LONG TERM STRATEGY OF ROMANIA

5th of May 2023

Foreword

This strategy was prepared by PricewaterhouseCoopers Management Consultants SRL (“PwC”), with the rich support of the experts at the Macedonian Academy of Sciences and Arts.

The strategy was drafted within the "Implementing the national energy and climate plan and developing the long-term strategy of Romania" project, financed by the European Union through the Technical Support Instrument, managed at the level of the Directorate-General for Structural Reform Support (DG REFORM), carried out on the basis of contract no. REFORM/2021/OP/0006-07 LOT 1, concluded between the consulting company PricewaterhouseCoopers EU Services EESv and DG REFORM and signed in October 2021.

This strategy may be published for public consultation by the Beneficiaries (Ministry of Energy and Ministry of Environment, Waters and Forests). PwC assumes no liability or responsibility for this strategy to anyone other than the Beneficiaries and DG REFORM.

The sources for the data and information used in the document are indicated in the text and in the footnotes. The data and information are believed to be correct and have not been independently checked for the purpose of this endeavour.

This strategy was produced with the financial support of the European Union. The views expressed in this strategy do not reflect the official opinion of the European Union.

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EXECUTIVE SUMMARY

The European Union (EU) and its Member States are determined to implement the Paris Agreement on climate change, adopted in December 2016 and entered into force in November 2017, of the 2030 Agenda for Sustainable Development and contribute to the achievement of their goals. At the same time, EU calls for the acceleration of the global efforts in this regard, especially given the latest scientific information published by the Intergovernmental Panel on Climate Change (IPCC).

The National Strategy for the Sustainable Development of Romania 2030 (SNDDR 2030)[1] and National Action Plan for implementing the SNDDR 2030 are Romania's response to the 2030 Agenda for Sustainable Development and establish the national framework for the implementation of the 17 Sustainable Development Goals (SDGs), providing adequate responses to the challenges of climate change, in line with the goals of the Paris Agreement and the Sendai Framework for disaster risk reduction, as well as with EU strategic documents, to ensure policy coherence for sustainable development at national level.

According to Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action, each Member State (MS) develops and presents to the European Commission (EC) its long-term strategy for reducing greenhouse gas emissions, with a perspective of at least 30 years. The national Long Term Strategies (LTS) of the SMs aim and plan to: (1) significantly reduce greenhouse gas (GHG) emissions and improve GHG sinking / capture at the sectoral level, in areas such as electricity production, industry, transport, heating and cooling in buildings (residential and commercial), agriculture, waste, land use, land-use change and forestry (LULUCF); (2) accomplish expected progress on the transition to a low-GHG economy, including projections regarding GHG intensity, CO_2 intensity of gross domestic product (GDP), related estimates of long-term investment, and strategies for related research, development and innovation (RDI); (3) assess the expected socio-economic effect of the decarbonisation measures; (4) provide links and coordination with other national long-term objectives, planning and other policies and measures, and investment.

Romania's Long-Term Strategy was developed in accordance to the provisions of Annex IV of Regulation (EU) 2018/1999.

Romania's LTS considers 3 possible scenarios: the Reference Scenario (REF), the Middle Scenario (Middle) and Romania Neutral scenario (RO Neutral). The Reference Scenario was built starting from the National Energy and Climate Plan (NECP) 2021-2030 and considering a significant increase in the global share of renewable energy sources (RES) in the gross final energy consumption: increase from 30.7%, as indicated in the current version of the NECP, to 34.3%, in the case of the REF Scenario of the LTS. The RO Neutral Scenario aims to achieve Romania's climate neutrality in 2050, by reducing the net emissions with 99% compared to 1990. The Medium Scenario was built as a middle solution between the REF Scenario and the RO Neutral Scenario. The RO Neutral scenario was the one selected by the Romanian authorities to be implemented by 2050. The targets and key assumptions for all scenarios are detailed in the following chapters.

The process of elaborating the national and sectoral targets of the LTS was based on the LEAP_RO energy and climate model, developed specifically for the strategy. LEAP_RO takes into account the contributions of all economic sectors with impact in the field of energy and climate change, including the targets set-up in adopted sectoral and national strategies. LEAP_RO was developed starting from historical statistical data for the period 2010-2019, taking 2010 as the base year and 2010-2019 as reference period. Following a complex calibration and optimization process and building upon statistical results reported for 2010, the LEAP_RO model predicted, with a maximum relative error of 3%, statistical data recorded for the period 2011-2019. The calibration and optimization process of the model and the comparison between the model predictions and statistical data from 2011-2019 are presented in Chapter 9. At the same time, the LEAP_RO model results were compared with the 2020 statistical data and with the statistical data available for the years 2021 and 2022, and the accuracy was found to remain at the same level.

Based on LEAP_RO, the LTS presents 2023-2050 predictions for the evolution of GHG emissions at national level (Chapter 3), share of energy from renewable sources in gross final energy consumption (RES – Chapter 4), and energy efficiency (EE – Chapter 5) for the 3 analysed scenarios. Chapter 6 presents LEAP_RO predictions for sectoral emissions, together with the main hypothesis considered for reaching the sectoral targets. The 2023-

[1] https://www.edu.ro/sites/default/files/Strategia-nationala-pentru-dezvoltarea-durabila-a-Rom%C3%A2niei-2030.pdf

2050 LEAP_RO predictions lead to the LTS national and sectoral targets summarized in this chapter and extensively presented in Chapters 3-6. Considerations regarding the financial and social impact of implementing the LTS, together with aspects regarding the RDI policies and measures that need to be implemented for supporting the achievement of LTS targets, are presented in Chapter 7. The indicators for monitoring the implementation of the LTS and their coordination with the sustainable development goals (SDG) indicators are inserted in Chapter 8. Chapters 1 and 2 refer to the EU climate policies and targets, summarize the main findings of the analysis regarding the LTS of other Member States (MS) and indicates the legal and policy context for elaborating the LTS of Romania.

