural sector, the following main objectives have been identified:

- reducing and/or optimising emissions in the agricultural sector;

- raising awareness of both farmers and administrations about the impact of their actions on climate change.

In order to achieve the above-mentioned objectives, the following priorities have been identified:

- reducing emissions from agricultural land;
- reduction of methane emissions from organic fermentation in livestock farming;
- improving manure management;
- optimising the use of plant residues in agriculture;
- improving the management of rice fields and rice production technologies;
- improving farmers' and administration's knowledge on reducing emissions from the agricultural sector.

Waste management sector

The main targets in the waste management sector foresee a significant increase in the share of waste for treatment and recycling over the years and use Bulgaria's significant potential to improve waste management and prevent waste generation.

Therefore, several measures identified to achieve the 2030 targets will be further developed and implemented by 2050:

- extending and extending the scope of separate collection of green waste in municipalities;
- biogas capture and combustion in all new and existing regional landfills;
- biogas capture in old municipal landfills scheduled for closure;
- development of anaerobic sludge stabilisation through biogas capture and combustion in new plants and plants subject to reconstruction;
- construction, extension and/or upgrading of separate waste collection systems;
- improving the knowledge base on the circular economy, waste monitoring and material flows to promote the transition to a circular economy;
- development of municipal facilities for the recovery of biodegradable waste with a capacity to generate energy and produce compost;
- raising awareness of sustainable consumption practices and behaviour, as well as information and awareness campaigns for stakeholders and the population.

Land Use, Land Use Change and Forestry (LULUCF) sector

LULUCF measures and activities aim to have both direct and indirect positive effects both on the adaptation of forest ecosystems to climate change and on the reduction of the negative effects of climate change, including increasing the absorption of greenhouse gases from the atmosphere. In this respect, the current operational measures and policies are expected to be implemented by 2050, aiming at:

- increasing forest areas, timber and carbon stocks in forest areas;
- improving forest management and use;
- improving the effectiveness of prevention and control of forest fires and illegal forest activities;
- increasing the resilience and adaptability of forest ecosystems to climate change;
- increasing the absorption of greenhouse gases and protecting water sources by reducing long-term deforested land and increasing forested areas.

8. Decarbonisation – Renewable energy and Energy Efficiency

Part of the response to the challenge of climate change lies in the use of renewable energy, greater efficiency and circularity in the use of resources. Renewable energy already has the potential to replace a significant part of fossil fuels and thus eliminate GHG emissions and other pollution associated with their operation and use.

In order to achieve the agreed 2050 targets for renewable energy, both existing and additional policy measures for 2030 will be developed and extended until 2050.

By 2050, the development of the electricity sector will take into account the high degree of integration of renewable energy generated in the energy market, decentralised electricity production and the provision of renewable energy to consumers at the lowest possible price. As regards the share of renewable energy in the heating and cooling sector, priority will be given to the commissioning of high-efficiency heating and cooling systems, the deployment of innovative geothermal, hydrothermal and solar technologies and the use of waste heat and cold.

RES-E

In order to achieve a carbon-neutral society, Bulgaria has developed several measures and policies that aim to phase out the use of fossil fuels in electricity generation, in particular coal, and to promote the production of energy from renewable sources. This transition is facilitated by the reduction in the cost of renewable electricity generation technologies, which has already been observed in recent years, coupled with a reduction in the cost of storage solutions that will facilitate the phase-out of coal by 2050. Therefore, the main drivers of decarbonisation within the electricity generation sector are related to further deployment of renewable energy and phase-out of fossil fuels, development and deployment of storage solutions and smart grids and grid flexibility to facilitate RES integration. Additional RES-E measures and policies are described below:

- Supporting the integration of electricity from renewable sources into the transmission and distribution network, through the development of smart grids and the use of energy storage systems;
- development of energy storage capacity to facilitate the integration of renewable energy sources;
- developing a favourable market to support the development and integration of the production of energy from renewable sources;
- promoting the production and use of energy from biomass (sustainable production of biomass as a renewable energy source);
- enabling self-consumption of energy from renewable sources and energy communities;
- development and production of hydrogen from renewable sources.

RES-T

The transport sector, together with the electricity sector, is one of the main pollutants at national level. In addition, the sector has experienced a large increase in emissions in recent years due to increasing transport activity. This sector includes road, rail, waterborne and air transport and can be divided into passenger and freight transport.

The main enablers of decarbonisation in the sector are electrification, the development of biofuels and hydrogen, improved efficiency of public transport and a higher share of low-emission vehicles.

Therefore, the main measures through which Bulgaria seeks to improve energy efficiency and the use of renewable energy in the transport sector are the following:

- increasing the share of public electric transport;

- increasing the share of electric and hybrid vehicles and charging infrastructure in urban areas;
- development and promotion of cycling;
- the introduction of electric mobility in transport, through the construction of road transport infrastructure and the introduction of new technologies in rail transport;
- promoting the use of advanced biofuels, renewable liquid and gaseous fuels of non-biological origin and recycled carbon fuels;
- construction and improvement of railway infrastructure;
- development and deployment of second generation biofuels.

RES – Heating and cooling

Heating and cooling are another important sector where energy is consumed to provide energy services such as space heating and cooling, lighting, storage, water heating, etc.

The promotion of the use of renewable energy in buildings will continue throughout the period analysed. The development of renewable energy will take into account technical feasibility and economic viability. The main decarbonisation drivers in the heating and cooling sector are energy efficiency, the use of solar and geothermal energy and the development and deployment of heat pumps. In this regard, in order to promote renewable energy in the heating and cooling sector, measures such as:

- the introduction of solar thermal installations;
- renovation and thermal insulation of buildings;
- district heating powered by biomass or geothermal energy;
- supporting and implementing projects for the construction of small decentralised heating and/or cooling systems;
- development of heat pumps and geothermal systems close to the surface.

6. The potential to achieve climate neutrality by 2050 of Bulgaria based on the results of energy and climate modelling

This chapter presents Bulgaria's energy and climate potential based on results from long-term strategic modelling. The scenarios are developed in line with the provisions of the Paris Agreement, which aims to limit the average global temperature increase to well below 2 °C and pursue efforts to limit the average global temperature increase to 1.5 °C. Long-term strategic scenarios can be considered in two categories depending on the size of the emission reduction target: 2 °C or even 1.5 °C. Furthermore, each category includes different scenarios that are set out for the strategy's main priority in terms of transformations and technologies, which are complementary to the key policy priorities. Therefore, the long-term strategic scenarios have been adapted to quantify Bulgaria's possible long-term strategic scenarios:

- Improving energy efficiency and electricity for 2 °C and 1.5 °C (ElecEE) – these scenarios explore the maximum possibilities for energy efficiency and electrification of final energy consumption;
- New energy carriers for 2 °C and 1.5 °C (NC) – these scenarios envisage the development of new energy carriers to be used for both storage and end-use purposes.

The main policies are common to all scenarios. The scenarios simulate trajectories to achieve the 2050 climate targets without developing innovative policies and technologies in the period 2030-2050.

Scenarios to improve energy efficiency and electricity quality for 2 °C and 1.5 °C do not envisage the creation of climate neutral (synthetic) fuels for end-use, but envisage savings and electricity beyond conventional practices (e.g. grouping of nearly zero-energy buildings, circular economy, vehicle sharing, use of high-temperature electricity in industry, etc.).

Scenario options that lead to the 1.5 °C objective must be designed to minimise greenhouse gas emissions in all sectors. Measures shall be developed to the maximum extent possible, including the use of carbon capture, storage and reutilisation (CCUS) technologies, but only to a limited extent for sector-specific emissions. On the other hand, scenarios serving the 2 °C objective do not include CCUS technologies.

In addition, two additional scenarios have been developed for new energy carriers (for 1.5 °C and for 2 °C) (NC_var), which require a significant amount of electricity production: in this scenario, the planned decommissioning of Units 5 and 6 of the Kozloduy Nuclear Power Plant planned for 2047 and 2049 is not happening and their lifetime is extended beyond 2050.

A. Decarbonisation – greenhouse gas emissions

In line with the objective of achieving EU neutrality by 2050 in an effective and fair manner, Bulgaria has identified the policies and measures necessary to achieve the objective. Nevertheless, the transition to a carbon-neutral economy (net emissions equal to zero) requires long-term planning and strategy, which must take into account both the opportunities and risks associated with the respective transformation of the economic environment.

In this respect, this chapter provides an insight into key future trends in GHG and renewable energy emissions involving all sectors of the economy (electricity generation, industry, transport and domestic needs) in order to achieve the objective of carbon neutrality by 2050.

In addition, this chapter presents the results of the modelling for each of the six scenarios. Nevertheless, as previously presented, all scenarios contain common core policies and have as their starting point the PECP covering the period 2021-2030.

The identification of greenhouse gas emission trajectories for carbon neutrality is supported by modelling covering all sectors of the economy with a significant contribution to total national emissions and all greenhouse gases.

In terms of total greenhouse gas emissions, the scenarios achieve between almost 80 % greenhouse gas emission reductions for the 2 °C scenarios and between 83 % and 85 % for the 1.5 °C scenarios compared to 1990 levels. The measures leading to an increase in the share of renewable energy in energy production and the share of renewable energy in transport, the renovation and insulation of public and private buildings, as well as the changes envisaged for the internal energy market and the decommissioning of certain plants, contribute significantly to the reduction of greenhouse gas emissions.

Table 6: Change in greenhouse gas emissions as a percentage from 2005 levels under the chosen scenarios

	2015	2020	2025	2030	2035	2040	2045	2050
NECP2019v2 Scenario	— 42.64	— 43.56	— 43.95	— 49.00	— 57.56	— 66.03	— 66.73	— 64.01
NC2Cb Scenario	— 42.64	— 43.53	— 43.78	— 49.33	— 68.63	— 74.14	— 78.65	— 78.33
EE2Cb Scenario	— 42.64	— 43.69	— 43.90	— 49.09	— 69.49	— 75.90	— 79.58	— 79.38
NC_var2Cb Scenario	— 42.64	— 43.58	— 43.78	— 49.28	— 69.03	— 73.44	— 78.18	— 78.65

NC1p5Cb Scenario	— 42.63	— 43.61	— 43.94	— 49.37	— 74.51	— 80.28	— 83.66	— 83.65
EE1p5Cb Scenario	— 42.64	— 43.60	— 43.83	— 49.09	— 71.77	— 80.89	— 84.35	— 84.11
NC_var1p5Cb Scenario	— 42.63	— 43.63	— 44.00	— 49.37	— 75.39	— 80.17	— 83.47	— 83.75

Source: (B) EST model, E3-Modelling

In terms of CO2 emissions from energy, the scenarios achieve approximately 90 % reductions for the 2 °C scenarios and just over 94 % for the 1.5 °C scenarios compared to 2005 levels. The projections take into account both existing measures and additional and planned measures to reduce greenhouse gas emissions. Bulgaria is taking significant measures to restructure the country's energy system. In addition, once energy efficiency measures and policies are implemented, final energy consumption is expected to decrease in all sectors, resulting in further reductions in greenhouse gas emissions. To reach the target (net-zero emissions by 2050), all sectors will contribute significantly based on their individual potential.

The decarbonisation objective can be achieved by reducing the carbon intensity of electricity generated in Bulgaria (energy produced from renewable sources), together with a gradual substitution of fossil fuels by electricity in most sectors of the economy (e.g. transport). The CO_2 emission curve is shown in the table below:

Table 7: Change in total CO_2 emissions in% from 2005 levels under the selected scenarios

	2015	2020	2025	2030	2035	2040	2045	2050
NC2Cb Scenario	— 9.26	— 10.35	— 12.71	— 26.41	— 62.49	— 75.38	— 87.47	— 89.19
EE2Cb Scenario	— 9.26	— 10.69	— 12.97	— 25.89	— 64.07	— 78.88	— 88.89	— 90.69
NC1p5Cb Scenario	— 9.26	— 10.51	— 13.04	— 26.50	— 69.28	— 82.67	— 92.37	— 94.22
EE1p5Cb Scenario	— 9.26	— 10.50	— 12.80	— 25.89	— 68.63	— 83.14	— 92.47	— 94.57
NC_var1p5Cb Scenario	— 9.26	— 10.57	— 13.18	— 26.50	— 71.23	— 82.43	— 91.94	— 94.44
NC_var2Cb Scenario	— 9.26	— 10.46	— 12.69	— 26.30	— 63.35	— 73.96	— 86.74	— 89.36

Source: (B) EST model, E3-Modelling

B. Decarbonisation – Renewable energy

In the context of current and additional policies and measures, an increase in the overall share of renewable energy is expected. Projections show an increasing global share of renewable energy in gross final energy consumption from approximately 20 % in 2020 to over 27 % in 2030 and reaching between 60 % and 70 % in 2050. The overall target for the share of renewables has been calculated on the basis of Directive (EU) 2018/2001 of the European Parliament and of the Council on the promotion of the use of energy from renewable sources.

The overall share of expected renewable energy development is presented below:

Table 8: Indicative trajectory for the overall share of energy from renewable sources in final energy consumption 2015-2050 (%)

	2015	2020	2025	2030	2035	2040	2045	2050
NC2Cb Scenario	18.38	20.18	23.46	27.40	35.19	42.03	56.60	62.99
EE2Cb Scenario	18.38	20.09	23.44	27.17	30.40	37.83	53.65	60.88
NC1p5Cb Scenario	18.38	20.18	23.58	27.55	35.55	44.81	57.48	70.22
EE1p5Cb Scenario	18.38	20.18	23.47	27.31	35.61	42.96	56.64	64.74
NC_var1p5Cb Scenario	18.38	20.18	23.73	27.52	35.42	45.21	57.87	64.23
NC_var2Cb Scenario	18.38	20.21	23.38	27.29	35.35	44.14	58.95	62.89

Source: (B) EST model, E3-Modelling

The sectors' contribution to the overall share of renewable energy in gross final consumption by 2050 is expected to have the following distribution between sectors:

- 42 % to 51 % share of renewable energy in the electricity sector;
- 120 % – 192 % in relation to the integration of renewable energy in the transport sector (share WI-T as a result of the model in 2050 was more than 100 % due to the multipliers defined by the calculation formula established by Directive (EU) 2018/2001);
- 73 % – 81 % share of renewable energy in heating and cooling.

Table 9: Indicative trajectory for the share of electricity from renewable sources in gross final gross electricity consumption 2015-2050 (%)

	2015	2020	2025	2030	2035	2040	2045	2050
NC2Cb Scenario	19.38	21.40	24.15	31.33	40.18	36.81	40.42	47.38
EE2Cb Scenario	19.38	21.21	24.26	30.55	36.06	35.77	39.56	50.89
NC1p5Cb Scenario	19.38	21.45	24.32	31.32	41.81	38.10	36.75	47.38
EE1p5Cb Scenario	19.38	21.50	23.98	30.56	43.29	38.13	39.58	49.03
NC_var1p5Cb Scenario	19.38	21.53	24.58	31.34	41.52	41.91	39.83	42.53
NC_var2Cb Scenario	19.38	21.42	24.05	31.08	40.81	41.35	44.31	47.03

Source: (B) EST model, E3-Modelling

Table 10: Indicative trajectory for the share of renewable energy in final energy consumption in transport 2015-2050 (%)

	2015	2020	2025	2030	2035	2040	2045	2050
NC2Cb Scenario	6.27	9.89	9.96	14.28	31.33	52.96	107.70	120.89
EE2Cb Scenario	6.27	9.89	9.97	14.22	30.37	54.92	121.67	145.75
NC1p5Cb Scenario	6.27	9.89	9.97	14.28	34.15	64.61	113.74	133.48
EE1p5Cb Scenario	6.27	9.90	9.96	14.22	34.58	68.79	143.64	192.31
NC_var1p5Cb Scenario	6.27	9.90	9.98	14.28	34.05	67.03	116.53	126.71
NC_var2Cb Scenario	6.27	9.89	9.96	14.26	31.48	55.06	110.47	120.41

Source: (B) EST model, E3-Modelling

Starting in 2030, the increase in renewable energy production is mainly due tofurther wind developments, as

Table 11: Indicative trajectory for the share of energy from renewable sources in final consumption of energy for heating and cooling 2015-2050 (%)

	2015	2020	2025	2030	2035	2040	2045	2050
NC2Cb Scenario	28.94	30.99	37.92	42.53	49.05	57.60	73.41	73.93
EE2Cb Scenario	28.94	30.96	37.77	42.61	44.82	56.48	79.36	77.43
NC1p5Cb Scenario	28.94	30.95	38.08	42.95	49.78	63.26	78.99	81.27
EE1p5Cb Scenario	28.94	30.95	38.11	43.03	52.84	65.29	82.83	77.96
NC_var1p5Cb Scenario	28.94	30.91	38.29	42.89	49.66	57.31	74.31	75.93
NC_var2Cb Scenario	28.94	31.07	37.80	42.46	48.87	57.40	72.24	75.33

Source: (B) EST model, E3-Modelling

the net installed capacity of these facilities is expected to increase from approximately 1,1 GWe in 2030 to over 5,5 GWe in 2050. Furthermore, installed solar photovoltaic capacity will increase by approximately 74 % between 2030 and 2050 and geothermal energy will develop after 2040. On the other hand, hydropower and biomass are expected to remain stable over the period 2030-2050.

In the case of renewable energy in the transport sector, the projections of the long-term strategy show accelerated electrification in the transport sector, reaching a final electricity consumption of almost 5 600 GWh in 2050, together with an increase in energy from VI-E. Moreover, advanced biofuels and the introduction of hydrogen in 2030 will gradually replace conventional fuels (liquid fuels, conventional biofuels, etc.), leading to a reduction in diesel consumption of more than 85 % in 2050 compared to 2030 levels.

The increase in the share of renewable energy in the heating and cooling sector is mainly due to the electrification of the sector, supported by the increase in energy from VI-E and the development of additional solar devices. Similarly, the share of renewable energy in the heating and cooling sector is supported by the increasing use of heat pumps by 2040, reaching final consumption of more than 1.500 GWh in 2040 under all scenarios (and more than 1.800 GWh in the 2 °C scenarios). However, after 2045, the final consumption of heat pumps in the 2 °C scenarios is expected to maintain a steady pace (more than 1.800 GWh), with a decrease in the use of 1.5 °C pumps expected to result in final consumption of less than 1.000 GWh in 2050. Moreover, the consumption of waste in the sector is expected to continue to increase until 2035, reaching more than 1.000 GWh in 2035 (compared to an average of 870 GWh in 2030) and stabilised in 2050. there are no significant changes in biomass consumption in the heating and cooling sector in the period 2030-2050 (consumption expected to fall slightly over this period – less than 15 % under all scenarios).

C. Role of the electricity sector in achieving carbon neutrality

The electricity sector accounts for the largest share of total national CO_2 emissions (in 2017, energy industries accounted for around 45 % of total greenhouse gas emissions – without LULUCF[7]), which will then be a key driver of carbon neutrality. In addition, the growing consumption caused by the increasing electrification of various sectors will trigger an important increase in renewable energy production capacity by 2050.

Therefore, taking into account the expected electrification of different sectors, reducing emissions from electricity production will play a central role throughout the transition towards decarbonisation of the entire Bulgarian economy. This leads to the need to phase out the use of fossil fuels in electricity generation, in particular lignite and further development of renewable energy capacity.