Main targets of the LTS

According to the RO Neutral scenario, which is the chosen one, Romania aims at becoming climate neutral in 2050, reaching **99% net emission reduction in 2050**, compared to the 1990 level. As shown in Figure 1, Romania has already started the decarbonization process by reducing net emissions by 62% in 2019 compared to 1990. However, further efforts are needed for reaching carbon neutrality in 2050, by first reaching the 2030 milestone of 78% emission reduction, relative to the 1990 level. Only by putting in place the necessary policies and measures in each sector, as detailed in Table 2 , can the sectorial emission reduction roadmap shown in Table 1 be achieved. Some sectors require extra attention to first put a stop to the rising emission trend, as is the case for sectors marked by X in Table 1 and then to start and achieve the decreasing trend of emissions.

Figure 1. National target for net emissions and indicative milestones by 2050 (RO Neutral scenario)

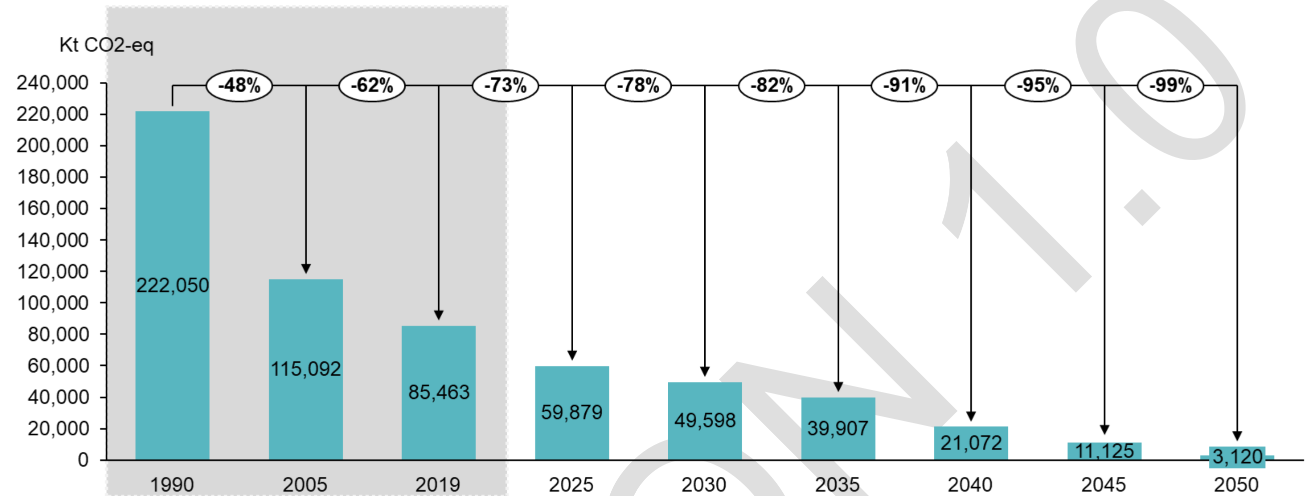
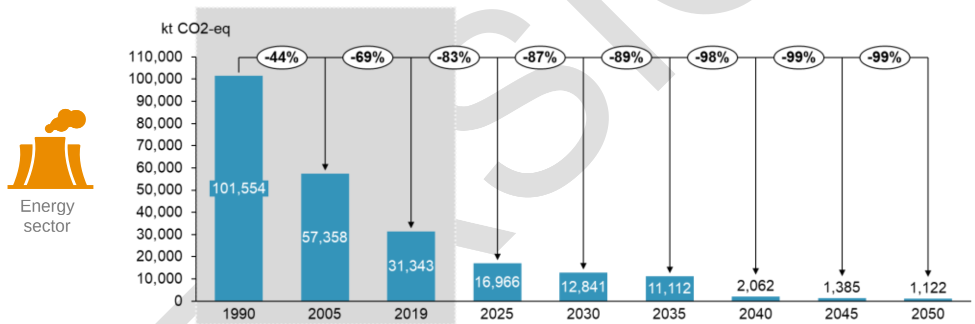
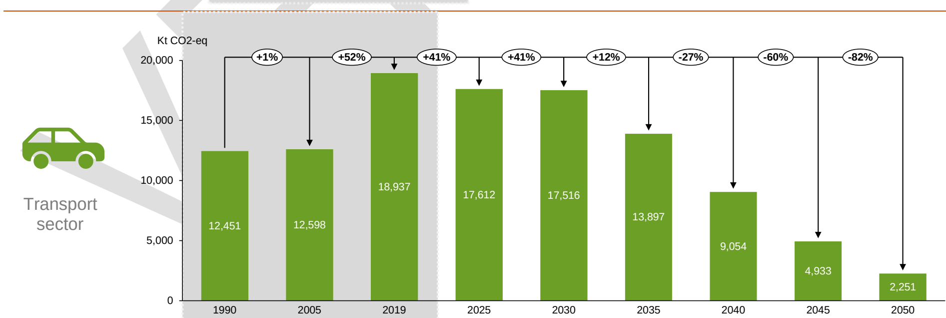


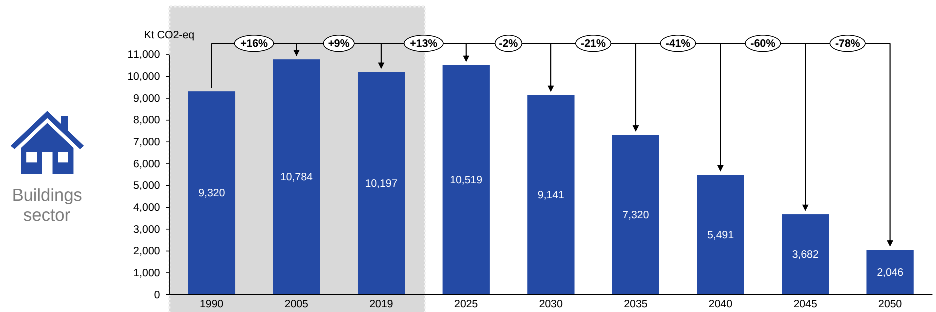
Table 1. Sectoral targets and milestones for emission reductions by 2050 (RO Neutral scenario)



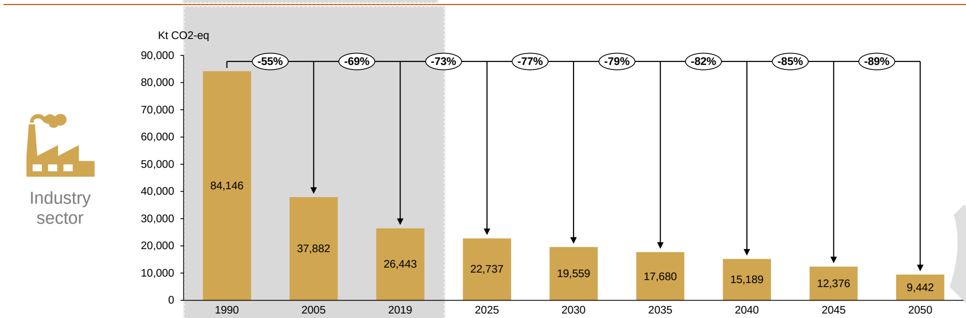
√ The decarbonization of the energy sector has already started, and in 2019 69% of the 2050 goal was already achieved. By 2035, 98% of the goal will have been achieved.



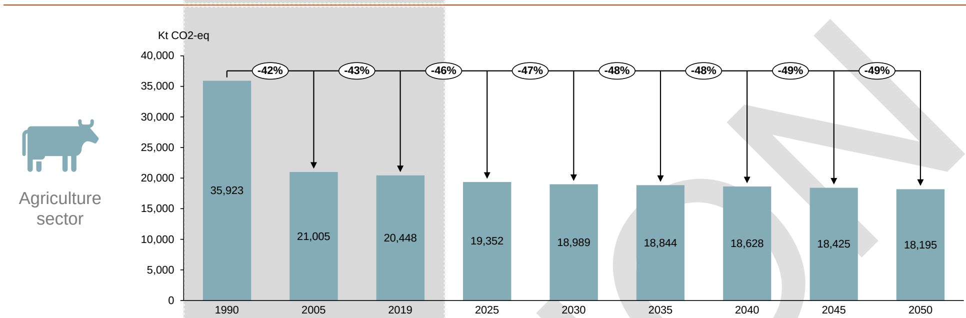
X In the period 1990-2019 the emissions from the transport sector have increased by 41%. The goal is to lower the sectoral emissions by 82% in 2050 compared to 1990. This will be accomplished by first stopping the increasing trend, compared to 1990, by 2035.



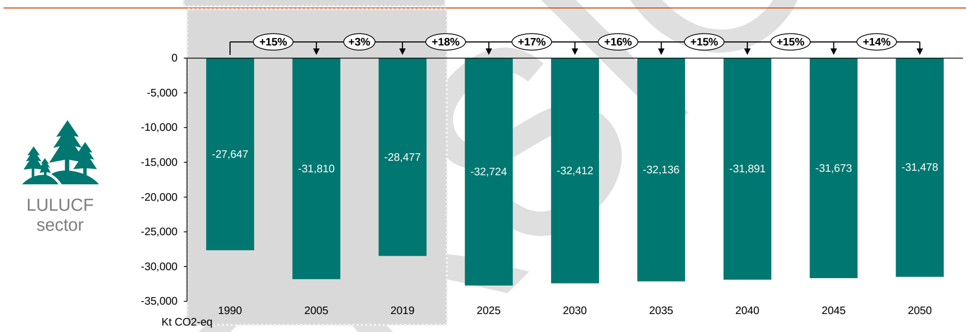
X The emissions from the buildings sector have grown by 9% from 1990 to 2019 and are predicted to continue raising by 2025. Following 2025, the emissions will start decreasing and should be 78% lower in 2050 compared to 1990.



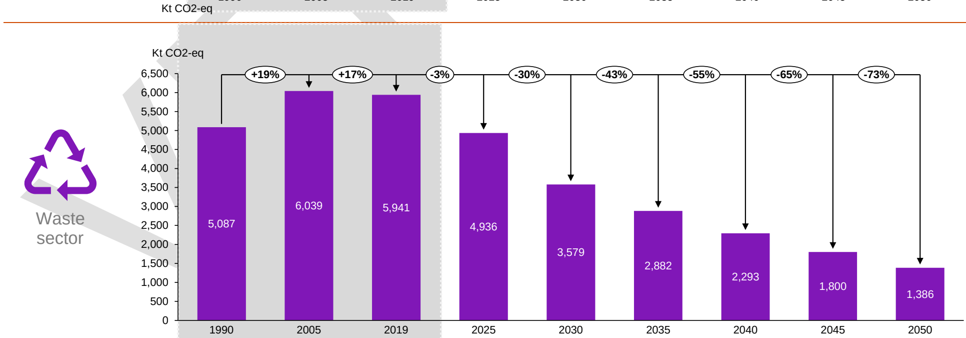
√ The industry sector has already attained 73% of emissions reductions in the period 1990–2019. The target is to reduce emissions by 89% from 1990 level by 2050.



√ The 2050 goal for this sector is to reduce the emissions by 49% compared to 1990. By 2019, 43% emission lowering was achieved.



√ The 2050 goal of this sector is to increase the absorption level by 14% compared to 1990, which is similar to what was already achieved in 2005.