By 2050, it is expected to continuously reduce CO_2 emissions from electricity production, reaching even negative levels in 2050, which in fact means that the sector will generate negative net CO_2 emissions, as described in the table below:

7Forth Biennial Report of Bulgaria (BG BR4) – June 2020

Table 12: CO_2 emissions – electricity generation sector (KTH. CO_2)

	2015	2020	2025	2030	2035	2040	2045	2050
NC2Cb Scenario	26.527	25.708	24.841	19.242	4.779	2.164	411	523
EE2Cb Scenario	26.527	25.467	24.632	19.460	4.327	508	952	— 605
NC1p5Cb Scenario	26.534	25.611	24.672	19.212	2.485	668	667	1.162
EE1p5Cb Scenario	26.527	25.655	24.795	19.483	3.341	363	391	— 1.019
NC_var1p5Cb Scenario	26.534	25.628	24.623	19.238	1.509	— 376	— 542	— 348
NC_var2Cb Scenario	26.527	25.659	24.856	19.296	4.348	2.820	624	534

Source: (B) EST model, E3-Modelling

This evolution is facilitated by the reduction in the cost of renewable electricity generation technologies, which are expected to suffer further cost reductions in the coming years, which is also confirmed by an expected rapid fall in the cost of storage solutions.

Onshore wind is expected to experience the largest increase, rising from a net installed capacity of 0.8 GW in 2030 to over 7 GW in 2050. Solar photovoltaic technology will also significantly increase by more than 160 % in 2050 compared to the installed capacity in 2030. As a result, these two sources will constitute the main pillars for facilitating the transition to carbon neutrality in the electricity sector, as these sources will provide more than 40 % of the electricity produced in 2050. The evolution of the expected net installed capacity below is presented:

Table 13: Net installed capacity – power generation sector (GWe)

Year	Scenario	Nuclear energy	Hydro-energy	Onshore wind energy	Slunch Eva Energy (PV)	Solid fuels	Gas	Biomass	Geothermal energy
2015	**NC2Cb**	1.89	2.36	0.70	1.03	4.30	1.91	0.05	0.00
	EE2Cb	1.89	2.36	0.70	1.03	4.30	1.91	0.05	0.00
	NC1p5Cb	1.89	2.36	0.70	1.03	4.30	1.91	0.05	0.00
	EE1p5Cb	1.89	2.36	0.70	1.03	4.30	1.91	0.05	0.00
	NC_var1p5Cb	1.89	2.36	0.70	1.03	4.30	1.91	0.05	0.00
	NC_var2Cb	1.89	2.36	0.70	1.03	4.30	1.91	0.05	0.00

2020	**NC2Cb**	1.9	2.5	0.7	1.0	4.3	1.9	0.1	0.0
	EE2Cb	1.9	2.5	0.7	1.0	4.3	1.9	0.1	0.0
	NC1p5Cb	1.9	2.5	0.7	1.0	4.3	1.9	0.1	0.0
	EE1p5Cb	1.9	2.5	0.7	1.0	4.3	1.9	0.1	0.0
	NC_var1p5Cb	1.9	2.5	0.7	1.0	4.3	1.9	0.1	0.0
	NC_var2Cb	1.9	2.5	0.7	1.0	4.3	1.9	0.1	0.0
2030	**NC2Cb**	1.89	2.51	0.91	3.54	2.52	2.37	0.30	0.00
	EE2Cb	1.89	2.51	1.10	3.02	2.52	2.40	0.30	0.00
	NC1p5Cb	1.89	2.51	0.83	3.67	2.52	2.40	0.31	0.00
	EE1p5Cb	1.89	2.51	1.06	3.02	2.52	2.45	0.33	0.00
	NC_var1p5Cb	1.89	2.51	0.86	3.61	2.52	2.38	0.32	0.00
	NC_var2Cb	1.89	2.51	0.79	3.70	2.52	2.40	0.29	0.00
2040	**NC2Cb**	3.89	2.51	2.96	4.67	1.45	2.95	0.33	0.04
	EE2Cb	3.89	2.51	2.49	3.03	1.45	2.98	0.36	0.04
	NC1p5Cb	3.89	2.51	3.19	4.96	1.45	3.53	0.44	0.04
	EE1p5Cb	3.89	2.56	2.58	3.59	1.45	3.05	0.46	0.04
	NC_var1p5Cb	3.89	2.51	3.69	5.52	1.45	3.65	0.75	0.04
	NC_var2Cb	3.89	2.51	3.69	4.96	1.45	3.22	0.32	0.04
2050	**NC2Cb**	2.00	2.51	5.64	10.13	1.08	7.01	0.71	0.15
	EE2Cb	2.00	2.51	5.63	5.24	1.08	4.79	0.68	0.14
	NC1p5Cb	2.00	2.51	7.32	9.77	1.08	7.68	0.47	0.14
	EE1p5Cb	2.00	2.56	5.64	4.91	1.08	4.75	0.76	0.14
	NC_var1p5Cb	3.89	2.51	5.90	9.41	1.08	6.69	0.73	0.16
	NC_var2Cb	3.89	2.51	6.23	9.18	1.08	6.18	0.74	0.16

Source: (B) EST model, E3-Modelling

However, due to their daily and average annual volatility, these technologies pose challenges in terms of security of supply. Therefore, the development of RES in the electricity generation sector will be further encouraged by the development of a smart grid for transmission and distribution, which will subsequently increase system flexibility. Moreover, as storage facilities will become increasingly cost-effective, their deployment will contribute to the stability of the system together with the maintenance of several gas-fired facilities. Nevertheless, measures to create a favourable market design to support the integration of new RES capacities is expected to be implemented throughout the period analysed.

D. Role of the transport sector in achieving carbon neutrality

The transport sector has the second largest share of CO2 emissions(accounting for more than 20 % of total energy-related CO_2emissions), which has experienced a significant increase in emissions in recent years due to increasing transport activity. This sector includes road, rail and waterborne and air transport (only its national components) and can be divided into passenger and freight transport.

Road transport currently accounts for more than 85 % of total CO_2 emissions in the sector. The main measures will therefore focus mainly on this segment. As a result, the planned measures and policies will lead to a reduction of approximately 28 % of the specific passenger transport consumption (GWh/Mvkm) in 2050 compared to 2030 levels and by more than 40 % of freight transport. All these measures will contribute to a gradual reduction of CO2 emissionsin the transport sector, reaching approximately 3000 KTH. Co_2 for 2 °C scenarios, respectively about 1500 KTH. Co_2 for 1.5 °C scenarios.

Table 14: CO_2 emissions – transport sector (KTH. CO_2)

	2015	2020	2025	2030	2035	2040	2045	2050
NC2Cb Scenario	9.465	9.918	10.268	10.148	8.826	6.569	3.726	3.054
EE2Cb Scenario	9.465	9.928	10.269	10.151	8.869	6.637	3.772	3.160
NC1p5Cb Scenario	9.465	9.919	10.267	10.146	8.518	5.651	2.651	1.541
EE1p5Cb Scenario	9.465	9.919	10.266	10.146	8.534	5.785	2.732	1.621
NC_var1p5Cb Scenario	9.465	9.919	10.264	10.146	8.527	5.684	2.693	1.534
NC_var2Cb Scenario	9.465	9.918	10.269	10.150	8.829	6.594	3.771	3.014

Source: (B) EST model, E3-Modelling

Thetransition is mainly facilitated by electrification in the sector, as electricity consumption in the sector will reach more than 6 500 GWh in 2050, confirmed by the growing share of RES. In addition, the gradual replacement of conventional biofuels with advanced biofuels and the introduction and development of hydrogen will also play an important role in the decarbonisation of the sector. These three sources will represent almost 60 % of total final energy consumption in 2050, as described below:

Table 15: Final energy consumption by fuel type – transport sector (GWh)

Genes of	Scenarios	Liquids fuels	Gas	Biogas	Conventional biofuels	Biofuels a new generation	Hydrogen	Electric energy
2015	NC2Cb	34.822	2.588	—	1.698	—	—	352
	EE2Cb	34.822	2.588	—	1.698	—	—	352
	NC1p5Cb	34.822	2.588	—	1.698	—	—	352
	EE1p5Cb	34.822	2.588	—	1.698	—	—	352
	NC_var1p5Cb	34.822	2.588	—	1.698	—	—	352
	NC_var2Cb	34.822	2.588	—	1.698	—	—	352
2020	NC2Cb	36.612	2.598	—	2.207	322	—	422
	EE2Cb	36.611	2.649	—	2.207	322	—	422
	NC1p5Cb	36.611	2.601	—	2.207	322	—	422
	EE1p5Cb	36.611	2.602	—	2.207	322	—	422
	NC_var1p5Cb	36.611	2.601	—	2.207	322	—	422
	NC_var2Cb	36.612	2.600	—	2.207	322	—	422
2030	NC2Cb	37.566	2.301	—	1.494	1.095	32	952
	EE2Cb	37.566	2.317	—	1.494	1.095	610	2.138
	NC1p5Cb	37.567	2.291	—	1.494	1.095	32	951
	EE1p5Cb	37.565	2.293	—	1.494	1.095	32	953
	NC_var1p5Cb	37.567	2.289	—	1.494	1.095	32	951
	NC_var2Cb	37.566	2.313	—	1.494	1.095	32	952
2040	NC2Cb	24.375	2.218	134	683	3.127	2.324	3.577
	EE2Cb	24.046	2.019	135	683	3.461	2.312	3.581

Genes of	Scenarios	Liquids fuels	Gas	Biogas	Conventional biofuels	Advanced biofuels	Hydrogen	Electric energy
2050	NC1p5Cb	21.343	2.109	100	631	3.481	2.458	4.563
	EE1p5Cb	20.781	1.955	100	630	4.022	2.466	4.566
	NC_var1p5Cb	21.359	2.329	100	632	3.484	2.455	4.560
	NC_var2Cb	24.397	2.349	135	684	3.130	2.324	3.567
	NC2Cb	12.254	3.398	567	155	4.098	5.131	5.610
	EE2Cb	10.108	2.826	584	156	6.346	5.074	5.597
	NC1p5Cb	9.208	3.207	414	88	2.961	5.830	6.728
	EE1p5Cb	4.280	2.741	446	90	8.106	5.620	6.749
	NC_var1p5Cb	9.210	3.046	417	88	2.961	5.850	6.711
	NC_var2Cb	12.273	2.916	566	156	4.109	5.121	5.597

Source: (B) EST model, E3-Modelling

The transition will be facilitated by the replacement of conventional fuels (diesel, gasoline) with electric vehicles, together with the development of the necessary infrastructure (e.g. charging stations, etc.).

Moreover, the development of public transport systems through the expansion of networks (e.g. metro) will be an important vector in urban areas, while the development and introduction of new technologies in rail transport will generate additional efficiency in long-distance interurban transport. All this will lead to an increase in the share of public transport that can be reflected in emission reductions.

In a transitional phase, hybrid vehicles will play an important role in decarbonisation, mainly in individual transport, due to the development of advanced biofuels, especially in long-distance road passenger and freight transport, where the distances covered are longer. Starting in 2030, hydrogen will play an increasingly important role, which will then also mean the development of appropriate infrastructure.

E. Role of the industrial sector in achieving carbon neutrality

The industrial sector contains various activities and processes, including sectors such as iron and steel, paper and pulp, chemicals, construction materials, textiles, etc. Emissions derive mainly from fossil fuel consumption and from the internal processes involved. In 2015, industrial emissions accounted for approximately 6 % of energy-related national CO_2emissions.

The domestic industry will undergo deep transformations, significantly reducing its emissions to less than 200 KTH. Co_2 emissions in all scenarios in 2050, as highlighted in the table below:

Table 16: CO_2 emissions – industrial sector (KTH. CO_2)

	2015	2020	2025	2030	2035	2040	2045	2050
NC2Cb Scenario	2,695	2,614	2,465	2,282	1,449	937	260	185
EE2Cb Scenario	2,695	2,637	2,472	2,285	1,322	949	251	140
NC1p5Cb Scenario	2,695	2,626	2,462	2,280	1,210	591	175	77
EE1p5Cb Scenario	2,695	2,622	2,474	2,285	1,181	697	218	186
NC_var1p5Cb Scenario	2,695	2,620	2,460	2,275	1,219	596	154	61
NC_var2Cb Scenario	2,695	2,630	2,471	2,283	1,462	951	340	135

Source: (B) EST model, E3-Modelling

In the period 2030-2050, industry will shift from conventional fuels (solid, liquid and gas) to more sustainable sources such as biomass and waste and electricity, as presented in the table below.

For biomass, it is expected that biomass sourcing will comply with the sustainability criteria of the Renewable Energy Framework Directive (Directive (EU) 2018/2001),[8] in order to be counted as RES target and set as RES target.

Biomass is considered to be derived mainly from the use of agricultural, aquaculture and forestry and biodegradable waste. No additional harvesting beyond current levels is foreseen at the expense of biomass sourcing.

Table 17: Direct fuel use – industrial sector (GWh)

Year	Scripts and	Solid fuels	Liquid fuels	Gas	Biomass and waste	Slan cheva	Geotherma	Steam	Electric energy
2015	NC2Cb	1.320	2.026	8.319	1.197	—	—	8.520	8.957
	EE2Cb	1.320	2.026	8.319	1.197	—	—	8.520	8.957
	NC1p5Cb	1.320	2.026	8.319	1.197	—	—	8.520	8.957

[8] Article 26 to 29 of Directive (EU) 2018/2001 of 11 December 2018 on the promotion of the use of energy from renewable sources (RED Directive) and Annex 9 for the production of biofuels. Further criteria for biofuels are presented in Delegated Regulation (EU) 2019/807 of 13 March 2019.

Year	Scripts and	Solid fuels	Liquid fuels	Gas	Biomass and waste	Slan cheva	Geotherma	Steam	Electric energy
2020	EE1p5Cb	1.320	2.026	8.319	1.197	—	—	8.520	8.957
	NC_var1p5Cb	1.320	2.026	8.319	1.197	—	—	8.520	8.957
	NC_var2Cb	1.320	2.026	8.319	1.197	—	—	8.520	8.957
	NC2Cb	1.156	1.459	8.963	1.657	—	—	8.294	10.243
	EE2Cb	1.162	1.467	9.058	1.667	—	—	8.245	10.171
	NC1p5Cb	1.159	1.464	9.014	1.662	—	—	8.310	10.164
	EE1p5Cb	1.158	1.462	8.996	1.660	—	—	8.284	10.211
	NC_var1p5Cb	1.158	1.461	8.988	1.659	—	—	8.296	10.210
	NC_var2Cb	1.160	1.465	9.031	1.668	—	—	8.222	10.223
2030	NC2Cb	640	828	9.086	3.323	—	—	8.500	11.159
	EE2Cb	640	828	9.097	3.321	—	—	8.507	11.144
	NC1p5Cb	639	828	9.076	3.325	—	—	8.479	11.187
	EE1p5Cb	640	829	9.097	3.325	—	—	8.496	11.148
	NC_var1p5Cb	638	827	9.055	3.321	—	—	8.447	11.245
	NC_var2Cb	640	829	9.087	3.327	—	—	8.466	11.183
2040	NC2Cb	80	268	5.689	5.977	154	154	6.927	12.597
	EE2Cb	42	179	4.394	5.671	138	138	6.293	11.964
	NC1p5Cb	25	150	4.248	6.062	139	139	5.928	12.124
	EE1p5Cb	20	117	3.264	7.043	147	147	5.713	12.392
	NC_var1p5Cb	25	151	4.285	6.084	139	139	5.939	12.052
	NC_var2Cb	81	271	5.773	6.009	154	154	6.958	12.424

Year	Scripts and	Solid fuels	Liquid fuels	Gas	Biomass and waste	Slan cheva	Geotherma	Steam	Electric energy
2050	NC2Cb	5	129	1.670	9.622	739	739	1.300	17.271
	EE2Cb	2	63	613	9.137	736	736	1.112	16.786
	NC1p5Cb	2	71	1.481	9.181	742	742	1.068	15.860
	EE1p5Cb	2	69	836	9.417	778	778	1.286	16.054
	NC_var1p5Cb	2	58	1.168	9.167	739	739	829	16.455
	NC_var2Cb	4	95	1.208	9.603	735	735	598	18.612

Source: (B) EST model, E3-Modelling

There is a key potential in the electrification of industry, so electricity consumption will increase by more than 50 % in 2050 compared to 2030 levels. The electrification process is supported by an increase in renewables in the electricity sector. In addition, biomass and waste will play a central role in the industry's transition to carbon neutrality, as its use is expected to almost triple over the period 2030-2050, replacing conventional fuels.

Gas appears as a transitional fuel as its consumption will increase until 2030 and decrease thereafter due to some processes being electrified (direct gas use will decrease from more than 9 000 GWh in 2030 to approximately 1 200 GWh in 2050).

In addition, the development and deployment of solar and geothermal heat will further contribute to the decarbonisation of the sector.

The transition to a carbon-neutral environment is also supported through improved energy efficiency policies and measures aimed at reducing heat losses. In order to implement effective measures, energy efficiency audits will be a key tool for adapting and improving the proposed measures and policies.

There is now a strong need for innovation and the creation of new business models in industry. In this way, the industrial sector should be encouraged to invest in R & D and innovation in widely used production methods aimed at optimal resource efficiency. This measure will be continued by promoting the exchange of good practices between businesses and industries.

The above policies and measures will support the development and implementation of CCS in the industrial sector, which is expected to become profitable by 2050.

F. Role of the residential sector in achieving carbon neutrality

Buildings, including residential buildings, are major energy consumers, currently accounting for more than 20 % of final energy consumption and being one of the most important sources of CO_2 emissions.