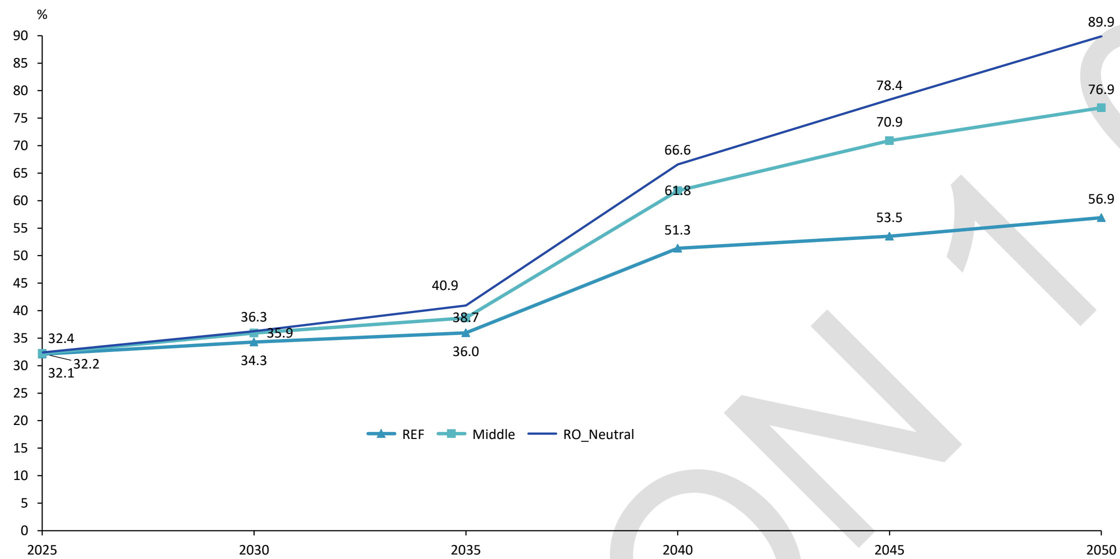
X In 2050, 73% emission reductions should be achieved in the Waste sector. However, between 1990-2005 the emissions have increased by 19%. A slightly decreasing trend can be noticed by 2019, which should continue at a much faster rate by 2050.

According to the chosen RO Neutral scenario, the RES share in the gross final energy consumption should reach 89.9% in 2050 and 36.3% in 2030 (Figure 2). When analysing at sectoral level, an increase in the gross final energy consumption from RES will occur in all three sectors: transport, electricity and heating and cooling. The RES share in the transport sector will reach around 243% in 2050, as a results of the increased use of electricity and hydrogen. In the Middle scenario, this share will be also larger than 100%. This is possible because, according to the Renewable Energy Directive (Directive (EU)2018/2001), the RES-based electricity consumption in the transport is counted with a factor higher than 1 (for example, 4 for road transport and 1.5 for rail transport).

The drastic increase of electricity generation from wind and solar power plants, as well as from hydrogen plants, contributes to the RES share in the gross final energy consumption from the electricity sector reaching approximately 107.5% in 2050 in the RO Neutral scenario. This percentage is also higher than 100% because part of the electricity that is produced from RES is not directly consumed, being used for green hydrogen production, thus the amount of electricity produced from RES is larger than the RES-based gross final energy consumption.

The increased use of heat-pumps, solar thermal collectors and hydrogen pushes the share of RES in the gross final energy consumption from heating and cooling sector to around 97.5% in 2050 for the RO Neutral scenario.

Figure 2. RES share in gross final energy consumption – REF, Middle and RO Neutral scenarios



As the **energy efficiency** target of Romania is set according to the RO Neutral scenario, the target for **2030** is to reach **46%** and **45%** reductions of the **primary** and the **final** energy consumption, respectively, when compared to the reference 2030 values from the Primes model (Figure 3 and Figure 4). For 2050, the primary energy consumption should be additionally reduced by 11% and the final energy consumption by 26%, compare to the 2030 level.

Figure 3. EE national target and indicative milestones for primary energy consumption

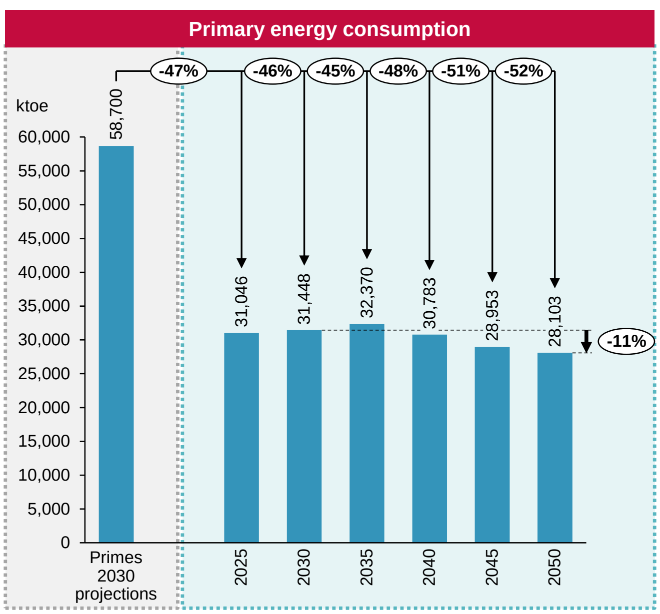
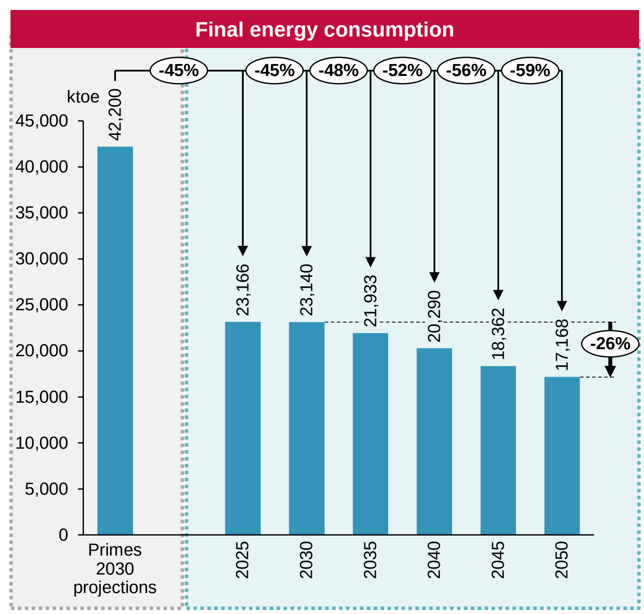


Figure 4. EE national target and indicative milestones for final energy consumption



Main hypotheses of the LTS

Table 2 below summarizes the key assumptions considered per economic sector and scenarios for achieving the sectoral and national LTS targets.