The promotion of the use of renewable energy in buildings will continue throughout the time horizon. Policies and measures related to energy efficiency and continued inclusion of RES in the sector (mainly solar, geothermal, heat pumps) will contribute significantly to reducing CO_2 emissions by 2050, as presented in the table below:

Table 18: CO2 emissions – residential sector (KTH. CO2)

	2015	2020	2025	2030	2035	2040	2045	2050
NC2Cb Scenario	773	816	576	296	134	77	50	37
EE2Cb Scenario	773	815	575	295	102	65	60	59
NC1p5Cb Scenario	773	815	576	296	108	45	23	12
EE1p5Cb Scenario	773	816	575	295	85	65	57	55
NC_var1p5Cb Scenario	773	816	576	296	108	45	24	12
NC_var2Cb Scenario	773	818	576	296	134	78	51	37

Source: (B) EST model, E3-Modelling

Bulgaria aims to stop the consumption of solid and liquid fuels in the residential sector, and this trend will be accelerated from 2030. Natural gas and biomass are required as transitional fuels as their consumption increases until 2030 and then falls due to the fact that the sector is becoming more and more electrified, as highlighted in the table below:

Table 19: Final energy consumption by fuel – residential sector (GWh)

Genes of	Scenarios	Solid fuels	Liquid fuels	Gas	Biomass and waste	Solar energy	Heat	Electric energy
2015	NC2Cb	1,577	397	602	8,328	112	3,869	10,644
	EE2Cb	1,577	397	602	8,328	112	3,869	10,644

Genes of	Scenarios	Solid fuels	Liquid fuels	Gas	Biomass and waste	Solar energy	Heat	Electric energy
2020	NC1p5Cb	1,577	397	602	8,328	112	3,869	10,644
	EE1p5Cb	1,577	397	602	8,328	112	3,869	10,644
	NC_var1p5C b	1,577	397	602	8,328	112	3,869	10,644
	NC_var2Cb	1,577	397	602	8,328	112	3,869	10,644
	NC2Cb	1,661	403	658	8,820	112	3,930	11,310
	EE2Cb	1,661	399	658	8,817	112	3,896	11,337
	NC1p5Cb	1,660	401	658	8,814	112	3,926	11,319
	EE1p5Cb	1,660	402	658	8,816	112	3,926	11,316
	NC_var1p5C b	1,660	402	658	8,816	112	3,928	11,315
	NC_var2Cb	1,664	404	660	8,839	112	3,884	11,324
2030	NC2Cb	400	121	621	9,831	162	3,669	12,748
	EE2Cb	400	120	621	9,829	162	3,659	12,765
	NC1p5Cb	401	122	622	9,838	163	3,667	12,730
	EE1p5Cb	400	120	621	9,827	162	3,665	12,762
	NC_var1p5C b	401	122	622	9,837	163	3,674	12,724
	NC_var2Cb	401	121	622	9,834	163	3,668	12,739
2040	NC2Cb	14	17	464	8,201	299	3,004	13,668
	EE2Cb	6	17	295	4,148	306	2,222	13,527
	NC1p5Cb	5	18	302	4,186	313	2,221	13,499
	EE1p5Cb	4	17	295	4,282	330	2,164	13,475
	NC_var1p5C b	5	18	304	4,191	314	2,248	13,476

Genes of	Scenarios	Solid fuels	Liquid fuels	Gas	Biomass and waste	Solar energy	Heat	Electric energy
	NC_var2Cb	14	18	469	8,211	302	2,992	13,595
2050	NC2Cb	—	9	387	6,727	312	2,875	14,409
	EE2Cb	—	5	283	4,037	325	2,267	14,393
	NC1p5Cb	—	5	282	4,034	327	2,306	14,372
	EE1p5Cb	—	2	272	4,122	359	2,220	14,351
	NC_var1p5C b	—	5	280	4,036	327	2,268	14,404
	NC_var2Cb	—	8	384	6,717	310	2,772	14,440

Source: (B) EST model, E3-Modelling

An increase in thermal comfort in dwellings is expected, both in heating and cooling, resulting from the continuing trend of electrification in the sector, the use of more efficient appliances, the increased use of insulation materials and higher levels of renovation of the building stock. All these measures are expected to reduce final energy consumption in the residential sector by more than 10 % by 2050 compared to 2030 levels. The reduction is partly compensated by a higher standard of living of the population (e.g. more household appliances, etc.).

The continued focus on urban regeneration will provide an opportunity to include improvements in energy and water efficiency, the inclusion of low-carbon materials and RES (geothermal and solar installations), thus contributing to the decarbonisation of the sector.

Measures for household gasification through natural gas grid development are expected by 2030 to gradually reduce conventional fuels (solid fuels). After 2030, small decentralised heating and/or cooling systems based on renewable energy (geothermal energy) are planned to be developed to achieve a carbon-neutral environment.

All these measures will reduce the carbon intensity from 0,11 tonnes of CO_2 per capita in 2005 to 0,04 tonnes of CO_2 per capita in 2030 and reach 0,01 tonnes of CO_2 per capita in 2050.

G. Waste management

Waste is one of the main sources of non-carbon emissions. Each forecast points to a decline in waste in regional landfills and waste water by more than five times by 2050.

Table 20: Projection of non-carbon emissions from the Waste Sector (KTH CO_2 eq.)

				Year			
	2020	2025	2030	2035	2040	2045	2050

Regional landfills	2,097	1,906	1,667	1,372	1,052	730	413
Wastewater	957	941	925	910	896	883	807
Total	**3,054**	**2,847**	**2,592**	**2,282**	**1,948**	**1,614**	**1,220**

Source: (B) EST model, E3-Modelling

Although the data of five different scenarios have been analysed, the result shows the same projection of non-carbon emissions for each scenario.

Such a decline in non-carbon emissions will not be possible without the implementation of clear prevention strategies outlined in Directive 2008/98 EC on waste, also known as the Waste Framework Directive as amended by Directive 2018/851 of 30 May 2018. Following the waste management hierarchy described in the Directive, policies must respect the following principles:

- The waste will be managed without endangering human health and the environment and, in particular, without posing a risk to elements (air, soil, plants, etc.);
- The waste will be managed without causing adverse noise or odours;
- The waste will be managed without adversely affecting the surroundings or sites of special interest.

The waste hierarchy generally prioritises the most environmentally friendly options in relation to waste legal provisions and policies and under Article 4 of the Waste Framework Directive.

Directive 2018/851 of 30 May 2018, which amends the Waste Framework Directive, states in its preamble that municipal waste accounts for between 7 % and 10 % of the total waste generated in the EU and explains that the challenges in the management of municipal waste result from its extremely complex and mixed composition, the immediate proximity of the waste generated to citizens, its visibility and its impact on the environment and human health. In that sense, the preamble to the Directive concludes that the way in which public waste is managed demonstrates the quality of overall waste management in a country.

From this point of view, it is encouraging for Bulgaria that the model shows a downward trend in municipal solid waste, taking into account the measures already taken and the policies that will be put in place in the waste management sector to bring it into line with European legislation.

Waste management will be further aligned with the specific reuse and recycling targets, supporting the transition to a circular economy.

Public policies will also be aligned with the new waste management taxonomy described in Directive 2018/851 of 30 May 2018, aligning the objectives to the expected results at European level.

H. Agriculture

Agriculture accounts for more than 10 % of total GHG emissions in the European Union. Total non-carbon (CH_4 and N_2O) GHG emissions from agriculture are expected to fall by 2030 (1.5 % to the equivalent of 433 million tonnes of CO_2) compared to the base year 2005. Livestock will continue to contribute 99 % to methane (CH_4) emissions from agriculture in 2030, with the largest share (85 %) of ruminants.

The model shows that non-carbon emissions in Bulgaria will increase by 2050 mainly in the agricultural sector, starting from 4,071 KTH CO_2 Eq. in 2020 to 6,348 KTH CO_2 Equivalent in 2050.

Table 11: Forecast of non-carbon emissions in the agriculture sector (KTH CO_2 ecca.)

	Year						
	2020	2025	2030	2035	2040	2045	2050
Plant breeding	4,071	4,465	4,822	5,188	5,578	5,960	6,348
Animal husbandry	2,185	2,259	2,367	2,514	2,623	2,732	2,841
Growing of rice	99	99	98	98	98	98	98
Total	6,354	6,823	7,287	7,800	8,299	8,790	9,286

Source: (B) EST model, E3-Modelling

Although data from several scenarios have been analysed, the results of the non-carbon projection are the same for each scenario.

The European Commission published a strategy to reduce methane emissions at EU8 level on 14 October 2020, which describes methane emissions as part of the commitment to reach climate neutrality by 2050. The strategy highlights that promoting the collection and use of organic waste that emits high levels of methane (or agricultural residues as biogas substrates can help reduce emissions.9

In order to better align agricultural practices with the new emission reduction targets, Bulgaria will also take into account the Commission's upcoming assessment of best practices and available and innovative technologies.

Bulgaria will also aim to reduce emissions in agriculture, taking the example of best practices in the A Farm to Fork Strategy10, which can achieve significant reductions in methane in particular. Moreover, Bulgaria will pursue digitalisation in rural areas, thus enabling farmers to be connected to fast and trustworthy internet, which is a key enabler of work, business and investment in rural areas and will lead to the integration of precision farming and the use of artificial intelligence.

Bulgaria has also taken into account an in vitro study, the results of which show that seaweed can strongly contribute to low-level methane production.11 12

I. LULUCF

This part presents the modelling results for the six GHG sink scenarios up to 2050. As presented above, all scenarios contain key policies and take as starting point the INECPs for the period 2030-2021.

Forest ecosystems contribute most to the absorption of greenhouse gases by all ecosystems, followed by grasslands and afforestation. The policies and measures referred to above aim at a more sustainable management of forests and the increase of their land. However, the overall trend is that their absorption capacity will decrease over time for all scenarios.

The reason for the decline in absorption capacity is the noticeable decline in the growth rate of forests, with the average age of forests steadily increasing. There has also been an increase in middle-aged and mature

8COM (2020) 663 final, 14.10.2020

9"Opportunities and barriers to achieving reduction of methane emissions from waste and from agriculture through biogas production", 17 July 2020.

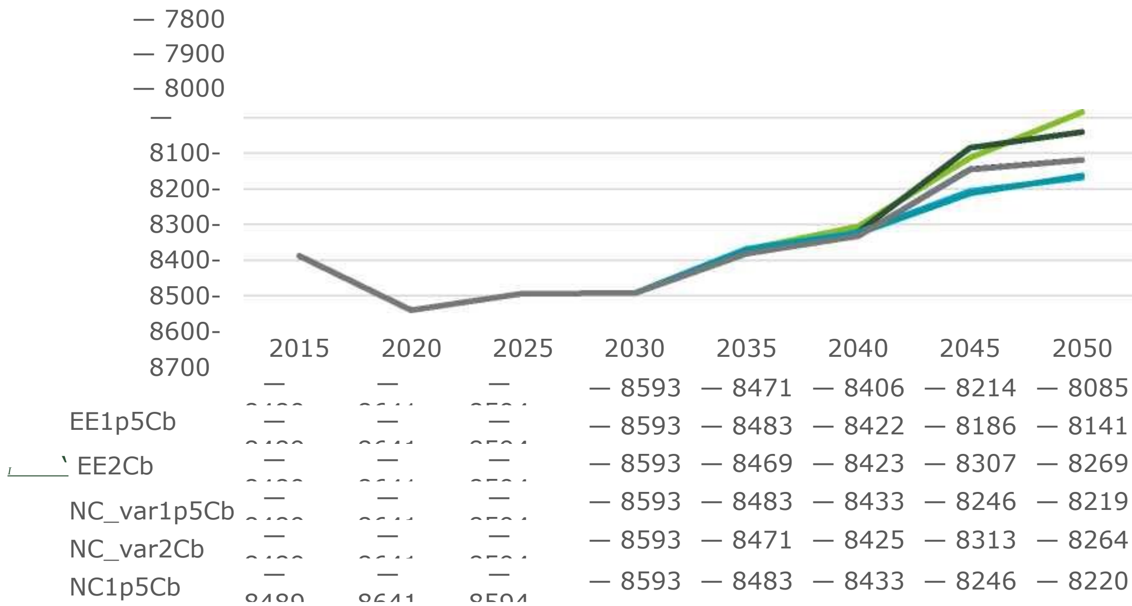
10A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system COM (2020) 381 final, 20.05.2020

11 https://www.publish.csiro.au/an/AN15576

12Celebio – Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 838087 forests, affecting growth and, subsequently, the prediction of absorption capacity. The average age of forests in Bulgaria for 2013 is 53 years. Despite a noticeable decline, the share of absorption of total greenhouse gas emissions(in CO 2-eq) is still significant. The main contributor to the increase of afforested areas in Bulgaria is the self-afforestation of abandoned agricultural land and the gradually increasing contribution to greenhouse gas removals by the sector.

Growth in biomass use varies from each scenario, but is expected not to prevent land from being used for production. There is considerable potential for using forest and agricultural residues for biomass production, according to a report on the development of a bio-based industry in Bulgaria and the Celebio13 project financed by the European Commission under the H2020 programme.

Figure 4: CO_2 emissions in the LULUCF sector (in CCS. CO_2)



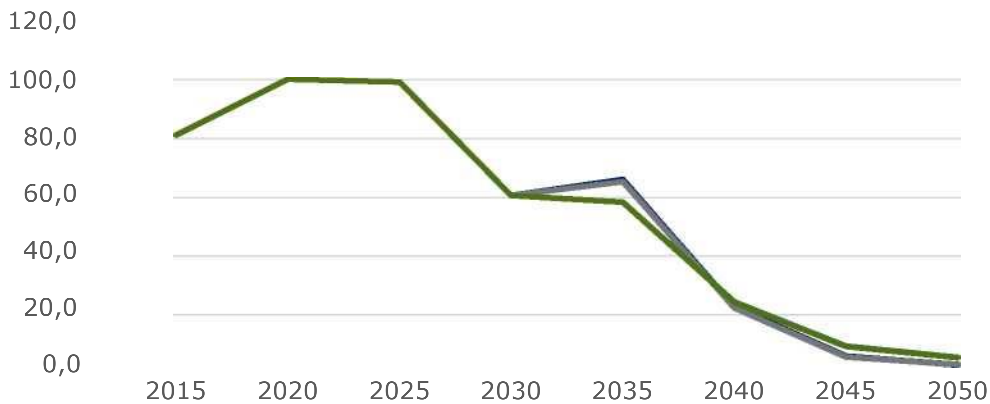
Source: (B) EST model, E3-Modelling

To meet the needs for the necessary biomass, it is envisaged that Bulgaria will unlock its untapped potential in biodegradable products, waste, including sludge from wastewater treatment plants, and residues of biological origin from agriculture, fisheries and aquaculture. This will be in line with the criteria set out in Article 29 of Directive (EU) 2018/2001 of 11 December 2018 on the promotion of the use of energy from renewable sources. The model also complies with Commission Delegated Regulation (EU) 2019/807 of 13 March 2019 for the LULUCF sector with regard to sustainability criteria for biofuels and biomass. As the necessary solid biomass is expected to be sourced mainly from residues, no additional land is foreseen to produce bioenergy for biomass due to the assumed switch from conventional to advanced biofuels.

The main difference between the scenarios is determined by the biomass quantities foreseen in the renewable energy sector to meet the decarbonisation objectives. In particular, the split between conventional and advanced biofuels to be produced and the mass of advanced biofuels that need to penetrate and absorb their respective share in the energy mix makes the difference in reduction projections in different scenarios. This is the result of the incentive measures for advanced biofuels, which will continue beyond the forecast period.

Conventional use of biofuels and land needed for production will decrease significantly over the projection horizon under all scenarios.

Figure 5: Land needed for conventional biofuels in kha

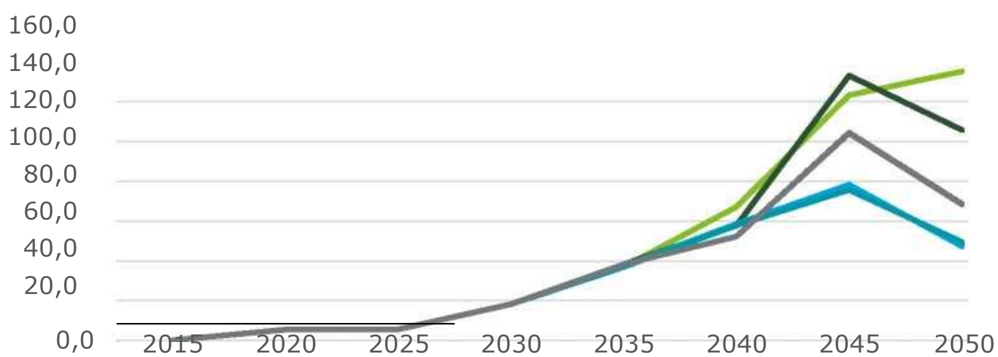


	2015	2020	2025	2030	2035	2040	2045	2050
IEE1p5Cb	81,1	100,1	99,1	60,5	65,3	22,5	5,8	3,2
EE2Cb	81,1	100,1	99,1	60,5	58,3	24,4	9,4	5,6
NC_var1p5Cb	81,1	100,1	99,1	60,5	66,0	22,8	6,0	3,0
NC_var2Cb	81,1	100,1	99,1	60,5	58,3	24,4	9,4	5,5
NC1p5Cb	81,1	100,1	99,1	60,5	65,2	22,4	5,7	3,1
NC2Cb	81,1	100,1	99,1	60,5	58,3	24,4	9,4	5,5

Source: (B) EST model, E3-Modelling

The model foresees a significant growth in the land used to produce advanced biofuels in EE1p5Cb and EE2Cb scenarios. This is due to the fact that ElecEE scenario implies high levels of electrification.

Figure 6: Land requirements for advanced biofuels in kha

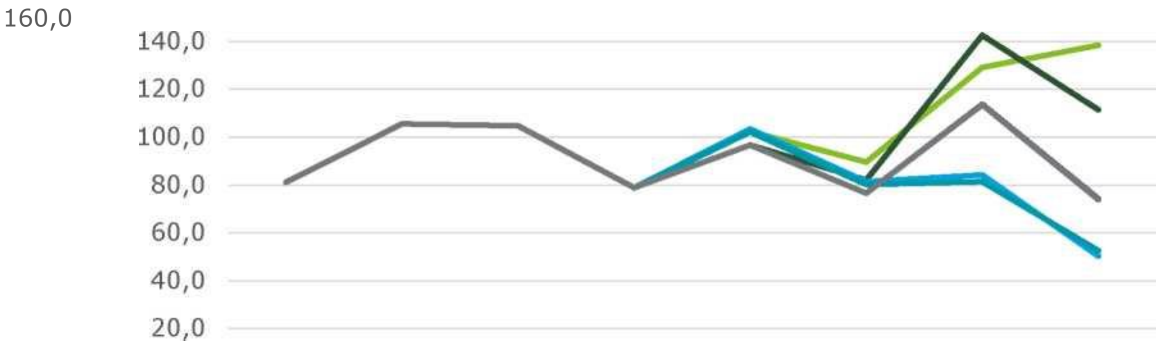


	2015	2020	2025	2030	2035	2040	2045	2050
I EE1p5Cb	0,0	5,4	5,6	18,3	36,9	67,1	123,3	135,1
EE2Cb	0	5,4	5,6	18,3	38,3	57,7	133,1	105,8
FURTHERMORE,	0,0	5,4	5,6	18,3	37,3	58,6	78,2	47,3
NC_var2Cb	0	5,4	5,6	18,3	38,3	52,2	104,2	68,5
FURTHERMORE,	0	5,4	5,6	18,3	36,9	57,8	75,6	49,4
FURTHERMORE, NC	0,0	5,4	5,6	18,3	38,3	52,1	104,1	68,3

Source: (B) EST model, E3-Modelling

The increase in land needed to produce advanced biofuels will be offset by the overall decline in land needed for conventional biofuels.

Figure 71: Land needed for energy crops in kha



	2015	2020	2025	2030	2035	2040	2045	2050
EE1p5Cb	81,1	105,5	104,7	78,8	102,2	89,5	129,1	138,4
EE2Cb	81,11	105,48	104,72	78,77	96,58	82,06	142,50	111,37
NC_var1p5Cb	81,1	105,5	104,7	78,8	103,4	81,4	84,2	50,3
NC_var2Cb	81,1	105,5	104,7	78,8	96,6	76,6	113,6	74,1
NC1p5Cb	81,1	105,5	104,7	78,8	102,1	80,2	81,3	52,6
NC2Cb	81,1	105,5	104,7	78,8	96,6	76,5	113,5	73,8

Source: (B) EST model, E3-Modelling

A. Assessment of the impact of existing and planned policies and measures

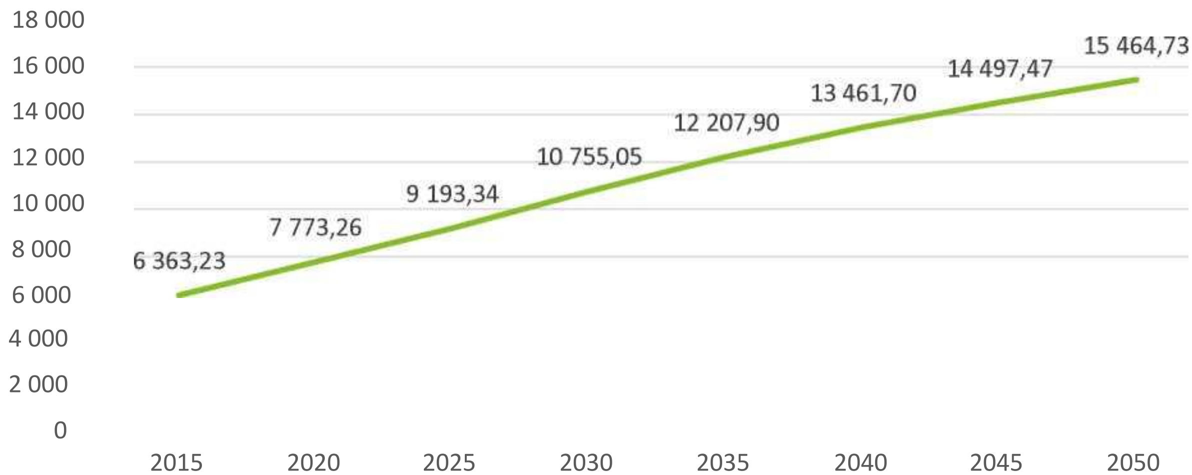
7.1. Macroeconomic impacts

An in-depth analysis of the available economic target variables (comparison between the six models for the long-term strategy).

- **. Brief analysis of trends in key input variables (same in different scenarios): GDP, GDP per capita, sector value added and population.**

All macroeconomic assumptions from the WEM and NECP scenarios are also valid for the long-term strategy scenarios. GDP is forecast to grow steadily while the population will continue to decline, albeit at a slightly lower pace towards the end of the projection horizon. GDP per capita will double between 2020 and 2050, reaching almost EUR 15 465.

Figure 2: BPD per capita forecast 2015-2050 (EUR)



Source: Assigned values to (B) EST model

Thelong-term trend of economic growth will bring about structural changes in terms of the sectoral composition of the economy. The relative contribution to GDP of some sectors, including services, machinery and iron and steel, will increase. This is in line with the decreasing share in the total value added of other sectors such as agriculture, food, non-ferrous metals, textiles and chemicals. Finally, there are two sectors, paper and pulp and building materials, which are likely to maintain their share of the total value added over the 30-year period of 2020-2050.

Figure 9: Sectoral value added as a percentage of total value added 2020-2050 (%)

Source: Assigned values to (B) EST model

Similarly to the 2020-2030 period, there will be two main drivers of economic growth between 2030 and 2050: high investment costs and improved energy efficiency. The expected investment boost results from the high capital intensity of projects related to the development of renewable energy, electrification and more generally the transformation of the energy sector. Increased energy efficiency means reduced energy costs that can be allocated to other production purposes.

B. Investment cost

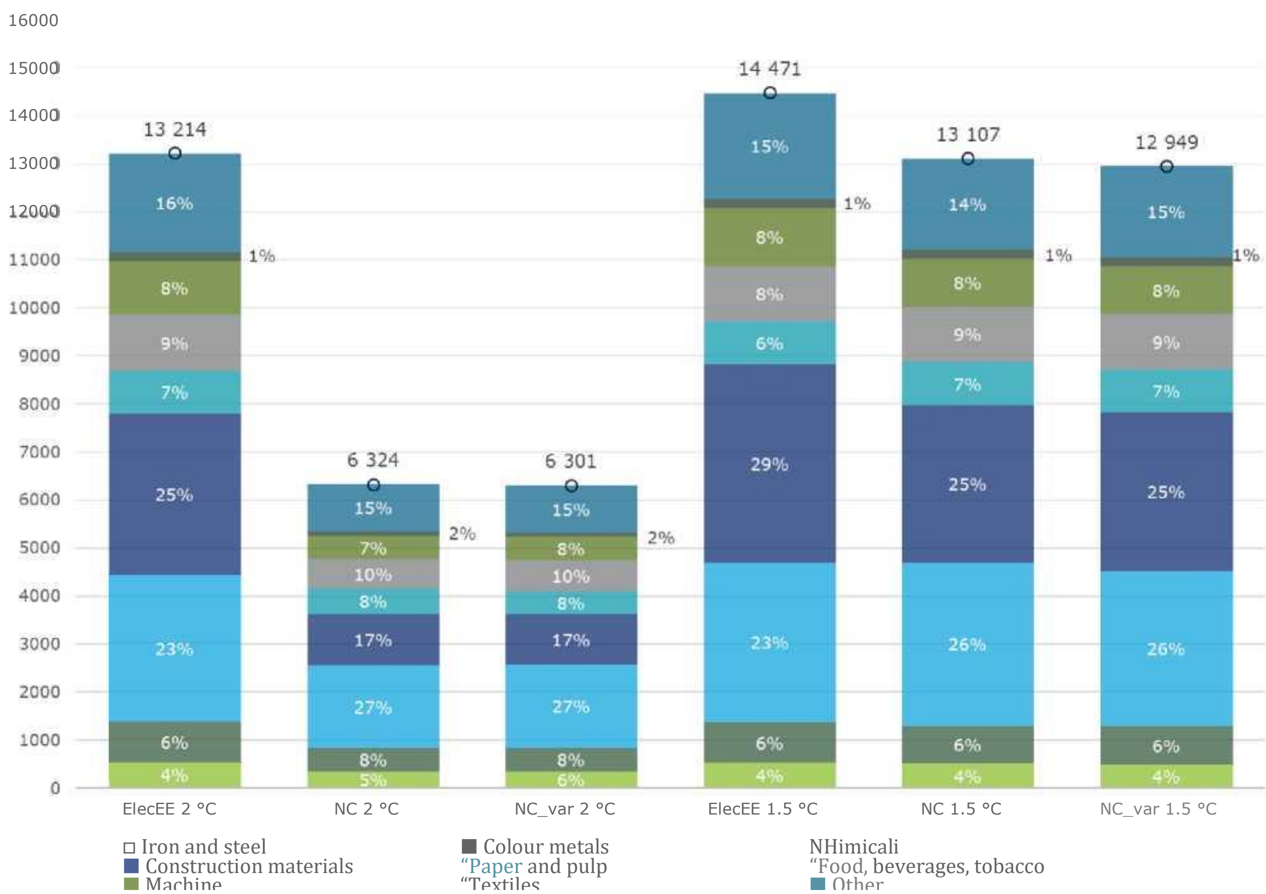
The model calculates that the investment costs for the industry for the six scenarios are as follows: ElecEE EUR 13 214 million in a 2 °C scenario and EUR 14 471 million at 1.5 °C, NC EUR 6324 million at 2 °C and EUR 13 107 million at 1.5 °C and NC_var: EUR 6301 million and EUR 12 949 million for scenarios of 2 °C and 1.5 °C respectively.

On average, investment costs in 1.5 °C scenarios are close to 60 % higher than in 2 °C scenarios. However, in this respect there are significant differences between different types of scenarios. The ElecEE scenario has relatively failed to respond to the assumed temperature increase – the 1.5 °C scenario requires a cost increase of just over EUR 1 200 million, which is a 8 % increase. On the other hand, the other 2 scenarios require significant investments to move to the more ambitious path of EUR 6 783 million in the NC scenario (increase of 107 %) and EUR 6 648 million in the NC_var scenario (an increase of 106 %).

In both ElecEE scenarios, the model predicts the highest investment costs in the construction materials industry (2529 % of total costs). The reason is that this industry is relatively highly exposed to environmental risk. This is particularly the case for cement and other heavy building materials, which often require significant fuel use and consequently lead to significant greenhouse gas emissions. Therefore, investments in intensification of alternative fuel use and the use of alternative raw materials will generate significant costs.

In the NC and NC_var scenarios, the highest investment costs are estimated in the chemical industry (2627 %). This is because this sector is particularly energy-intensive and offers technologies and products that are crucial for the transformation of the whole economy. In addition, the chemical industry will be required to move away from petrochemical products and move towards bio-based chemicals, which are key enablers of the green transition. Examples include: bioplastics (which contribute to the circular economy), biofuels (which support the shift to clean road transport) and biosolvents (which are key components of a thin film used in solar panels).

Figure 10: Industrial investment costs (in million EUR) for all scenarios in the period 2031-2050.



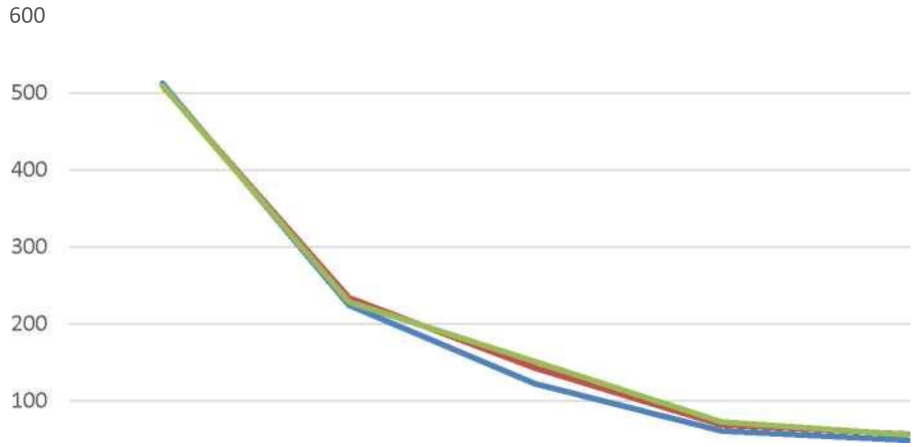
Source: (B) EST model, E3Modelling

C. Energy intensity of GDP and carbon intensity of GDP

The energy transition will drastically reduce the carbon intensity of GDP in all six scenarios – by 90 % in 2 °C and 94 % in 1.5 °C scenarios. The differences between certain scenarios for a given temperature increase are minimal. Differences occur in terms of energy intensity of GDP – the ElecEE scenario shows larger decreases in the indicator than the other scenarios. This happens independently of the given temperature pathway (42 % reduction in energy intensity compared to 2333 % reduction in other scenarios).

Figure 3: Carbon intensity of GDP (tonnes CO_2 million) – scenarios 2 °C

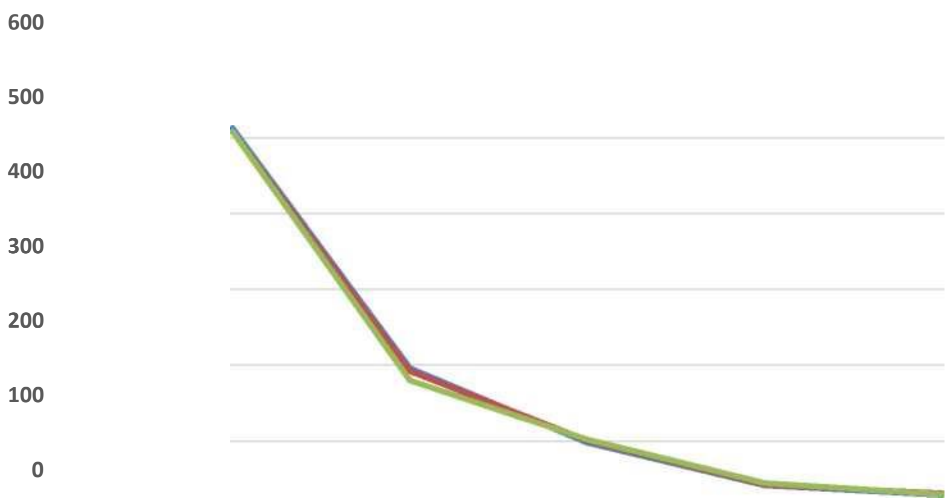
0



	2030	2035	2040	2045	2050
ElecEE 2 °C	512,38	224,19	122,29	61,07	49,00
NC 2 °C	508,78	234,05	142,57	68,85	56,91
NC_var 2 °C	509,51	228,71	150,81	72,86	55,99

Source: (B) EST model, E3Modelling

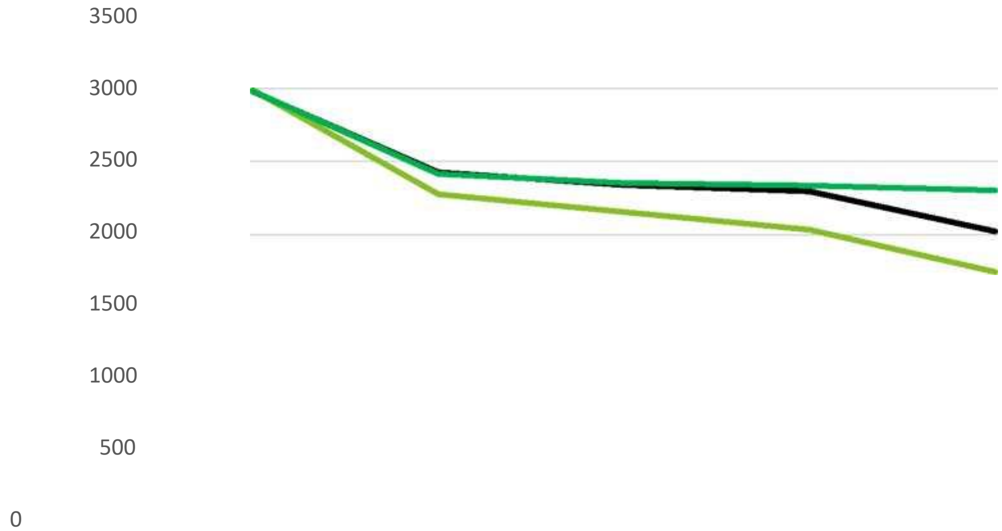
Figure 12: Carbon intensity of GDP (tonnes CO_2 million) – 1.5 °C scenarios



	2030	2035	2040	2045	2050
ElecEE 1.5 °C	512,34	195,77	97,62	41,37	28,57
NC 1.5 °C	508,15	191,73	100,33	41,96	30,44
NC_var 1.5 °C	508,13	179,51	101,76	44,30	29,26

Source: (B) EST model, E3Modelling

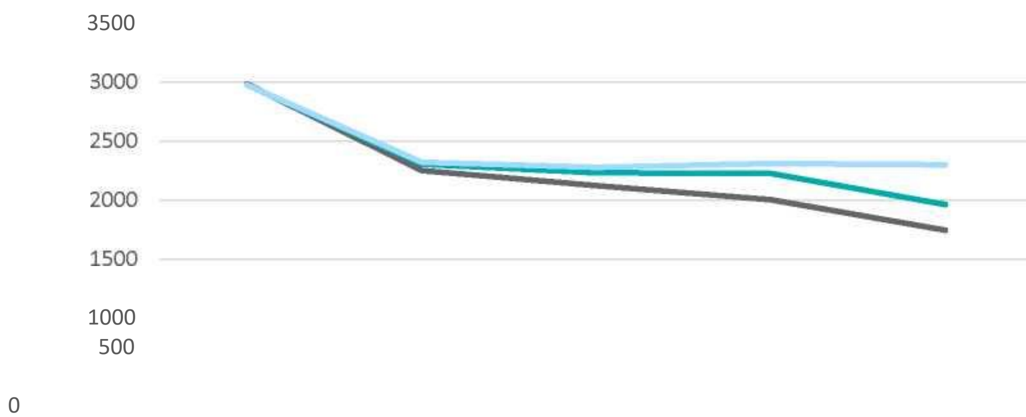
Figure 13: Energy intensity of GDP (in MWh million) – 2 °C scenarios



	2030	2035	2040	2045	2050
ElecEE 2 °C	2985,19	2274,93	2154,29	2033,83	1745,46
NC 2 °C	2977,98	2424,38	2338,80	2293,98	2020,96
NC_var 2 °C	2979,42	2414,34	2352,83	2335,28	2301,14

Source: (B) EST model, E3Modelling

Figure 14: Energy intensity of GDP (in MWh EUR million) – scenarios of 1.5 °C



	2030	2035	2040	2045	2050
ElecEE 1.5 °C	2984,76	2250,39	2122,65	2004,00	1744,56
NC 1.5 °C	2977,36	2304,49	2231,78	2226,54	1963,31
NC_var 1.5 °C	2976,89	2320,64	2277,16	2309,51	2300,27

Source: (B) EST model, E3Modelling

D. Imports of electricity and fuels

The energy transformation will have a huge impact on fuel imports. The percentage decrease in net imports varies depending on the scenario. The 2 °C NC scenario shows a decrease of around 19 % in net imports in 2050 (compared to 2030), while the NC_var scenario for 2 °C shows a decrease to 43 % (over the same period). Net solid fuel imports are expected to fall to almost 0 and oil imports to decrease by 7791 % depending on the scenario.

The model predicts a dramatic increase in net imports of biomass and waste, from close to 128 % for NC_var for 1.5 °C to almost 700 % in the ElecEE scenario for 1.5 °C. This is due to the fact that the ElecEE scenario foresees high levels of electrification, together with the impossibility to introduce new e-fuel types. As electrification will not be feasible in all markets (e.g. aviation or maritime transport), imports of biomass will be necessary. Similar effects are expected to occur in the NC scenario, albeit of a lower magnitude.

Exports of electricity do not exist in every scenario, except in the NC_var scenarios, which foresee that nuclear energy will still be produced.

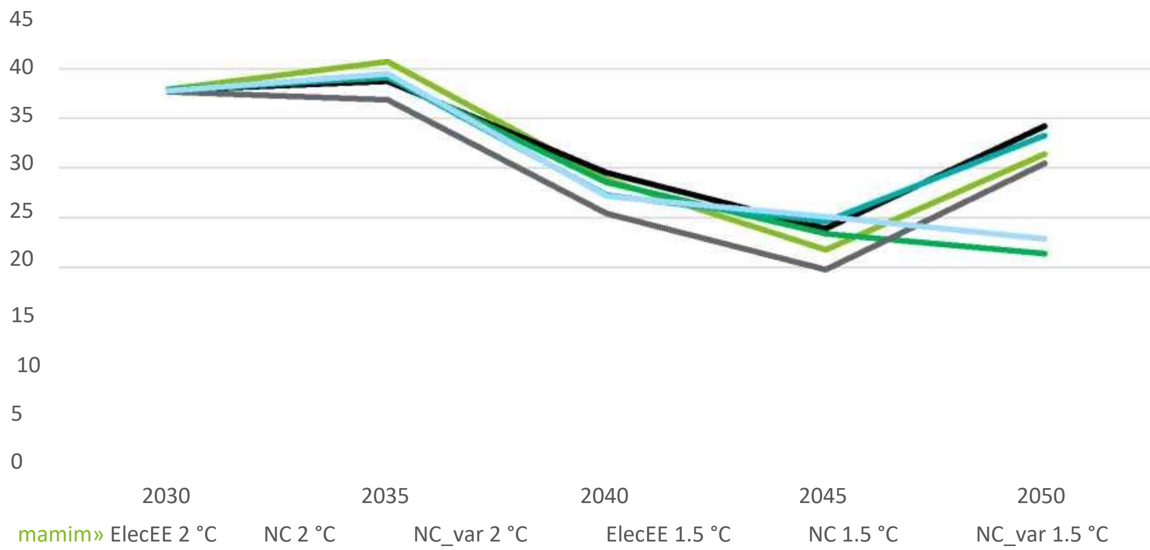
Table 22: Net fuel imports in 2050 compared to 2030

	ElecEE 2 °C	NC 2 °C	NC_var 2 °C	ElecEE 1.5 °C	NC 1.5 °C	NC_var 1.5 °C
Net Imports (GWh)	— 35.95 %	— 19.34 %	— 42.74 %	— 37.88 %	— 23.76 %	— 38.78 %
Solid fuels	— 99.747 %	— 99.713 %	— 99.724 %	— 99.752 %	— 99.748 %	— 99.752 %
Petroleum	— 77.53 %	— 79.60 %	— 77.00 %	— 90.43 %	— 90.74 %	— 89.76 %
Natural gas;	12.89 %	60.48 %	23.84 %	23.95 %	67.59 %	53.78 %
Electricity	no exports, no imports	no exports, no imports	exports maintained at 8 TWh, no imports	no exports, no imports	no exports, no imports	exports maintained at 8 TWh, no imports
Biomass and waste	512.55 %	236.47 %	244.30 %	699.56 %	133.01 %	127.74 %

Source: (B) EST model, E3Modelling

All six scenarios are expected to reduce Bulgaria's import dependency by 2045. From the initial 37 % in 2030, the model projects import dependency to fall to 1926 % in 2045, depending on the scenario. However, between 2045 and 2050, four scenarios are expected to recover to above 30 %, with the two NC_var scenarios showing a further decrease. This is due to the fact that the NC_var scenarios foresee the maintenance of nuclear energy as part of the energy mix.