Table 2. Key assumptions by sectors and scenarios considered for achieving LTS national and sectoral targets

Note: **PV auto & rooftop** refers to the capacities of electricity production based on solar energy owned by entities that do not have as their main activity the production of electricity and that can use, partially or fully, the production of electricity for self-consumption; **Wind auto** refers to the electricity production capacities based on wind energy owned by entities that do not have as their main activity the production of electricity and that can use, partially or fully, the production of electricity for self-consumption; **Passenger road transport vehicles** refers to buses and mini-buses

Key hypothesis	Reference scenario	Middle scenario	RO Neutral scenario
Energy system	Available capacities to the model • Nuclear energy: ○ Currently, Romania has in place, operating, U1 (CANDU) – 700 MW and U2 (CANDU) – 700 MW ○ U1 will be repowered during 2027-2029 ○ U2 will be repowered during 2036-2038 • New nuclear capacities ○ 462 MW starting form 2029 • All coal and lignite-powered capacities will be closed by 2031 ○ 1,695 MW were closed on 31.12.2021 ○ 660 MW was scheduled to be closed on 31.12.2022 ○ 1,425 MW will be closed on 31.12.2025 ○ 1,140 MW will be closed / placed in stand-by on 31.12.2026 • All natural gas-powered plants (CCGT, CHP) will be 100% ready for renewable gases (green hydrogen) by 2036 • New CCGT capacities: ○ 430 MW starting from 2024 ○ 430 MW starting from 2025 ○ 430 MW starting from 2026 ○ 1,325 MW starting from 2027 • New CHP capacities: ○ 80 MW starting from 2024 ○ 52 MW starting from 2025 ○ 365 MW starting from 2026 ○ 50 MW starting from 2027 ○ 200 MW starting from 2028 ○ 200 MW starting from 2029 • New PV PP – 600MW each year from 2023 to 2025, 700 MW each year from 2026 to 2030, 350 MW each year from 2031 to2050 • New PV auto & rooftop PP - 100MW each year from 2023 to 2050 • New wind PP – 550MW each year from 2023 to 2025, 600 MW each year from 2026 to 2040, 400 MW each year from 2041 to 2050 • New wind auto PP – 40MW each year during 2023-2050 • New biomass CHP – 10 MW each year by 2050 • New biogas CHP – 5 MW each year by 2050	Available capacities to the model • Nuclear energy: ○ Currently, Romania has in place, operating, U1 (CANDU) – 700 MW and U2 (CANDU) – 700 MW ○ U1 will be repowered during 2027-2029 ○ U2 will be repowered during 2036-2038 • New nuclear capacities ○ 462 MW starting from 2029 ○ 700 MW starting from 2030 ○ 700 MW starting form 2031 • All coal and lignite-powered capacities will be closed by 2031 ○ 1,695 MW were closed on 31.12.2021 ○ 660 MW was scheduled to be closed on 31.12.2022 ○ 1,425 MW will be closed on 31.12.2025 ○ 1,140 MW will be closed / placed in stand-by on 31.12.2026 • All natural gas-powered plants (CCGT, CHP) will be 100% ready for renewable gases (green hydrogen) by 2036 • New CCGT capacities ○ 430 MW starting from 2024 ○ 430 MW starting from 2025 ○ 430 MW starting from 2026 ○ 1,325 MW starting from 2027 • New CHP capacities: ○ 80 MW starting from 2024 ○ 52 MW starting from 2025 ○ 365 MW starting from 2026 ○ 50 MW starting from 2027 ○ 200 MW starting from 2028 ○ 200 MW starting from 2029 • New PV PP – 600MW each year from 2023 to 2025, 700 MW each year from 2026 to 2030, 450 MW each year from 2031 to 2050 • New PV auto & rooftop PP – 100MW each year from 2023 to 2029 and 400MW each year from 2030 to 2050 (solar strategy EU) • New wind PP – 550MW each year from 2023 to 2025, 600 MW each year from 2026 to 2030, 550 MW each year from 2031 to 2040 and 650 MW each year from 2041 to 2050 • New wind auto PP – 40MW each year during 2023-2030, 50MW each year during 2031-2050 • New biomass CHP – 10 MW each year by 2050	Available capacities to the model • Nuclear energy: ○ Currently, Romania has in place, operating, U1 (CANDU) – 700 MW and U2 (CANDU) – 700 MW ○ U1 will be repowered during 2027-2029 ○ U2 will be repowered during 2036-2038 • New nuclear capacities ○ 462 MW starting from 2029 ○ 700 MW starting from 2030 ○ 700 MW starting form 2031 • All coal and lignite-powered capacities will be closed by 2031 ○ 1,695 MW were closed on 31.12.2021 ○ 660 MW was scheduled to be closed on 31.12.2022 ○ 1,425 MW will be closed on 31.12.2025 ○ 1,140 MW will be closed / placed in stand-by on 31.12.2026 • All natural gas-powered plants (CCGT, CHP) will be 100% ready for renewable gases (green hydrogen) by 2036 • New CCGT capacities ○ 430 MW starting from 2024 ○ 430 MW starting from 2025 ○ 430 MW starting from 2026 ○ 1,325 MW starting from 2027 • New CHP capacities: ○ 80 MW starting from 2024 ○ 52 MW starting from 2025 ○ 365 MW starting from 2026 ○ 50 MW starting from 2027 ○ 200 MW starting from 2028 ○ 200 MW starting from 2029 • New PV PP – 600MW each year from 2023 to 2025, 700 MW each year from 2026 to 2030, 525 MW each year from 2031 to 2050 • New PV auto & rooftop PP – 100MW each year from 2023 to 2029 and 800MW each year from 2030 to 2050 (solar strategy EU) • New wind PP – 550 MW each year from 2023 to 2025, 600 MW each year from 2026 to 2030, 675 MW each year from 2031 to 2040 and 750 MW each year from 2041 to 2050 • New wind auto PP – 40MW each year during 2023-2030, 60MW each year during 2031-2040 and 100 MW each year during 2041-2050

	• New biogas PP - 5 MW each year by 2050 • New hydro PP: ○ 65 MW starting from 2024 ○ 12 MW starting from 2025 ○ 148 MW starting from 2027 ○ 50 MW starting from 2028 ○ 29 MW starting from 2030	• New biogas CHP – 5 MW each year by 2050 • New biogas PP – 5 MW each year by 2050 • New hydrogen CHP – 5MW each year from 2027 to 2040 and 20MW each year from 2041 to 2050 • New hydro PP: ○ 65 MW starting from 2024 ○ 12 MW starting from 2025 ○ 148 MW starting from 2027 ○ 50 MW starting from 2028 ○ 29 MW starting from 2030	• New biomass CHP – 10 MW each year by 2050 • New biogas CHP – 5 MW each year by 2050 • New biogas PP – 5 MW each year by 2050 • New hydrogen CHP – 30MW each year from 2027 to 2040 and 40MW each year from 2041 to 2050 • New hydro PP: ○ 65 MW starting from 2024 ○ 12 MW starting from 2025 ○ 148 MW starting from 2027 ○ 50 MW starting from 2028 ○ 29 MW starting from 2030
Transport	1. Occupancy - 1.98 persons per car, 9.36 persons per passenger road transport vehicle and 3.2-7.3 tonnes per heavy good vehicle (HGV), including Light Commercial Vehicles (LCV) 2. Average km per year – 6,500 km for cars, 64,500 km for passenger road transport vehicles and 8,900 km for HGV & LCV 3. Cars share by fuel (2050) a. Gasoline – 10% b. Hybrid – 25% c. Plug-in hybrid – 34% d. Electric – 20% e. Diesel – 10% f. LPG – 1% 4. Passenger road transport vehicles share by fuel (2050) a. Hybrid – 35% b. Electric – 30% c. Diesel – 29% d. Rest (gasoline, LPG, CNG) – 6% 5. HGV & LCV share by fuel (2050) a. Diesel – 40% b. Gasoline – 5% c. Hybrid – 25% d. Hydrogen – 5% e. Electric – 25%	1. Occupancy - 1.98 persons per car, 9.36 persons per passenger road transport vehicle and 3.2-7.3 tonnes per HGV, including LCV 2. Average km per year – 6,500 km for cars, 64,500 km for passenger road transport vehicles and 8,900 km for HGV & LCV 3. Cars share by fuel (2050) a. Gasoline – 2% b. Hybrid – 10% c. Plug-in hybrid – 38% d. Electric – 40% e. Diesel – 0% f. Hydrogen – 10% g. LPG – 0% 4. Passenger road transport vehicles share by fuel (2050) a. Hybrid – 25% b. Electric – 50% c. Diesel – 10% d. Hydrogen - 15% e. Rest (gasoline, LPG, CNG) – 0% 5. HGV & LCV share by fuel (2050) a. Diesel – 15% b. Gasoline – 2% c. Hybrid – 20% d. Hydrogen – 20% e. Electric – 43%	1. Occupancy - 1.98 persons per car, 9.36 persons per passenger road transport vehicle and 3.2-7.3 tonnes per HGV, including LCV 2. Average km per year – 6,500 km for cars, 64,500 km for passenger road transport vehicles and 8,900 km for HGV & LCV 3. Cars share by fuel (2050) a. Gasoline – 2% b. Hybrid – 0% c. Plug-in hybrid – 13% d. Electric – 65% e. Diesel – 0% f. Hydrogen – 20% g. LPG – 0% 4. Passenger road transport vehicles share by fuel (2050) a. Hybrid – 0% b. Electric – 75% c. Diesel – 0% d. Hydrogen – 25% e. Rest (gasoline, LPG, CNG) – 0% 5. HGV & LCV share by fuel (2050) a. Diesel – 0% b. Gasoline – 0% c. Hybrid – 3% d. Electric – 62% e. Hydrogen – 35%
Buildings	1. Renovation rate according to Building renovation strategy scenario 2, as it is defined in WAM scenario of NECP 2. Replacement of energy production sources based on biomass, coal, lignite, oil, needed for heating / cooling processes with heat pumps, until reaching a 15% share of heat pumps in the useful energy demand for heating / cooling in 2050. 3. Water heating – share of solar thermal collectors a. Urban - 2030, 10% and 2050, 18% b. Rural – 2030, 7.5% and 2050, 19%	1. Renovation rate according to Building renovation strategy scenario 2, as it is defined in WAM scenario of NECP 2. Replacement of energy production sources based on biomass, coal, lignite, oil, needed for heating / cooling processes with heat pumps, until reaching a 20% share of heat pumps in the useful energy demand for heating / cooling in 2050. 3. Water heating – share of solar thermal collectors a. Urban - 2030, 25% and 2050, 39% b. Rural – 2030, 14% and 2050, 28%	1. Renovation rate according to Building renovation strategy scenario 2, as it is defined in WAM scenario of NECP 2. Replacement of energy production sources based on biomass, coal, lignite, oil, needed for heating / cooling processes with heat pumps, until reaching a 25% share of heat pumps in the useful energy demand for heating / cooling in 2050. 3. Water heating – share of solar thermal collectors a. Urban - 2030, 28% and 2050, 54% b. Rural – 2030, 16% and 2050, 33%
Industry	1. Reduction of the use of fossil fuels (such as natural gas and coal) and their replacement with electricity, hydrogen, energy-reach waste, RES (including biomass), and heat (including heat produced by autoproducers and waste heat from thermal processes), in compliance with the rules regarding environmental protection	1. Replacement of fossil fuels (such as coal and oil), reduction of use of natural gas and their replacement by electricity, hydrogen, energy-reach waste, RES (including biomass), and heat (including heat produced by autoproducers and waste heat from thermal processes), in compliance with the rules regarding environmental protection	1. Replacement of fossil fuels (such as coal and oil), reduction of the use natural gas and their replacement by electricity, hydrogen, energy-reach waste, RES (including biomass), and heat (including heat produced by autoproducers and waste heat from thermal processes), in compliance with the rules regarding environmental protection