Figure 15: Import dependency, comparison of six scenarios

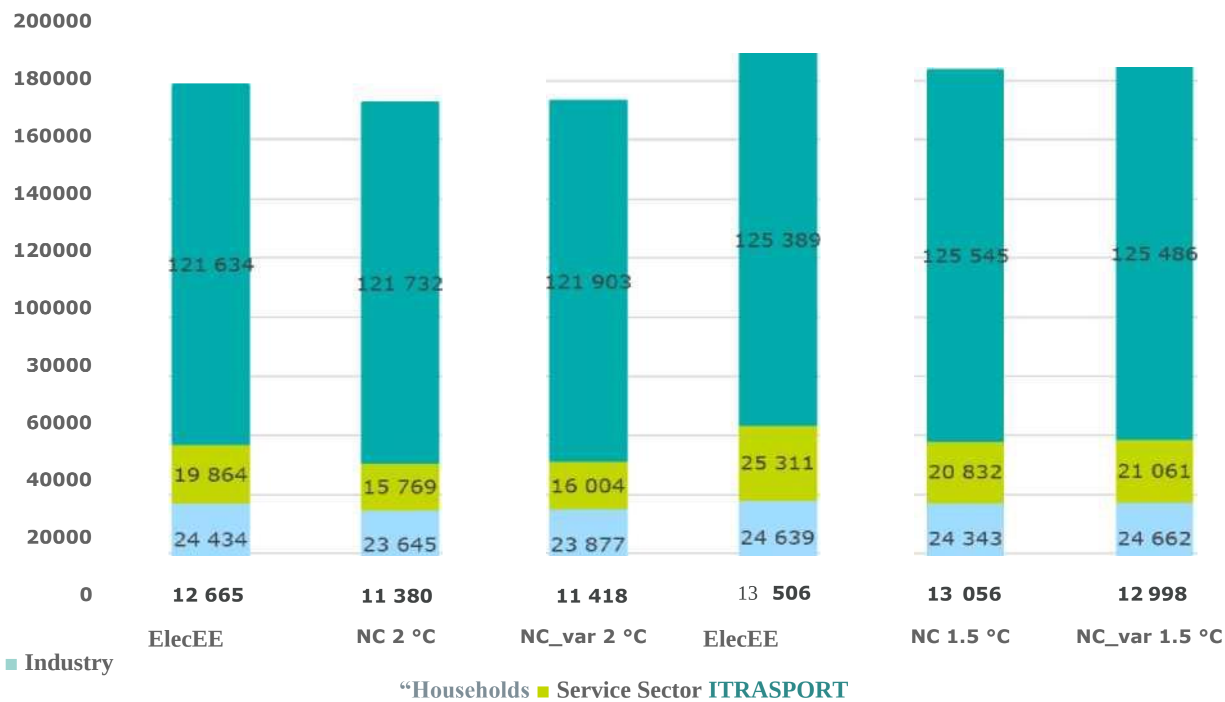


Source: (B) EST model, E3Modelling

E. System costs

Depending on the scenario, system costs between 2030 and 2050 ranged between EUR 172 billion (NC_var for 2 °C) and EUR 189 billion (ElecEE for 1.5 °C). For each scenario, approximately 2/3 of the expenditure belongs to transport, 1314 % to households and 67 % to the industrial sector.

Figure 4: Total system costs between 2030 and 2050 (EUR million), comparison of six scenarios



Source: (B) EST model, E3Modelling

In terms of sectoral impacts, the energy transition is expected to benefit the construction, manufacturing and related sectors, i.e. services. On the other hand, the coal industry will be reduced and utilities will suffer delays due to energy efficiency measures. The impact on the oil and gas sector will be moderate as they are less carbon-intensive.

7.2. Social impact

A. Employment, job creation and labour

Based on IRENA estimates, the energy[14] transition is expected to have a net positive effect on employment levels. In Bulgaria, the unemployment rate stood at around 4.2 % at the end of[15] 2019, mainly in construction and manufacturing. This rate is expected to fall in the future as a result of overall economic growth due to the green transition.

In general, the transition is expected to mitigate job polarisation and favour medium-skilled and medium-paid STEM (Science, Technology, Engineering and Mathematics) skills.[16] Skills predicted most in demand are teamwork, problem-solving, customer awareness, autonomy and IT literacy. However, different skill levels will be affected at the different stages of the process. Overall, demand for less skilled labour will

[14] IRENA. 2019 Perspectives for the Energy Transition: Investment Needs for a Low-Carbon Energy System. *International Energy Agency. International Renewable Energy Agency, Paris, Bonn*, 2017.
[15] National Statistical Institute of Republic of Bulgaria; https://www.nsi.bg/en/content/6503/unemployed-and-unemployment-rates-national-level-statistical-regions-districts.
[16] Czako, V. Employment in the Energy Sector Status Report 2020. *Publications Office of the European Union, Luxembourg*, 2020.

increase over time. This is particularly true for waste management and circular economy sectors. It should be noted, however, that in later stages of the transition automation can turn the process and direct demand back to a highly skilled workforce.

It must also be stressed that the positive impact on employment will not be extended to all sectors. The fossil fuel industry will experience a significant reduction in employment.

Another major obstacle (to be tackled in a timely manner) is skills mismatch. 21 out of 27 countries surveyed by the ILO in 2018 identified large imbalances between supply and demand for the transition.17

The country has the tools to address both issues. The country must consistently implement education and reskilling/upskilling programmes. This can be done in partnership with the private sector, i.e. the #Skills4Climate Coalition, which aims to stimulate policy action to address the skills gap in the construction sector. At the same time, to expand and further integrate environmental education through extracurricular forms of training on climate change. This will lead to more environmentally friendly citizens, with a double impact on the economy – a transition in labour supply and demand for consumer goods.

B. Human well-being

The development of green energy reduces the externalities associated with the impact of non-renewable energy use on human health and climate, mainly by reducing air pollution.

Human health and well-being are closely linked to the state of the environment. Good ambient air quality is a critical component for a healthy living environment, with a direct impact on the health, comfort and working ability of the population. Systemic exposure to elevated levels of atmospheric pollutants directly or indirectly provokes a range of undesirable effects, from minor functional disturbances to the occurrence of serious organ and system diseases.

Exposure to polluted air has been found to cause more than 400 000 premature deaths in the EU every year. For Bulgaria, exposure to fine particulate matter (PM 2,5) and ozone alone is estimated to account for approximately 9 % of all deaths in 2019 (over 11 000 deaths), which is higher than the EU average (4 %).

IRENA estimates that the health benefits of the green transition alone are 2 to 6 times the systemic costs of decarbonisation. The impact on health is the result of improvements in air quality due to the limitation of fossil fuel combustion. The positive impact on health will result in lower healthcare expenditure, amounting to 8.4 % of Bulgaria's GDP in 201718. Other aspects of the transition that have a positive impact on health are the improvement of heating systems and insulation in buildings. The transition is expected to slightly increase the birth rate and reduce energy poverty, both of particular relevance for Bulgaria.

Figure 17: Costs and reduced externalities of decarbonisation, 2050

USD trillion/yr

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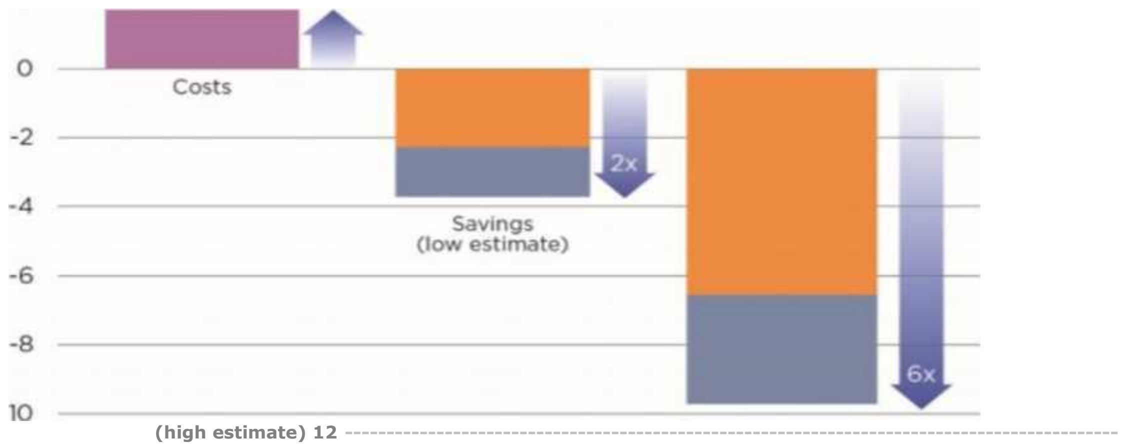
[17] (See 21).

[18] OECD. Health expenditure in relation to GDP. In: Health at a Glance: Europe 2018: State of Health in the EU Cycle. *OECD Publishing, Paris*, 2018.



Key message• Benefits from reduced externalities removed the costs of decarbonisation by a factor between two and six in 2050. Health benefits from reduced air pollution health alone removed the costs.

Source: IEA, IRENA. Perspectives for the Energy Transition: Investment Needs for a Low-Carbon Energy System. International Energy Agency. International Renewable Energy Agency, Paris, Bonn, 2017.

C. Household consumption and expenditure pattern

The transition will also affect household consumption patterns and expenditure. In terms of greenhouse gas emissions, food and transport consumption accounts for the largest share of household consumption. Due to the growing awareness and policies implemented, the negative environmental impact of food consumption is expected to decrease, mainly as a result of decreasing consumption of meat and animal products.19

As regards transport, the roll-out of electric cars, the construction of recharging infrastructure and shared travel are expected to be some of the main drivers of the transition to green consumption. This will be the result of a combination of market trends (falling prices and the increasing availability of electric and rental vehicles) as well as fiscal factors (increased taxation on jet fuel).

Increased consumption of energy-efficient equipment and housing will lead to a reduction in household energy consumption, a key factor for a successful green transition. At the same time, the EU regulatory pressure to implement circular economy solutions is expected to drastically reduce the consumption of single-use products and favour reusable or repairable goods20. On the other hand, the growing popularity of the shared economy and product-to-service models can significantly transform the products and equipment owned by households. This should prove useful in terms of waste generation (in particular WEEE), as these consumption patterns incentivise producers to prolong the life of the products they produce.

Total household expenditure is expected to increase as a result of higher real disposable income. The change is likely to be caused by reduced income taxes (which is the result of increased government revenues from the carbon price – double dividend effect) and reduced energy costs in the long term (as reported and analysed by the International Renewable Energy Agency (IRENA)). Global energy transformation: The ReMaP transition pathway (Background report to 2019 edition). Abu Dhabi, 2019).21

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[19] Swedish Environmental Protection Agency. Transition to sustainable consumption alternatives. *Naturvårdsverket, Sweden*, 2017.
[20] Cordella, M., Alfieri, F., Sanfelix, J., Analysis and development of a scoring system for repair and upgrade of products – Final report. *Publications Office of the European Union, Luxembourg*, 2019.
[21] International Renewable Energy Agency (IRENA). Global energy transformation: The ReMaP transition pathway

7.3. Energy system

A. Impact of existing policies and measures

Most of the Bulgarian energy system, like in other European countries, is based on fossil fuels. However, due to current policies and measures, this situation is changing as the increasing number of renewables drives the electrification of the energy system at all levels, from residential to industrial.

Key policy documents on the energy system are the National Integrated Energy and Climate Plan 2030 and the Third National Climate Action Plan. Current policies and measures aim at reducing losses, increasing efficiency and reducing emissions in the energy system.

Measures and policies aimed at reducing losses:

- Reducing heat network losses;

  Result: 1 000 GG$_{CO_2}$e, calculated annual reduction for 2020, 2025 and 2030.

Measures and policies aimed at increasing efficiency:

- Increase of high-efficiency cogeneration.
  Result: 200 GG CO_2e, calculated annual reduction for 2020, 2025 and 2030.
- Improving production efficiency in existing coal-fired power plants.
  Currently, the average emission intensity of electricity generation from coal-fired power plants is 1,2 tonnes of CO_2e/MWh. Through measures to improve production efficiency, this factor can be reduced and is planned to be reduced by existing coal-fired power plants.
- Institutional support for investments in emission-free power generation facilities: nuclear power stations, and

Measures and policies aimed at reducing emissions:

- Refurbishment of cogeneration and central heating boilers with natural gas turbines.
  Result: 950 GG CO_2e, calculated annual reduction for 2020, 2025 and 2030.
- Fuel replacement from coal to natural gas.
  Result: 2 700 GG$_{CO_2}$e, calculated annual reduction for 2020, 2025 and 2030.

(Background report to 2019 edition). *Abu Dhabi*, 2019.

Table 23: Existing policies and measures in the energy sector

Measure	Relevant objective and/or activities	Greenhouse gases	Estimated reduction effect (per year, in Gg CO2c.)		
			2020	2025	2030
Refurbishment of cogeneration plants and natural gas turbine central heating boilers	Production of low-emission electricity	CO_2	950	950	950
Reduction of distribution and transmission network losses	Reduction of electricity losses	CO_2	1 100	1 000	1 000
Reduction of heat network losses	Reduction of heat losses	CO_2	1 000	1 000	1 000
Biomass for electricity and heat production	Renewable electricity	CO_2	600	600	600
Improving the efficiency of production in existing coal-fired power plants	Increase silo energy efficiency	CO_2	466	585	585
Fuel replacement – from coal to natural gas	Reducing emissions through fuel replacement	CO_2	2 700	2 700	2 700
Institutional support for investment in emission-free power plants: nuclear energy	Production of low-emission electricity	CO_2	—	—	—
Increase of high-efficiency cogeneration	More efficient electricity production	CO_2	200	200	200
Increasing the share of renewable energy for heating and cooling	Promoting renewable energy production	CO_2	61	66	70

While current policies and measures contain only obligations and targets until 2030, Bulgaria is expected to continue its decarbonisation work, as defined by current policies and measures, but more intensively. This will further support economic growth, energy consumption and greenhouse gas emissions.

In order to develop measures to achieve a 80 % reduction in greenhouse gas emissions by 2050, please refer to Chapter 5 above.

B. Projected emissions

By 2050, a continued decline in CO2 emissionsfrom energy production is expected, reaching even negative figures in 2050, meaning that the sector will generate negative net CO_2 emissions for at least three of the scenarios analysed. This decline will be mainly driven by an increase in the share of renewable energy. Therefore, the main drivers for decarbonisation in the energy production sector are related to the further recovery of renewable energy and the phasing-out of fossil fuels, the development and deployment of storage solutions, and the smartness and flexibility of the grid to support the integration of renewable energy.

For further developments on the future emission trajectory, please refer to Chapter 6.

C. Emission reduction options

Reducing final energy consumption and improving the efficiency of the energy system

Reducing final energy consumption and improving energy efficiency also leads to a reduction in primary energy consumption. An overall reduction in energy consumption is an effective way of realising the environmental, social and economic benefits of reducing emissions.

Due to its cost-effectiveness, energy efficiency is the first step towards reducing emissions.

Increasing the use of carbon-free energy sources

According to the integrated national energy and climate plan of the Republic of Bulgaria, the share of energy from renewable sources in net electricity production is almost equal to nuclear energy and the two together account for more than half of the total net electricity production.

Carbon capture and utilisation

Another option to reduce emissions as it is relatively easy to integrate into the existing energy system is carbon capture and utilisation (CCS). It can be used to reduce greenhouse gas emissions. As natural gas is expected to remain in the energy mix beyond 2030, its share of electricity production may increase significantly.

CCS can also become an important opportunity to consider because of its link with biomass. In the case of bioenergy from carbon capture and storage (BECCS), bioenergy is extracted from biomass while capturing and storing the carbon. The process can be considered useful as biomass during growth or cultivation can act as a sink.

D. Expected progress in the transition to a low greenhouse gas emission economy

Electricity consumption

By 2050, the use of fossil fuels must be replaced by e-liquid fuels or other fuels from the energy system. Although natural gas is becoming an important fuel for Bulgaria’s transition, in the long term it can be partially replaced by e-gas. Changes in the energy mix lead to improved energy security.

Solar thermal, geothermal and environmental energy are expected to be rather limited in the energy mix.

Production of electricity

Significant changes in the energy mix in Bulgaria are expected by 2050. The transition started in 2020 but will intensify after 2030. The electrification of the energy mix is a dominant process.

In addition to electricity production, the use of biogas is expected to evolve and approach natural gas consumption. Other RES are increasing, but at a slower pace. Solar and wind energy is expected to grow more slowly. The integration of renewable energy production also reinforces the need for adequate energy storage, especially given the increase in electricity consumption. The amount of electricity stored is expected to increase significantly by 2050. Electricity storage helps to further increase the share of renewable energy in the energy mix as it helps to balance fluctuations in availability.

While CCS is considered an opportunity for decarbonisation, its role in Bulgaria by 2050 is expected to be still very limited. Other sources of balancing renewable energy, such as wind, solar, biomass, are expected to be more competitive and more widespread.

Research & development

Research, development and innovation policies and measures in the field of energy are expected to continue and intensify in the years after 2030, aiming again to foster scientific excellence in the application of innovative energy technologies, including clean energy technologies and the efficient use of energy in final consumption.

In order to achieve a sustainable transition, it is vital to ensure the competitiveness of the sectors affected by the measures and policies. One of the policy objectives of creating good conditions for the development and use of advanced biofuels, renewable liquid and gaseous fuels of non-biological origin and recycled carbon fuels is to achieve sustainable growth and a competitive economy.

Bulgaria plans to participate and develop programmes to promote scientific achievements in the application of innovative energy technologies, such as partnerships in Horizon Europe, and to increase flexibility or security in the internal energy market, e.g. through the FLEXITRANSTORE, INTERRFACE, SDN-microSENSE, FORESIGHT, EnergyShield, X- FLEX, FARCROSS and TRINITY programmes. The mentioned programmes are described in more detail in the PECP.

National scientific programmes of the Ministry of Education and Science – Low Carbon Energy for Transport and Household (EPLS) and Environmental Protection and Risk Reduction of adverse events and natural disasters are currently being implemented. The Ministry of Education and Science generally supports project initiatives (exploration of gas hydrate deposits in Bulgarian waters of the Black Sea; study of RES in Bulgaria) and implements a policy for the development of scientific infrastructure through the National Roadmap for Scientific Infrastructure. Its infrastructure and professional capacity will have a lasting impact on a range of scientific areas and research – circular use of water, waste, energy, obtaining valuable resources from waste, management of risk biological and environmental factors, etc.

7.4. Transport

A. Impact of existing policies and measures

The main strategy document in the field of transport is the Integrated Transport Strategy for the period up to 2030. The strategy outlines the main guidelines for the development of the national transport system until 2030. The mission of the transport sector is to ensure efficient, effective and sustainable transport, maintain balanced regional development and support Bulgaria's full integration into European structures.

The sustainable development of the transport sector is a key objective for Bulgaria. Sustainability is defined as a minimal external effect and creates current and future consumption. The transport sector makes a major contribution to greenhouse gas emissions, therefore a focus on integrated and sustainable development, including public transport, is key to addressing the aforementioned negative impacts.

A key priority of the European Green Deal for the transport sector is the shift of 75 % of inland road freight to rail and inland waterways. This requires the introduction of strong incentives for the development of environmentally friendly modes of transport. In order to achieve these objectives and to increase the efficiency of the transport system, the National Plan for the Development of Combined Transport in the period up to 2030 has been drawn up and approved by the Council of Ministers.

The national strategy papers, which are also relevant to transport and are currently in force, are the National Development Programme: Bulgaria 2030, the National Regional Development Strategy of the Republic of Bulgaria for the period 2012-2022 and the National Reform Programme. These strategic documents point to the direction of reducing transport-related greenhouse gas emissions by increasing the level of renewables in the fuel mix.

For Bulgaria, the development of the transport system is linked to increasing territorial cohesion and reducing regional disparities. In addition to the national objectives, Bulgaria's integration into the European transport system is also a key objective, for which a number of measures have already been put in place.

In summary, Bulgaria's strategic objectives in terms of transport system:

- Increasing the efficiency and competitiveness of the transport sector;
- Improving transport connectivity and accessibility (internal and external);
- Limiting the negative effects of the development of the transport sector.

Table 24: Existing policies and measures in the transport sector

Measure	Relevant objective and/or activities
Development of a concept, strategy and plan for the purchase of rolling stock (locomotives, freight wagons and passenger coaches) and upgrading of the existing condition meeting interoperability requirements, taking into account the specificities of the rail system.	Improve structure to car park c automotive transport, rolling stock in rail, aviation means, the maritime and river fleet

Drawing up and implementing uniform national minimum requirements for the maintenance and repair of freight wagons, passenger coaches and locomotives, and drawing up new administrative regulations for the repair and maintenance of each type of freight wagon, passenger wagon and locomotive placed in service and adjusting the current ones if they conflict with the TSI.	
Taking concrete actions aimed at improving the financial situation of commercial companies and state-owned companies railway companies.	
The renewal of port machinery and the creation of new technologies for the provision of services.	
Rationalisation of the rail network.	Improvement of infrastructure quality and parameters

Implementing measures to improve the energy efficiency of buildings.	(road, rail, airports, ports)
Promoting the use of biofuels and other renewable fuels in transport.	Promoting the use of alternative fuels

Using European and other funds to finance energy efficiency measures in transport.

Development of transport schemes and technologies meeting modern environmental and climate requirements.	Reducing harmful emissions from transport
Find the right formula and balance state and municipal interests with the societal need for a new and ecological urban environment and rethink the concept of forms of use of ports located in the hinterland of cities.	Reducing noise pollution
Introducing and promoting the use of fuels and energy from alternative and renewable sources.	Limiting the negative impact of transport on environment and health of common
Developing and promoting the use of hybrid and electric vehicles.	

Exemption from annual tax for electric cars and electric motorcycles and mopeds.

Encouraging the purchase of electric vehicles by reducing the consumer charge by 30 % (by BGN 44 compared to the current charge for a new car).

Encouraging the purchase of hybrid cars by reducing the consumer charge by 15 % (depending on age — BGN 22 to BGN 40 compared to conventional car charges).	Promoting the deployment of electric vehicles in transport

Use of the scheme to promote the use of electric vehicles implemented under the Climate Investment Programme of the National Trust Fund (operational since 2016).

Introduction of the right to free parking in the city centre (already in place in several municipalities in the country).

Use of electric buses in urban transport.

Introduction of an electric car sharing system Spark – as of October 2017

Implement a plan for the systematic deployment of charging infrastructure in the urban agglomeration.

In-use energy consumption standards (applicable not only on first registration but also on subsequent sale/registration of vehicles).

Emission standards for road vehicles (applicable not only on first registration but also on subsequent sale/registration of vehicles).

Introduction of access areas (especially in city centres) with only energy-efficient and low-emission efficient vehicles.

Progressive taxation promoting the use of energy-efficient and low-emission vehicles.

Direct subsidies for the purchase of new zero-emission vehicles (valid for a limited number/duration, until a minimum critical mass of vehicles is reached).

Tax credits for the purchase and use of zero-emission vehicles at the point of use (valid for a limited number/duration, until a minimum critical mass of vehicles is reached).

Access to bus lanes for zero-emission vehicles at the point of use (valid for a limited number/duration, until a minimum critical mass of vehicles is reached).

Use of electric vehicles for public administration and local authorities.

Incentivising the uptake of services for the shared use of zero-emission vehicles.	
Incentivising the passage of taxi companies and public transport operators towards the use of zero-emission vehicles.	
Direct investment.	
Fiscal stimulus: application of special tariffs for connection to the electricity distribution and transmission networks.	Deployment of recharging infrastructure for electric vehicles

Administrative facilities.	

A key objective is to promote the deployment of electric vehicles in the transport system. This measure is expected to have a significant effect after 2020. Most of the measures described above are financial measures supporting the deployment of electric vehicles. In addition to the final measures, infrastructure changes are required. This is addressed by additional financial incentives supporting the connection to the electricity distribution and transmission networks.

In order to develop measures to achieve a 80 % reduction in greenhouse gas emissions by 2050, please refer to Chapter 5. above.

B. Projected emissions

The transport sector is the second most significant source of CO_2 emissions and currently accounts for more than 85 % of total CO_2 emissions for the sector. However, emissions are expected to fall by 2050 KTH by 9,900. Co_2 to just over 3 000 KTH. Co_2, even in the worst-case scenario. The main drivers of decarbonisation in the sector relate to electrification, the development of biofuels and hydrogen, the improved efficiency of urban transport systems and the increase in the share of low-emission vehicles. All these measures are confirmed by the increasing share of RES-E.

For projections of future emissions in the transport sector, please refer to Chapter 6. above.

C. Emission reduction options

Reduction of traffic

Reducing traffic is an effective way to reduce fuel consumption. Increasing the number of drivers starting to use urban transport means reducing emissions. Furthermore, as some motor vehicles are in lower emission categories, the Bulgarian government plans to introduce higher Euro type vehicles. The modernisation of the car fleet is an important objective set out in the National Air Pollution Control Programme (2020-2030).

Policies and measures on time- and distance-based road charging were introduced in 2019. Such policies and measures will provide additional opportunities for decarbonisation. Limiting lower emission zones also contributes to reducing emissions. The low emission zones introduced by the National Air Pollution Control Programme will limit the access of drivers of non-Euro I and non-Euro I vehicles (many of which are diesel vehicles) to urban centres. Similar measures to those described in the programme are expected to continue beyond the 2020-2030 programming period.

Use of electric and other environmentally friendly vehicles

An obvious option for decarbonisation is to encourage the use and therefore production of electric and other environmentally friendly vehicles. In order to achieve an appropriate deployment of non-fossil fuel vehicles, awareness-raising campaigns are needed.

In addition to increasing the consumption of electric and other environmentally friendly vehicles, the construction of the necessary infrastructure must also be accelerated.

As an alternative to electric vehicles, e-fuels are also considered as decarbonisation options. However, their abatement potential strongly depends on the source of CO_2used for their production. Since both e-fuels and advanced biofuels can be used in conventional vehicles using the current charging infrastructure, they are considered as real alternatives to petrol and diesel.

Infrastructure optimisation and improvement

Rehabilitation and modernisation of existing infrastructure, including railways and roads, would ensure optimal vehicle speed and traffic modes, contributing to reducing emissions when railway lines are available, reducing electricity losses and fuel consumption. Optimising traffic control and management with intelligent systems would allow optimal use of infrastructure, thus helping to reduce emissions.

Promotion of alternative modes of transport

The development of the current cycling infrastructure and the construction of a new one would allow more people to choose Velritation. Cycling is also an effective opportunity to decarbonise urban transport systems. A municipal cycling system would serve as an alternative for short distance travel of vehicles and would support the creation of low emission zones.

Changes in the public transport system

The third National Climate Action Plan and the INECPs consider public transport to be an important factor in reducing emissions.

Electrification of public transport takes place through the development of rail transport, the construction of relevant infrastructure, the development of trolleybus, tramway and metro transport. In addition to the use of greener alternatives to fossil fuel trains, increasing the use of public transport by creating favourable conditions will contribute to increasing the added value of transport activity by reducing transport costs per unit of GDP.

Multimodal solutions

Multimodal solutions are now gaining ground around the world. The deployment of intelligent transport systems will enable information-driven shared transport solutions that would improve transport management and contribute to reducing emissions.

Multimodal solutions can be the most efficient in freight transport. The modernisation of rail infrastructure, combined with regional integration, would contribute significantly to the development of a low-carbon freight transport system.

D. Expected progress in the transition to a low greenhouse gas emission economy

Passenger transport

Significant changes in passenger transport are expected by 2050. Although passenger transport is expected to increase, emissions are expected to decrease as a result of policies and measures.

The share of alternative vehicles, such as electric battery, plug-in hybrids, biofuel and fuel cell vehicles, is expected to be relatively high by 2050.

Rail is expected to increase, as part of general public transport, due to a change in traffic mode stimulated by pricing schemes introduced to internalise the external costs of all modes of transport.

Aviation activity is expected to increase in the future. Decarbonisation of air transport is a challenge, but biokerosene is expected to provide a remarkable share of energy consumption in 2050.

Freight transport

Domestic freight traffic is expected to increase by 2050. The impact of decarbonisation policies on overall freight traffic is expected to be limited. However, a reduction in road freight is expected. Complementing supporting policies, promoting Cooperative Intelligent Transport Systems (C-ITS) and improved logistics are expected to contribute to the decarbonisation of freight transport.

Alternative fuels will also dominate freight transport. The share of vehicles with electric batteries, plug-in hybrids and other unconventional vehicles is expected to increase in 2050.

For heavy goods vehicles, moderate uptake of alternative propulsion methods is expected due to technical uncertainties. However, low-carbon fuels, especially e-fuels and biofuels, are expected to be present in the mix. This is expected to require significant changes to the refuelling infrastructure.

Research & development

Although the significant changes described above are expected in the transport system, their security is lower than decarbonisation measures in other sectors. Technical uncertainty can alter these possibilities and lead to very different results, especially in freight and air transport. However, electrification of passenger vehicles seems feasible in 2050.

Fuel types

Like other sectors, electrification is expected to be a key theme in the transport sector. For buses, rail rolling stock and passenger cars, the share of electric vehicles is expected to be significant. This change requires the implementation of major infrastructure projects aimed both at building the network and at improving charging systems.

The share of e-fuels is also expected to increase by 2050. Freight transport is expected to be e-gas driven.

For gas, a gradual decarbonisation of supply is needed.

Biokerosene can become an important fuel for air transport. It is important to mention that in aviation, the technical uncertainties described above are of the utmost importance. Forecasts also show the possible use of e-liquid fuels in air transport as well as inland freight transport due to their high energy density and the possibility of direct use in conventional vehicles.

7.5. Heating and cooling and buildings sector (residential and tertiary)

A. Impact of existing policies and measures

Existing policies and measures in the heating, cooling and buildings sector are presented in the National Air Pollution Control Programme (2020-2030) and the Energy Strategy of the Republic of Bulgaria until 2020.

The impact of existing policies and measures is expected to cause a decline in energy intensity and final energy consumption. Currently, the policies put in place set mandatory measures, such as energy efficiency audits and certification, mandatory measures, inspection of equipment and energy performance requirements. Due to substantial legal obligations, the price of electricity can be considered to have less impact on consumption.

Table 25: Existing policies and measures in the heating and cooling and buildings sector

Measure	Relevant objective and/or activities	Greenhouse gases	Calculated reduction effect (per year, in Gg CO2c.)		
			2020	2025	2030
Household gasification	Households and public buildings	CO_2	2 500	2 500	2 500
Solar collector installation	Households and public buildings	CO_2	20	25	40
Development and phased implementation of a national programme for '1 000 solar roofs'	Promote the use of renewable sources	CO_2	17	14	14
Implementation of the measures of the National Accelerated Gasification Programme (NAP) of the Republic of Bulgaria	Reduce the energy intensity of final consumption	CO_2	370	310	310
Renovation of state-owned and municipal buildings (with a total floor area of more than 250 m²) up to the annual percentage rate following the entry into force of the Energy Efficiency Directive	Improve the energy efficiency of municipal housing	CO_2	25	26	26
Introduction of a mandatory energy efficiency scheme (reduction of fuel and energy consumption in final energy consumption)	Improve energy efficiency	CO_2	18	18	18
Replacement of obsolete and inefficient energy production equipment with new	Improve energy efficiency	CO_2	9	9	9

For measures to achieve a 80 % reduction in greenhouse gas emissions by 2050, please refer to Chapter 5.

above.

B. Projected emissions

Projections for emissions in the residential sector point to a significant decrease inCOF emissions in each scenario analysed, including a reduction of just over 800 KTH. Co’ up to 59 KTH. The most pessimistic scenario until 2050. This significant dropin emissions will be mainly due to the successful introduction of the Long-term Innovation Strategy (introducing and developing measures and policies, including in the Long Term Innovation Strategy 2014-2020[22]). Energy efficiency will be the most important factor in reducing CO emissionsby 2050. Other important reasons for decarbonisation in the heating and cooling sector are the use of solar and geothermal energy, the development and deployment of heat pumps.

For more information on emission projections in the heating, cooling and building sector, please refer to Chapter 6.

C. Emission reduction options

Isolation

Insulation is an effective way to improve the energy efficiency of a building. In addition to the new lockdowns currently in place, new high-performance technologies are expected in the future.

Effective equipment

Improving energy efficiency is considered an efficient way to reduce energy consumption in buildings. Since Bulgaria is one of the countries where future warming conditions are significantly more extreme, the efficiency of air conditioning systems is an important problem. Legislation, such as environmental and environmental labelling policies, could support targeted consumer choices aimed at reducing energy consumption and improving energy efficiency.

Fuel change

Renewable energy can be used efficiently in heating and cooling. The level of deployment of renewable energy for heating and cooling can be supported by policies and measures. As heating and cooling account for a significant share of total energy consumption, decarbonisation of fuel supply is vital.

Innovation

Nearly zero-energy buildings and smart buildings use technical solutions to reduce energy absorption. In addition to lower energy consumption, smart buildings have additional benefits in terms of their ability to interact with the energy system. Smart buildings enable better energy management, lower energy costs and other societal benefits, for example by supporting independent living for the elderly.

D. Expected progress in the transition to a low greenhouse gas emission economy

Energy consumption

Although human self-awareness is expected to be a leading factor in consumer behaviour, energy

[22] Annex 6 of the National Energy Efficiency Action Plan 2014-2020

consumption with regard to small household appliances is expected to increase by 2050. This is mainly due to the increase in the number of appliances in each household. On the other hand, consumer behaviour, together with better insulation and more efficient electrical equipment, leads to a decrease in energy consumption for domestic heating in the residential and tertiary sectors. Due to higher economic activity, decreases in the services sector are expected to be lower than in the residential sector.

Fuel mix

Electricity is expected to be the main fuel for heating and cooling and the buildings sector. Electrification is predominant in residential space heating sectors, especially with regard to heat pumps. Electricity consumption in the services sector is also expected to increase by 2050 due to the above-mentioned effects. The expected increase in electricity consumption is also driven by the potential growth of its applications.

Electricity consumption in Bulgaria is expected to increase by 2050. The services sector is expected to show an even stronger trend. The heating of the rooms with electricity is expected to increase by 2050.

Fuel consumption of buildings, excluding electricity

Oil and coal are expected to leave the fuel mix completely by 2050. Non-electric fuels can include natural gas, biogas, e-gas, hydrogen, solid biomass, district heating and other RES.

Research & development

Research and development is expected to intensify in the areas of smart buildings, insulation and space heating and cooling, especially for the services sector. As mentioned for the energy system, storage will be an important area for research and development. However, the technology alone cannot support the intended emission reductions. In order to ensure a change in consumer behaviour, energy awareness needs to be raised.

7.6. Waste

A. Impact of existing policies and measures

In recent years, Bulgaria has focused on reducing methane emissions from landfills by, inter alia, limiting the disposal of municipal waste and the renovation of closed landfills; and the management of the collection and treatment of municipal waste.

The main policies and measures in the waste sector are set out in the Waste Management Act 2012, the National Strategic Plan for the gradual reduction of the quantities of biodegradable waste destined for landfilling (2012-2020), the National Strategic Plan for the Management of Sludge from UWWTP (2012-2020), the Regulation on the collection of bio-waste and the treatment of biodegradable waste, the Third National Climate Change Action Plan (2013-2020) and the National Waste Management Plan of the Republic of Bulgaria (2021-2028) and the Strategy for the Transition to a Circular Economy 2021-2027.

The Waste Management Act 2012 requires to reduce the amount of biodegradable municipal waste by up to 35 % by 31 December 2020 compared to 1995. Similar quantitative targets have been set for diverting biodegradable municipal waste from landfills.

Table 3: Existing policies and measures in the waste sector

Measures	Objectives and/or activities indicated	Greenhouse gases	Estimated reduction effect (annual, in Gg_{CO2}-eq.)		
			2020	2025	2030
Biogas capture and combustion in all new and existing regional landfills	Waste methane and electricity generation	CH_4, CO_2	634	634	634
Construction of mechanical and biological treatment plants and plants	Management of waste	CH_4	728	728	728
(MBT) for the treatment and recovery of compost and biogas					
Introduction of anaerobic stabilisation of sludge through the capture and combustion of biogas in new plants and plants being reconstructed in agglomerations with more than 20 000 population equivalent	Management of waste	CH_4, CO_2	128	128	128

According to the Third National Climate Action Plan (2020-2013), by 2020 all regional landfills for municipal waste will be equipped with biogas capture and incineration plants. The total reduction of installations is expected to result in 5 070 122 tonnes of CO_2– eq. by 2020.

Additional policies shall focus on the following:

- differentiated fees for waste generated,
- developing sustainable markets for materials derived from recycled waste,
- introducing separate collection of green waste in municipalities,
- capture and combustion of biogas in old, closing municipal landfills,
- assessment of the energy potential of biogas from landfills that are planned to be closed,
- measurement of the amount (flow) of biogas captured in combustion systems,
- introduction of anaerobic stabilisation of sludge with biogas capture and combustion in new and refurbished plants in settlements with more than 20 000 population equivalents,

- measure the amount (flow rate) of biogas captured in combustion systems.

The impact of existing policies and measures is relatively low. Existing policies and measures are expected to continue in the future, and are also expected to be significantly stepped up in line with the Circular Economy Directive.

B. Projected emissions

Projections for non-carbon emissions show significant progress in reducing emissions from landfills by 2050, reaching approximately 400 KTH CO_2 eq. in 2050 of almost 2000 KHH CO_2 eq., but less progress in waste water (however, a reduction of approximately 15 % between 2030 levels by 2050 is expected). For such reductions by 2050, the implementation of waste prevention strategies as well as the adoption of a strict waste management hierarchy are of paramount importance.

For further information on greenhouse gas emission projections in the sector, please refer to Chapter 6 above.

C. Emission reduction options

Control of technology

As described above in current policies and measures, methane reduction is an undeniable option for reducing emissions in the waste sector.