	2. The efficiency of the technologies will be increased according to the state-of-the-art of the Primes model and to the best available technologies from each industrial sector 3. Implementation of the Kigali amendment of the Montreal protocol in the Product uses as substitutes of ozone depleting substances 4. In the cement production, the activity data in 2040 will be in accordance with NC 8 (approx. 8,600kt clinker production), while the process emission factor level (calculated on the basis of CaO and MgO content originating from carbonates) will be lowered from 0.52 to 0.49 tCO2/t clinker, according to NC 8 5. The lime production will follow the production index growth trend (in accordance to the data from the National Commission for Strategy and Prognosis) and the emission factors will be in accordance with the BR 4 6. The glass production will follow the production index growth trend (in accordance with the data from CNSP) and the emission factors will be in accordance with BR 4 7. The level of production and emission in the ceramics industry and in all the other industries employing non-metallic minerals will be in accordance with BR 4 8. The annual growth rate of soda ash production will be 1.8%, in accordance with BR 4 9. The emission factor in the steel production will lower from1.01 tCO2/t to 0.3 tCO2/t in 2030, as a result of employing electric arc furnace (EAF) and DRI-EAF technologies 10. According to Net Zero Industry Act (Proposal for a regulation of the European Parliament and of the Council on establishing a framework of measures for strengthening Europe's net-zero technology products manufacturing ecosystem (Net Zero Industry Act) - COM(2023) 161, 16.03.2023), 2030 commitments for CO2 injecting and storing for the oil & gas industry are imposed.	2. The efficiency of the technologies will be increased according to the state-of-the-art of the Primes model and to the best available technologies from each industrial sector 3. By employing the carbon capture storage and utilization (CCUS) technologies in the Mineral industry (as defined in BR 5), at least 20% of the emissions will be captured by 2050. 4. Implementation of the Kigali amendment of the Montreal protocol in the Product uses as substitutes of ozone depleting substances 5. In the cement production, the activity data in 2040 will be in accordance with NC 8 (approx. 8,600kt clinker production), while the process emission factor level (calculated on the basis of CaO and MgO content originating from carbonates) will be lowered from 0.52 to 0.49 tCO2/t clinker, according to NC 8 6. The lime production will follow the production index growth trend (in accordance with the data from CNSP) and emission factors will be in accordance with BR 4 7. 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By employing the CCUS technologies in the Mineral industry (as defined in BR 5), at least 50% of the emissions will be captures by 2050. 4. Implementation of the Kigali amendment of the Montreal protocol in the Product uses as substitutes of ozone depleting substances 5. In the cement production, the activity data in 2040 will be in accordance with NC 8 (approx. 8,600kt clinker production), while the process emission factor level (calculated on the basis of CaO and MgO content originating from carbonates) will be lowered from 0.52 to 0.49 tCO2/t clinker, according to NC 8 6. The lime production will follow the production index growth trend (in accordance with the data CNSP) and the emission factors will be in accordance with the BR 4 7. The glass production will follow the production index growth trend (in accordance with the data from CNSP) and the emission factors will be in accordance with BR 4 8. The level of production and emission in the ceramics industry and in all the other industries employing non-metallic minerals will be in accordance with BR 4 9. The annual growth rate of soda ash production will be 1.8%, in accordance with BR 4 10. The emission factor in the steel production will lower from1.01 tCO2/t to 0.3 tCO2/t in 2030, as a result of employing electric arc furnace (EAF) and DRI-EAF technologies 11. According to Net Zero Industry Act, 2030 commitments for CO2 injecting and storing for the oil & gas industry are imposed.
Agriculture and Forestry	1. Reduction of emissions from enteric fermentation by introducing a proper diet. Based on this assumption, the emission factor for enteric fermentation will be reduced by 5% in 2030 and by 20% in 2050 compared to 2020. 2. Starting from 2050, no agricultural residues will be burned on the field 3. Emission factor of FSN_N in synthetic fertilizer will be reduced by 10% in 2050 4. By capturing and using the methane emissions of manure for producing biogas, the manure management emission level will be reduced by 20% in 2050 compared to 2020.	1. Reduction of emissions from enteric fermentation by introducing a proper diet. Based on this assumption, the emission factor for enteric fermentation will be reduced by 10% in 2030 and by 25% in 2050 compared to 2020. 2. Starting from 2040, no agricultural residues will be burned on the field 3. Emission factor of FSN_N in synthetic fertilizer will be reduced by 15% in 2050 4. By capturing and using the methane emission of manure for producing biogas, the manure management emission level will be reduced by 30% in 2050 compared to 2030 and	1. Reduction of emissions from enteric fermentation by introducing a proper diet. Based on this assumption, the emission factor for enteric fermentation will be reduced by 10% in 2030 and by 30% in 2050 compared to 2050. 2. Starting from 2030, no agricultural residues will be burned on the field. 3. Emission factor of FSN_N in synthetic fertilizer will be reduced by 20% in 2050 4. By capturing and using the methane emission of manure for producing biogas, the manure management emission level will be reduced by 40% in 2050 compared