Policies and measures

For waste, the most effective way to reduce emissions is through policy instruments incentivising waste reduction and high levels of recycling and recovery of waste.

D. Expected progress in the transition to a low greenhouse gas emission economy

Methane reduction

The Waste sector is key to reducing methane emissions, with the exception of agriculture and energy. In addition to reducing methane emissions, policies and measures will also contribute to the circular economy, efficiency and, more importantly, reducing N_2O.

Research & development

Research and development of new technologies always provide a certain opportunity to reduce emissions, but in the Waste sector the R & D potential is considered to be lower than in other sectors.

7.7. Agriculture

A. Impact of existing policies and measures

Agriculture, both livestock and crop production, are a key part of the Bulgarian economy. A key sectoral policy is the Rural Development Programme for Bulgaria 2014-2020. The programme has three priorities: improving the competitiveness of the agricultural sector and the viability of farms, as well as ensuring quality food production; preservation of ecosystems and sustainable use of natural resources in agriculture, forestry and food processing; the economic and social development of rural areas – creating jobs, reducing poverty, improving social inclusion and quality of life.

Table 27: Existing policies and measures in the agriculture sector

Measure	Purpose and/or activiti	Greenhouse gases	Estimated effect of reduction (annual, in Gg Co_2EVK.)

			2020	2025	2030
	Reducing and/or optimising emissions in the agricultural sector	CH_4, CO_2	—	—	—
	Increase silo farmers 'and administrators' awareness of the impact of different actions on the climate		—	—	—
Improvement of insemination and irrigation	Reducing emissions from agricultural land	CH_4, N_4O	170	170	170
	Reduction of methane emissions from biological fermentation in livestock farming	CH_4	—	—	—
	Improving fertiliser use and management	CH_4	0.146	0.146	0.146
	Optimising the use of plant residues in agriculture				
	Improving the management of rice fields and rice production technologies				
	Enhancing farmers' and administration's knowledge of emission abatement methods in the agricultural sector				
Promoting the use of crop rotation, especially for nitrogen-fixing crops	Preventing soil erosion and preserving organic carbon (carbon sequestration)	CH_4	1	1	1

Management of damaged agricultural land	Preventing soil degradation and biodiversity loss		2.5	2.5	2.5
Technical assistance to farmers in soil farming/stubble	Efficient recovery of waste will reduce the need for burning stubble	CH_4	0.094	0.094	0.094
Use of ‘non-afforested areas intended for afforestation’ in forest areas	Increase in forest area	CO_2	1.7	1.6	1.6
Afforestation of abandoned agricultural land, infertile and deforested land, eroded and threatened by erosion outside forest areas	Creation of new forests outside forest areas	CO_2	4	4.8	4.8
Increase of surface area for urban and suburban parks and green areas	Sequestration of carbon from new forests in these areas	CO_2	0.3	0.3	0.3
Restoration and sustainable management of wetlands Protection of wetlands in forest areas, peat bogs and marshes	Improve the efficiency of carbon storage	CO_2	0.5	0.7	0.7
Restoration and maintenance of protective forest belts and new anti-erosion afforestation	Sequestration of carbon from new forests in these areas	CO_2	0.8	1.2	0.8
Increasing the density of the listed natural and artificial plantations	Increasing carbon sequestration through new forests in these areas	CO_2	1	2.5	4

The Common Agricultural Policy (CAP) provides the framework for agricultural policies and measures. The

CAP provides financial and technical support for climate change mitigation and adaptation, resource management, sustainability.

B. Projected emissions

Projections show that in Bulgaria non-carbon emissions will rise by 2050, especially in the arable crops sector of the agricultural industry, increasing from 4 071 KHH CO_2 eq. in 2020 to 6 348 KHN CO_2 eq. in 2050. In order to address the problem, Bulgaria will further explore possibilities to meet the European targets. One of the measures envisaged is the implementation of the European Methane Strategy and the Farm to Fork Strategy.

For further information on projections of greenhouse gas emissions in agriculture, please refer to Chapter 6 above.

C. Emission reduction options

Mitigation opportunities

Increasing agricultural productivity or efficiency is a key opportunity to reduce emissions. By using less land and animals and less raw materials to produce the same amount of food (crops, dairy products and meat), greenhouse gas emissions for the same amount of food would be reduced.

Another important opportunity is the deployment of innovative technologies and practices. Innovative technologies and farming practices such as precision farming and enteric fermentation can reduce greenhouse gas emissions in the agricultural sector.

Changing eating habits

More and more studies are exploring the possibility of changing eating habits. Reducing the consumption of calories from animal products has significant potential to reduce greenhouse gases.

D. Expected progress in the transition to a low greenhouse gas emission economy

The mitigation potential of the agricultural sector is expected to be more limited than in other sectors. Food security is an imperative strategic objective as well as a key challenge to reduce emissions in agriculture. Agriculture is therefore expected to account for a certain amount of remaining greenhouse gas emissions after 2050.

Sectoral challenges and constraints

The agricultural sector is expected to be under great pressure due to the projected population growth in the region. Although Bulgaria’s population is expected to decline somewhat by 2050, food consumption is expected to grow steadily.

The pathway to the low greenhouse gas emission agricultural sector is expected to come from mitigation incentives.

Another negative effect is related to installations for the production of energy from renewable sources, such as solar panels and wind, which have become operational.

Reductions in agricultural GHG emissions are expected to lead to a significant change in consumer behaviour. Changes in eating habits are likely to occur, meaning lower consumption of calories of animal origin. This change will have an impact on methane and nitrous oxide emissions, which are expected to decrease.

Research & development

Based on the information currently available, it is expected that research and development will focus on precision and process improvement. There is no foreseeable innovation that radically changes the agricultural sector and completely eliminates emissions, especially in view of growing consumption.

Research and development will most likely continue in the areas of precision farming solutions and automation. Precision farming will make it possible to reduce emissions through rationalisation, improvement of processes and improved prediction for data-driven decision-making.

7.8. Land Use, Land Use Change and Forestry (LULUCF). Greenhouse gas emissions and removals

A. Impact of existing policies and measures

The main category that helps to reduce greenhouse gas emissions is the forest sector, followed by grasslands. The other categories (cropland, urban areas, water bodies) are sources of CO_2 emissions in the absence of targeted measures for their sustainable management. The increasing capacity to reduce is due to the growth of the sinks of grassland and other land, as well as sustainable logging. The absorption of greenhouse gases by the forest sector is gradually decreasing due to the growth rate of forests and given the average age of forests and the limited area for afforestation.

Table 28 presents greenhouse gas emissions projected against existing LULUCF policies and measures. The calculations are based on[Bulgaria]'s 4th Biennial Report. Current policies and measures only include obligations and targets up to 2030 and Bulgaria is expected to continue its work on decarbonisation compared to current policies and measures.

The projections have been calculated until 2030, taking into account the objectives set out in the following strategy papers:

- Third National Action Plan on Climate Change for the Period 2013 – 2020
- National Strategy for the Development of the Forestry Sector in the Republic of Bulgaria 2013-2020 (NSRG)
- Strategic Plan for the Development of the Forestry Sector (SFDP) 2014-2023
- EU agricultural policy 2014-2020

The main driver of the calculations is the growing growth of forests in Bulgaria. The emission factors used to determine changes in the range of dead organic matter and soil organic matter are the same as in the National Greenhouse Gas Inventory.

The estimates of LULUCF emissions/removals in the WEM scenario (taking into account existing measures) reflect all adopted policies and measures set out in the Forest and Agricultural Development Strategy Papers adopted after 2013.

Table 28: Estimated reduction effect (per year, in $Gg_{CO}2$-ECU.)

Year	Estimated reduction effect (per year, in Gg CO_2EVC.)		
	2020	2025	2030
Forest areas	— 7170.68	— 7108.90	— 6923.85
Arable	818.88	680.72	677.68
Pastures	— 1687.29	— 1825.30	— 1939.11
Wetlands	281.62	277.08	277.08
Localities	846.79	805.41	827.10
Other land	— 401.72	— 574.55	— 576.36
Harvested wood products	— 840.65	— 895.62	— 936.94
LULUCF	— 8040.25	— 8390.52	— 8343.76

Source: 4TH Biannual report as required by the United Nations Framework Convention on Climate Change (Decisions 2/CP.17)

B. Projected emissions

Projections for greenhouse gas sequestration in the sector will decrease slightly in each projected scenario by 2050, but this is mainly due to the ageing of Bulgarian forests. Although there are land use plans for bioenergy production, these developments should not have an impact on the planned greenhouse gas savings. Despite the decline observed, the share of absorption in total greenhouse gas emissions (inCO 2-eq) is still significant. Self-afforestation of abandoned agricultural areas is the main factor in increasing the area of forests in Bulgaria.

For more information on emission projections by sector, please refer to Chapter 6. above.

C. Options to reduce emissions and increase removals

The rate of accumulation of CO_2 in the atmosphere could be reduced, taking into account the fact that atmospheric CO_2 can accumulate as carbon in vegetation and soil in terrestrial ecosystems.

There are measures that can be introduced in forest management, agriculture and urban planning to reduce greenhouse gas emissions and increase soil and vegetation carbon stocks.

Forests provide significant carbon stocks accumulated through tree growth and increased soil carbon. In areas with degraded forests, sustainable forest management can increase carbon stocks and biodiversity. In the long term, the sustainable forest management strategy seeks to maintain and increase forest carbon stocks while generating a sustainable annual yield of wood, fibre or energy from the forest, which will generate the greatest permanent benefit.

It is necessary to recognise the significant potential of forest self-afforestation in abandoned agricultural land to increase greenhouse gas removals in the strategic plans of the Ministry of Agriculture, as in the LULUCF sector, by including it in the sustainable forest management plans.

Other terrestrial systems also play an important role. Most carbon stocks of cropland and grassland are found in underground organic plant material and soil. Therefore, soil carbon sequestration in cropland and grassland has a potential to limit by 0.4-8.6 CO 2-eq/year according to the Intergovernmental Panel on Climate Change (IPCC).

For options to increase sink capacity and interconnectedness with other sectors, please look at Section D.

D. Synergies between agricultural and rural policies and the potential for economic development

The role of LULUCF activities in mitigating climate change has long been recognised. The sector accumulates atmospheric CO_2 as carbon in vegetation and soils in terrestrial ecosystems. In addition to carbon sequestration, forests, grasslands and other ecosystems that are part of the LULUCF sector are the basis for a wide range of ecosystem services for people. These include providing drinking water, food, timber and biomass, adapting to climate change and protecting against natural disasters such as floods, providing active ingredients for medicines and other raw materials and a place in nature for our health and recreation. Given these ecosystem services, biodiversity and ecosystems are also the basis for economic development. Sustainable management of the natural environment is therefore economically justified in various sectors, such as forest management, agriculture, food production and urban planning.

In relation to climate change mitigation, the EU presents the measures in the Common Agricultural Policy (CAP) and the Farm to Fork Strategy, which are key to the potential of LULUCF on greenhouse gas removals. They aim to reduce carbon dioxide emissions from cropland soils and increase carbon stocks in soil and grassland.

Intensive use of agricultural land reduces the amount of carbon in the soil and currently arable soil is an average source of carbon dioxide. Various measures can be taken to reverse the current trend of decreasing soil carbon content and contribute to sustainable management of agriculture, such as soil enrichment by organic materials such as livestock manure, biogas or straw residues and crop rotation. Given that the increased soil carbon content also increases soil fertility, investments to increase carbon content are paid off in the long term[23]. Crop rotation is also linked to the reduction of nitrate pollution in groundwater by extracting residual nitrogen from the soil. Improving farm management by introducing sustainable management techniques to properly steer management, crop rotation and others are also fundamental to reducing surface and subsoil pollution.

23 Hedlund K. (ed.) (2012) SOILSERVICE. www.lu.se/soil-ecology-group/research/soilservice

The new rules provide Member States with a framework to incentivise climate-friendly land use without introducing new restrictions or red tape for individual actors. This will help farmers to create smart farming practices with regard to climate and to protect forests by focusing on the beneficial effects of wood products that can store carbon stored by the atmosphere and as a substitute for emission-intensive materials.

According to the Celebio report, the sustainable use of biomass from food and agriculture residues can reduce emissions in the food sector by 25 % and in agriculture by 30 %, creating more than 5,000 new jobs in the agriculture, forestry and food sectors, stimulating EUR 100 million of private investment over the next ten years by creating a new biobased value chain for the agriculture, food and forestry sectors.

Other measures to incentivise organic farming are expected to be put in place during this period, such as no use of nitrogen fertilisers, which will not lead to greenhouse gas emissions. In addition, this is significant and adds value due to the lack of poor impact on biodiversity – habitats and animal species.

Improving afforestation and creating new forest areas in rural areas and parks in urban areas also provide other ecosystem services, such as improving air quality, providing water, especially if the forest is maintained by a catchment area, as well as climate adaptation services such as reducing flooding risks in urban and rural areas, and mitigating urban heat islands. Afforestation in catchment areas and nearby and distant rivers helps to provide water as well as to protect water quality from diffuse pollution and many others. The European Biodiversity Strategy recognises all these benefits and envisages measures to improve ecosystem management and incorporate the ecosystem approach into economic development. The EC will fund activities on sustainable farming practices, afforestation, urban greening as well as regeneration of rivers, and measures to improve air and soil quality. They will all aim to contribute positively to climate change mitigation and adaptation, as well as to improve the provision of other ecosystem services, improving sustainable economic development and the well-being of citizens.

Bulgaria has accepted these considerations and recognises the opportunities in the National Recovery and Resilience Plan (NRRP), which aims to improve the economic and social situation after the pandemic. To achieve this objective, a set of measures and reforms have been chosen which will significantly contribute to restoring and unleashing economic growth potential, ensuring resilience to negative external factors. This will make it possible to achieve the strategic objective of aligning the economy and income in the long term for Central Europe. At the same time, the plan lays the foundations for a green and digital transformation of the economy in the context of the ambitious goals of the Green Agreement. The main drivers for economic recovery are sustainable agriculture, the circular and low-carbon economy, the ecosystem integration approach and the introduction of nature-based solutions.

7.9. Environmental effects

A. Key change factors for the scenarios analysed

Greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and certain synthetic chemicals capture a large part of the planet's output energy, thus preserving heat in the atmosphere. Such processes generate changes in the Earth's radiation balance, influencing climate and weather patterns on a global and local scale. Taking into account the above, the analysis of the environmental impact of long-term strategy scenarios does not focus on projected greenhouse gas emissions as a key performance indicator. It must be stressed that the impact of Bulgaria's efforts to mitigate climate change also depends on the efforts of other countries.

If the assumed sequence or evolution would take place under the baseline scenario (NECP 2019), total greenhouse gas emissions would decrease by 65.2 % in 2050 compared to 1990. Total CO_2 emissions from energy combustion would decrease by 74.8 % (compared to 2005) and the overall share of RES would amount to 29.6 %. According to the model of the long-term strategy, in terms of reducing total greenhouse gas emissions and total CO_2 emissions from energy combustion, the most promising results will be delivered by adopting the Electricity and Energy Efficiency Improvement scenario for 1.5 °C (-84.1 % and -94.6 % respectively in 2050). The highest overall RES share will be guaranteed following the New Energy Carriers scenario for 1.5 °C (70.2 %).

Table 29: Selected key performance indicators for Electricity and Energy Efficiency Improvement (1.5 °C) and New Energy Carriers (1.5 °C) scenario (2030-2050).

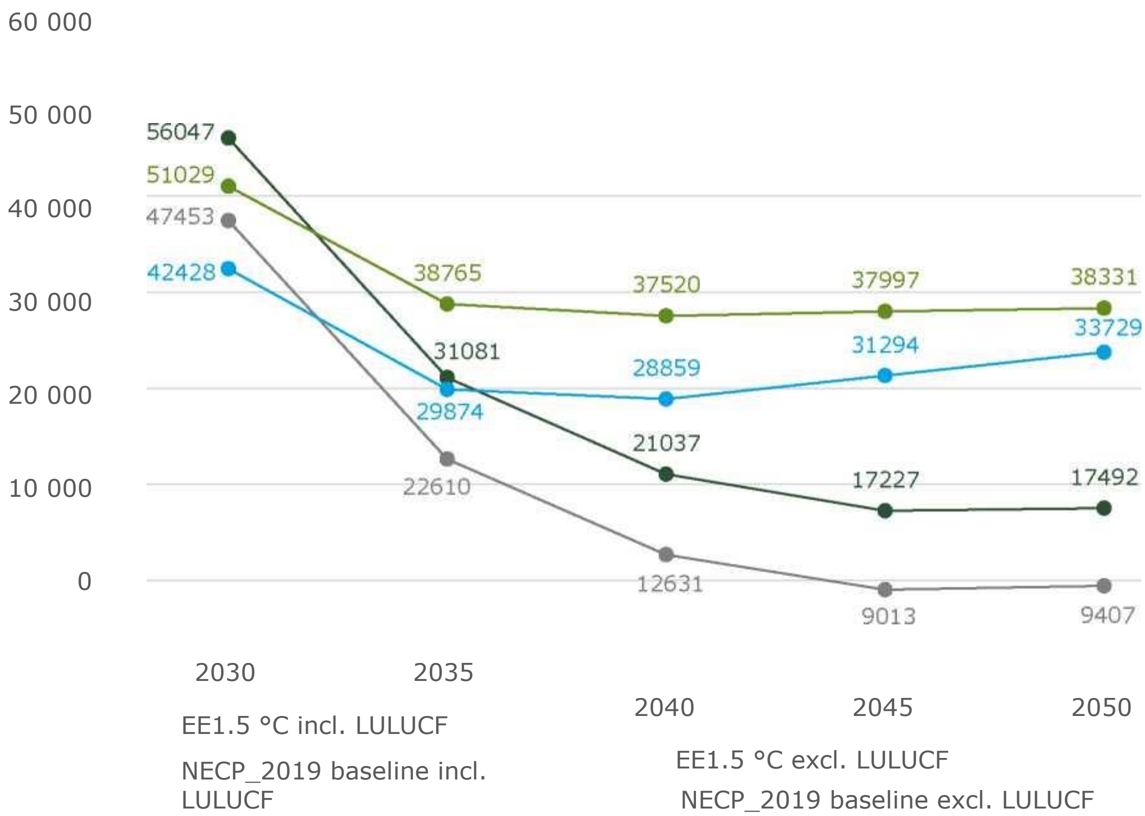
Electricity and Energy Efficiency Improvement scenario 1.5 °C	2030	2035	2040	2045	2050
Total GHG emissions (% change from 1990)	— 49.09	— 71.77	— 80.89	— 84.35	— 84.11
Total CO_2 emissions from energy combustion (% change from 2005)	— 25.89	— 68.63	— 83.14	— 92.47	— 94.57
Overall RES share (%)	27.31	35.61	42.96	56.64	64.74

New Energy Carriers 1.5 °C scenario	2030	2035	2040	2045	2050
Total GHG emissions (% change from 1990)	— 49.37	— 74.51	— 80.28	— 83.66	— 83.65
Total CO_2 emissions from energy combustion (% change from 2005)	— 26.50	— 69.28	— 82.67	— 92.37	— 94.22
Overall RES share (%)	27.55	35.55	44.81	57.48	70.22

Source: (B) EST model, LTS EE1p5Cb and NC1p5Cb scenarios

The Electricity and Energy Efficiency Improvement scenario for 1.5 °C can only lead to emissions of 9 407 KTH. CO_2-eq. (ref. LULUCF) in 2050. Comparing 33 729 KTH. CO_2-eq. (including LULUCF) projected for the baseline scenario, this translates into an improvement of around 72 %.

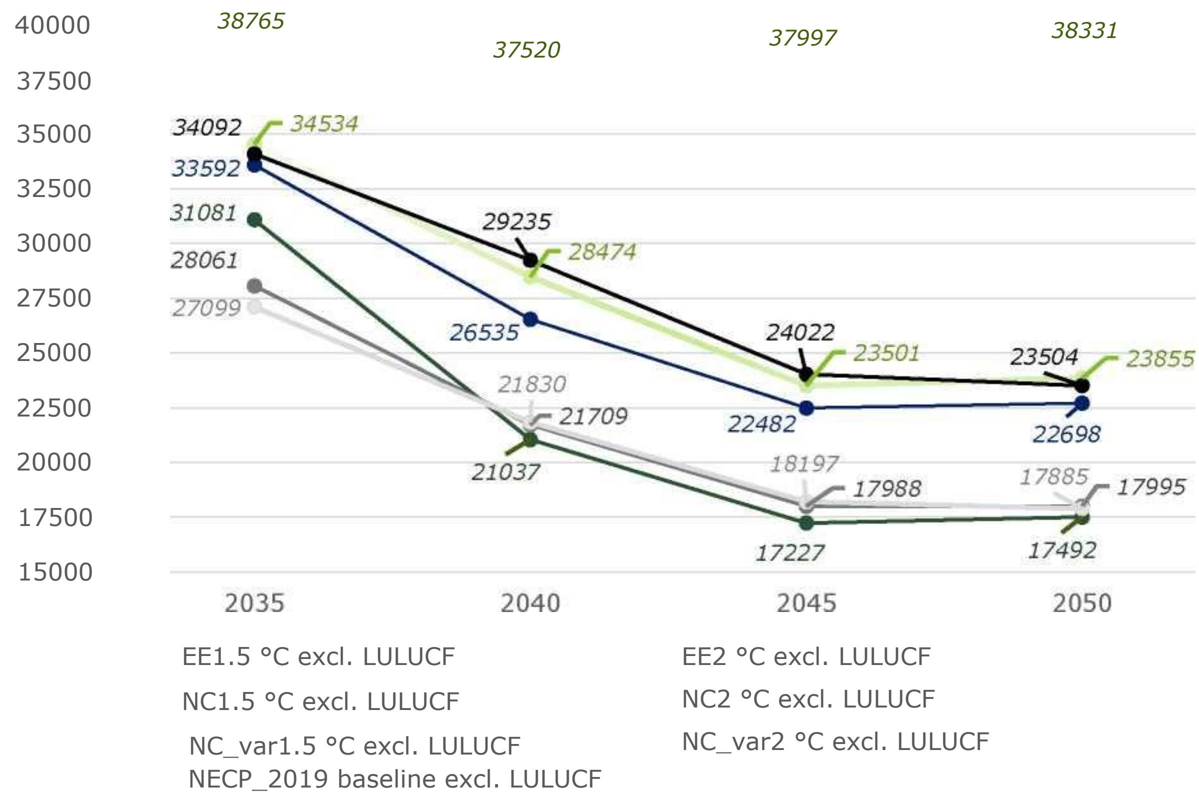
Figure 18: A comparison between the Electricity and Energy Efficiency Improvement (1.5 °C) scenario (including LULUCF) and the baseline scenario (total GHG emissions; KTN. CO2-ec.).



Source: (B) EST model, LTS EE1p5Cb scenario

A comparison of the projected results for 2050 for total greenhouse gas emissions shows that adopting the Electricity and Energy Efficiency Improvement (1.5 °C) scenario could lead to the most significant reduction in greenhouse gas emissions (-84.1 % compared to 1990) and lead to only 17 492 KTH emitted. Co2-ECU. (2050). Immediately after this decision, the New Energy Carriers, Nuclear and CCS (1.5 °C) and New Energy Carriers (1.5 °C) scenarios, promising, respectively, 83.8 % and 83.7 % greenhouse gas savings from one by one emitted only 17 885 and 17 995 KTH. Co2-ECU. (2050). The other, less ambitious 2 °C options of these scenarios came with less satisfactory results for 2050 (-79.4 %; —78.7 %; —78.4 % for the Electricity and Energy Efficiency Improvement 2 °C scenario; new Energy Carriers, Nuclear and CCS 2 °C scenario and New Energy Carriers 2 °C scenario). However, the effects of all the above mentioned strategies are significantly better than under the current baseline scenario. A comparison of total greenhouse gas emissions for specific strategies (excluding LULUCF) is presented in the graph below.

Figure 19: Comparison of scenarios used for LULUCF (total greenhouse gas emissions; KTN. Co2–EVK.)



Source: (B) EST model

B. Key impacts of climate change mitigation (1.5 °C vs. 2 °C global warming)

The projected magnitude and rate of occurrence of floods and droughts in certain regions is lower in a 1.5 °C scenario than in scenario 2 °C. The risks of water scarcity are the same. Already today, water scarcity is one of the main challenges for ecosystems and human societies in many regions of the world. Even without climate change, population growth is soon expected to put pressure on water resources in many regions. However, limiting global warming to 1.5 °C can reduce to 50 % the population exposed and affected by the limited availability of water caused by climate change. At the same time, it is expected that this will lead to smaller net decreases in cereal yields (such as maize, rice, wheat, soya, etc.). While scientists are considering potential increases in productivity of some crops (due to higher CO_2concentrations), there is a high variability in species' sensitivity to temperature and their tolerance to nutrient and water limitation. With a warming of 2 °C, agricultural yields are likely to decrease rapidly. At the same time, a global loss of up to 10 % of grazing animals is projected. The impact on food security in Europe will be different and could potentially reach a significant amount.

In addition, any increase in the global average temperature (even + 0.5 °C only) will have an impact on human health. This will of course be mostly negative consequences. Heat related morbidity and mortality risks are expected to be lower at 1.5 °C warming than at 2 °C. The difference between warming of 1.5 °C and 2 °C is significant. The higher the temperature, the worse the impacts affecting the planet and damaging communities, economies and ecosystems around the world.[24]

The threats to plant and animal species (risks of loss and extinction) are much lower in a 1.5 °C warming scenario than 2 °C. Species are expected to lose more than half of their original geographical coverage (18 % of insects, 16 % of plants and 8 % of vertebrates if the increase in global average temperature exceeds 1.5 °C, to 6 % of insects, 8 % of plants and 4 % of vertebrates if this does not happen). Risks related to other biodiversity factors (e.g. forest fires, extreme weather events as well as the spread of invasive species, pests and diseases) would also be lower at 1.5 °C than with 2 °C warming.

Ocean ecosystems are already affected by far-reaching changes caused by climate change and critical levels will be reached at 1.5 °C. On a global scale, sea level rise of around 48 cm is predicted in a 1.5 °C scenario, while if global average temperature increases by 2 °C, sea level rise could reach 56 cm. Current ocean ecosystem services will be reduced by 1.5 °C global warming and further reduced at 2 °C global warming. The risks associated with reduced ocean productivity, species migration, ecosystem damage, loss of fishing productivity and changes in ocean chemistry (oxidation, dead zones, oxygen scarcity, etc.) are expected to be significantly lower if global warming is limited to 1.5 °C.

C. Risks related to climate change and environmental vulnerability in Bulgaria

Bulgaria’s geographical location is particularly vulnerable to the negative impact of climate change. The country is thus likely to escalate the frequency of extreme weather events such as storms, hail, droughts, forest fires, landslides and floods.

Climate change can be an important factor for Bulgarian agriculture. Both droughts and floods due to prolonged intense rainfall have already been tested. Changes in the duration of the growing season in relation to the spread of pests and diseases may affect the volume of the main yields. Livestock will also be adversely affected by significant heat stress resulting from increased air temperature and humidity. Recurrent intense droughts are likely to increase soil drought. This, in combination with warm wind, increases the risk of soil erosion and degradation. At the same time, many factors can lead to water scarcity leading to increased irrigation needs and adverse effects on human health, fisheries and aquaculture.

Climate change has been identified as one of the five main and direct drivers of biodiversity loss, both at European and global level. Thanks to the diverse climatic, geological, topographical and hydrological conditions, Bulgaria is rich in biodiversity and faces a particular threat of biodiversity disruption. Bulgaria ranks among the most biologically diverse countries in Europe. Endemic plant species make up 5 percent of the total flora, a high proportion of other European countries. The country has more than 40 000 plant and animal species, including 25 per cent of species included in the Red List of Species in Europe according to IUCN criteria.[25] According to climate projections, adverse impacts of climate change can be expected in the short term at all levels of ecosystems in Bulgaria. The extinction of endangered species with limited range and migration opportunities is one of the main factors. Climate change can also affect the life cycle and breeding cycles of species, changing entire populations and ecosystem processes (e.g. food chains and competition for resources). Higher frequency of fires and disturbances such as heavy rains or winds may

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24IPCC, 2018: Global Warming of 1.5 °C.An IPCC Special Report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the thrust of climate change, sustainable development, and factors to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)].

25Republic of Bulgaria. National Climate Change Adaptation Strategy and Action Plan (2019).

also alter the structure of the ecosystem. The coastal zone, inland wetlands and forests in the south of the country are only some of the sensitive Bulgarian ecosystems.

These numerous manifestations of climate change are expected to have different impacts on different ecosystems and affect biodiversity and ecosystem services in different ways, including in a sharp and even catastrophic way. In particular, Black Sea beaches are vulnerable to rising sea levels. Research has shown that sea level rise will have a strong impact on Black Sea beaches, as 56 % of all beaches are expected to decrease by 50 % of their maximum width by 0.5 m.[26] Biodiversity conservation and climate change mitigation measures are closely interlinked and interdependent. The strong link between climate change and biodiversity is also recognised in the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD).

According to climate scenarios, drought and extreme climatic phenomena (storms, floods, landslides, winds, hail, etc.) can be expected in the medium term, but due to rising temperatures and growing season. In addition to seasonal extreme temperature variations, large temperature variations expected on a daily basis can cause shock effects on some of the plant and animal organisms in Bulgaria. As a result, adverse effects can be expected at all levels of biodiversity in the short term. Genetic diversity may decrease due to the extinction of endangered species – specialised species and endemics with a limited range and small migration opportunities. Climate change can also affect the life and reproductive cycles of species in ecosystems, affecting populations and processes in the ecosystem (food chains, competition for resources), including due to invasion of alien species. These numerous manifestations of climate change are expected to affect different types of ecosystems differently and affect biodiversity and ecosystem services in many ways, including sharply and even catastrophic.

A recent study highlights a shift in direction of pollutants brought from the Danube to the north-western shelf of the Black Sea, leading to an increase in the accumulation of pollutants in the region. This change is most likely due to recent climate-driven changes in circulation patterns in the Black Sea.[27]

Finally, global warming risks increasing deaths from heartdisease, strokes (heat waves and urban heat island effects), as well as human diseases caused by parasites, viruses and bacteria. An increase in the number of Salmonella infections is predicted; respiratory diseases (due to higher concentrations of CO_2, dust and particulate matter (PM) in the air) and allergic diseases due to earlier flowering and increased concentration of pollen.[28]

D. Selected positive environmental impacts of Electricity and Energy Efficiency Improvement and New Energy Carriers (1.5 °C) scenarios

Relying on renewable energy recovery allows a drastic reduction of greenhouse gas emissions from fossil fuels and can reduce air pollution. The selected benefits of RES acceptance for the biosphere are presented below:

Table 40: Positive effects of RES on the environment

26https://www.zora.uzh.ch/id/eprint/98291/
27 https://ec.europa.eu/jrc/en/science-update/climate-change-alters-pathways-river-borne-contaminants-black-sea
28Dale, N. and Zhekova, S., 2018. *Republic of Bulgaria. Draft Proposal for a National Climate Change Adaptation Strategy and Action Plan*. European Union (ESF).

Air	- improved air quality due to lower pollution levels from energy generation, transport and households (NO_x, SO_2, PM); - lower air temperature;
Biodiversity and ecosystems	- reduced air pollution and coal mining; - positive change in water use (wind/sun); - protection of living organisms;
Land	- reduced use of raw/raw materials and natural resources implies reduced unsustainable yield (circular economy); - reduced fertiliser use and reduced eutrophication, acidification and toxicity; - ecosystem conservation, sustainable management as well as sustainable agriculture;
Waters	- reduced use of water by saving water, producing energy and energy efficiency; - reduced local air and water pollution and disposal of waste materials due to the circular economy/material efficiency;
Natural resources	— reduced extraction of natural resources.

Source: Deloitte analysis

E. Risks and potential negative environmental impacts of new technologies

In addition to the indirect impacts of climate change that these scenarios mitigate, the technological changes analysed in these scenarios may have a direct impact on the environment. In this section, we focus on the most important environmental risks associated with the use of new energy sources and technologies, namely biomass and biofuels, solar and wind power, CCS, EV, and nuclear energy.

As regards the production of energy from biomass, the most known environmental impact factors are the production of raw materials and the emissions of pollutants. Studies show that the land use change effects of the expansion of biomass feedstock for energy have led to loss of habitats and biodiversity, especially in large-scale land conversion resulting from monocultural production of raw materials. In addition, several life cycle assessments (LCA) demonstrate that most biomass energy production methods emit greenhouse gases and atmospheric/water pollutants that may have negative impacts on ecosystems and biodiversity. Similarly, the production of raw materials has been identified as the most important mechanism of biofuel changes in ecosystems and biodiversity loss29. Comparative LCA shows that different biofuel options can have different greenhouse gas emissions depending on the feedstock, agricultural production practices and production area.

Large-scale solar energy affects ecosystems in many ways throughout their life cycle. Many of the documented negative impacts of solar energy on ecosystems and biodiversity are habitat loss and change. Solar energy infrastructure often occupies large areas of land, leading to fragmentation and modification of habitats simultaneously. The installations are also linked to pollution. To ensure the solar panel has access to the sun, dust and herbicides are usually applied. Due to the form of infrastructure, the soil temperature may also change, affecting the local microclimate. The deployment of solar photovoltaics on the roofs and facades of buildings can reduce some of the effects of habitat loss/solar energy change.

Every wind energy production facility results in a small loss of habitat. Either directly (by occupation of land) or indirectly (due to species avoiding areas in the vicinity of the facilities). With regard to habitat change, it is not surprising that the main threat to biodiversity stems from collision risks (birds and bats),

29Gasparatos A., et al., 2017. Renewable and Sustainable Energy Reviews. Renewable energy and biodiversity: Implications for transitioning to a Green Economy.

and rotary fins generate downward channels. Mitigation actions include reducing the speed of the rotor or stopping energy production during large periods of migration.

The scenarios analysed also imply the use of carbon capture and storage (CCS) systems. In general, according to many studies, the environmental risks associated with CCS are similar or smaller than those already experienced by the oil and gas industry. The greatest environmental risk associated with CCS is linked to the long-term storage of captured CO_2. The leakage of CO_2, gradually or during exceptional leakage, may reverse the positive environmental impact of reduced atmospheric levels of CO_2 and may have additional harmful effects on the environment.30

Finally, although generally perceived as a clean energy source, the stages in the nuclear fuel chain (such as mining, milling, transport, fuel production, enrichment, construction, decommissioning) use fossil fuels or involve changes in land use. They therefore emit carbon dioxide and conventional pollutants. The nuclear power plant continuously emits low levels of radiation in the environment.31

The use of new technology will also create new waste streams containing toxic substances or precious metals. At the end of the life cycle, renewable energy sources (especially electric vehicles, their batteries and photovoltaic equipment) require adapted waste management strategies. Nuclear energy also raises a range of issues in this respect, with at least three streams of waste affecting the environment. These are spent nuclear fuel at the reactor site, tailings ponds and waste rocks in uranium mining plants and the release of poorly defined quantities of radioactive materials during accidents.32

In general, the potential negative impacts of the deployment of new technologies need to be addressed with specific risk mitigation measures. There are examples from other countries that show that these technologies can be deployed in a sustainable way that reduces the negative impact on the environment. In order to identify the most effective measures, a comprehensive environmental compatibility assessment and impact assessment of the scenarios analysed, as well as a mitigation strategy with dedicated policies, are recommended.

8. Results of stakeholder engagement

Summary and overview of interested parties' comments

Importance of stakeholder engagement and views for the preparation of this report on Bulgaria's Long-Term Strategy

The draft Long Term Strategy was published for public consultation and all stakeholders had the opportunity to submit their comments and recommendations on it.

Written comments on the draft Long Term Strategy have been received from various stakeholders, such as

30Zapp, P. et al. (2012). Overall environmental impacts of CCS technologies – A lifecycle approach. Intergovernmental Journal of Greenhouse Gas Control.

31 A. S. Paschoa, (2004), Environmental effects OF NUCLEAR POWER GENERATION, in Interactions: Energy/Environment, [Ed. Jose Goldemberg], in Encyclopedia of Life Support Systems (EOLSS), Developed under the auspices of the UNESCO, Eolss Publishers, Oxford, UK, [http://www.eolss.net]

32Benjamin K. Sovacool. A Critical Evaluation of Nuclear Power and Renewable Electricity in Asia, Journal Contemporary Asia, Vol. 40, No. 3, August 2010, pp. 376

NGOs, private companies, industry associations, etc.

The following stakeholders submitted written comments on the draft Long Term Strategy: Bulgarian Industrial Association, Bulgarian Wind Energy Association, Solvay Sodi AD, Environmental Association Za Earth, WWF Bulgaria.

The contributions received are diverse in their content and approach and can be summarised as follows:

- Inclusion of industry and energy production for industry in the cycle of development and use of alternative fuels.
- The inclusion in all scenarios of CCU (carbon capture and (re) utilisation), in line with EU regulations, as well as promoting the transformation and use of already captured and/or stored carbon dioxide.
- For the waste management sector, focus also on the production of alternative fuels from non-hazardous waste, which make a significant contribution to reducing dependence on fossil fuels. In addition to the recovery of household waste, attention should also be paid to non-hazardous industrial waste, which could make a significant contribution to reducing carbon dioxide emissions when used as raw materials in new or existing industrial activities;
- To include the industrial sector in the strategy when considering increasing the share of renewable energy.
- The impact of the green certificate scheme should be taken into account. The industrial sector must be the main part of this mechanism and a clear scheme for supporting/subsidising decarbonisation solutions needs to be developed.
- Take into account the evolution of technologies for the future use of conventional solid fuels without increasing greenhouse gas emissions.
- Include research and development in the strategy and move towards national requirements for the production and use of alternative fuels, for the use of waste products for the production of existing or new products and for the construction of sites.
- The country shall provide funding for the development of industrial and energy innovation to increase efficiency in energy production, transmission and use.

- The development of long-term energy storage technologies, the increase of cross-border connections and capacities, the pooling of energy markets and the efficient management of networks must allow for a greater share of wind and solar energy.
- Assess the availability of local water resources.
- Encourage investment in energy storage installations, smart grids, demand side response.
- Identify objectives and measures to achieve a just energy transition, for the most vulnerable social groups and consumers (mainly in the energy, buildings and transport sectors), comparing positive and negative impacts on employment as well as on energy poverty.
- Analyse potential risks related to the absence of significant harm to environmental and biodiversity factors (DNSH principle), especially with regard to large-scale infrastructure projects (dams, NPPs, etc.) and concentration of RES in the so-called Go To Areas (RePowerEU Plan).
- Also analyse the links between the proposed approaches and strategies for energy transition and decarbonisation towards climate change adaptation objectives, especially with regard to the

availability of water resources and the possibilities for implementing ecosystem-based solutions.