	5. In terms of energy use in Agriculture, the share of solar energy will be increased to 15% in 2050, while diesel consumption will be reduced to zero. 6. The annual average forest burned area by 2050 will be equal to the average forest burned area during 2010-2019 7. Based on the data for Livestock in the BR4, on the 2010-2021 historical trends and on the sectoral investment plans, projections for the population of each type of Livestock is made • Buffalo female: -0.5% • Buffalo other: -0.5% • Dairy goats: +1.1% • Other types of goats: +0.4% • Horses: -1.1% • Mules and donkeys: +0.2% • Poultry adult for eggs: +0.7% • Poultry for meat: +0.7% • Rabbits: +0.5% • Cattle older than 2 years for slaughter: +0.13% • Dairy cow: +1.10% • Pigs under 20 kg: +1.85% • Pigs between 20 and 50 kg: +1.85% • Fattening: +1.85% • Boars: +0.50% • Breeding sows: +1.6% • Dairy sheep: +1.20% • Rams for breeding: +1.20% • Other types of sheep: +1.20%	5% of the energy demand in agriculture will be fulfilled 5. In terms of energy use in Agriculture, the share of solar energy will be increased to 15% in 2050, while diesel consumption will be reduced to zero. 6. The annual average forest burned area by 2050 will be equal to the average forest burned area during 2010-2019 7. Based on the data for Livestock in the BR4, on the 2010-2021 historical trends and on the sectoral investment plans, projections for the population of each type of Livestock is made • Buffalo female: -0.5% • Buffalo other: -0.5% • Dairy goats: +1.1% • Other types of goats: +0.4% • Horses: -1.1% • Mules and donkeys: +0.2% • Poultry adult for eggs: +0.7% • Poultry for meat: +0.7% • Rabbits: +0.5% • Cattle older than 2 years for slaughter: +0.13% • Dairy cow: +1.10% • Pigs under 20 kg: +1.85% • Pigs between 20 and 50 kg: +1.85% • Fattening: +1.85% • Boars: +0.50% • Breeding sows: +1.6% • Dairy sheep: +1.20% • Rams for breeding: +1.20% • Other types of sheep: +1.20%	to 2030 and 5% of the energy demand in agriculture will be fulfilled. 5. In terms of energy use in Agriculture, the share of solar energy will be increased to 15% in 2050, while diesel consumption will be reduced to zero. 6. The annual average forest burned area by 2050 will be equal to the average forest burned area during 2010-2019 7. Based on the data for Livestock in the BR4, on the 2010-2021 historical trends and on the sectoral investment plans, projections for the population of each type of Livestock is made • Buffalo female: -0.5% • Buffalo other: -0.5% • Dairy goats: +1.1% • Other types of goats: +0.4% • Horses: -1.1% • Mules and donkeys: +0.2% • Poultry adult for eggs: +0.7% • Poultry for meat: +0.7% • Rabbits: +0.5% • Cattle older than 2 years for slaughter: +0.13% • Dairy cow: +1.10% • Pigs under 20 kg: +1.85% • Pigs between 20 and 50 kg: +1.85% • Fattening: +1.85% • Boars: +0.50% • Breeding sows: +1.6% • Dairy sheep: +1.20% • Rams for breeding: +1.20% • Other types of sheep: +1.20%
Waste	1. 10% of the residual waste should be landfilled by 2035 2. By 2030, it is assumed that household waste per capita will be reduced by 10 % compared to 2017 (i.e. reduce Municipal Solid Waste (MSW) from the 228 kg per capita recorded in 2017 to 204 kg per capita by 2030). 3. Recycle – converting the waste materials to raw materials and composting. Recycling rate: a. Wood – 25% in 2025, 30% in 2030 (as in Zero Waste Europe-Policy briefing document) and 50% in 2050 b. Paper and textile – 80% in 2050 c. Food and garden waste – 50% in 2030 and 60% in 2050. The reduced amount of food and garden waste will be used in the composting process. Additionally, the emissions factors for composting will be reduced to 3kt CH_4/tonne and 0.24 kt N_2O/tonne in 2050, which is in accordance to the GHG Emission Factors Review – ESA 4. Energy recovery a. Energy production – it is assumed that, by 2050,	1. 10% of the residual waste should be landfilled by 2035 2. By 2030, it is assumed that household waste per capita will be reduced by 10 % compared to 2017 (i.e. reduce Municipal Solid Waste (MSW) from the 228 kg per capita recorded in 2017 to 204 kg per capita by 2030). 3. Recycle – converting the waste materials to raw materials and composting. Recycling rates: a. Wood – 25% in 2025, 30% in 2030 (as in Zero Waste Europe-Policy briefing document) and 50% in 2050 b. Paper and textile – 80% in 2050 c. Food and garden waste – 50% in 2030 and 60% in 2050. The reduced amount of food and garden waste will be used in the composting process. Additionally, the emissions factors for composting will be reduced to 3kt CH_4/tonne and 0.24 kt N_2O/tonne in 2050, which is in accordance to the GHG Emission Factors Review – ESA 4. Energy recovery a. Energy production – it is assumed that, by 2050, 55% of the emissions from the non-recycled waste plus the	1. 10% of the residual waste should be landfilled by 2035 2. By 2030, it is assumed that household waste per capita will be reduced by 10 % compared to 2017 (i.e. reduce Municipal Solid Waste (MSW) from the 228 kg per capita recorded in 2017 to 204 kg per capita by 2030). 3. Recycle – converting the waste materials to raw materials and composting. Recycling rates: a. Wood – 25% in 2025, 30% in 2030 (as in Zero Waste Europe-Policy briefing document) and 50% in 2050 b. Paper and textile – 80% in 2050 c. Food and garden waste – 50% in 2030 and 60% in 2050. The reduced amount of food and garden waste will be used in the composting process. Additionally, the emissions factors for composting will be reduced to 3kt CH_4/tonne and 0.24 kt N_2O/tonne in 2050, which is in accordance to the GHG Emission Factors Review – ESA 4. Energy recovery a. Energy production – it is assumed that, in 2050, 60% of the emissions from the non-recycled waste plus the

	40% of the emissions from the non-recycled waste plus the historical emissions will be used for electricity production (20% by 2030) b. Flaring – 50% of the emissions from the non-recycled waste plus the historical emissions will be used for flaring in 2050. 5. Incineration / co-incineration – The volume of municipal waste incinerated / co-incinerated will increase to 500kt in 2030 and to 900kt in 2050, with the option of this waste being used for energy recovery in recovery facilities and/or in cement plants. 6. Wastewater treatment a. 55% of the rural population will be connected to the sewage network by 2050. b. By 2030, all urban areas will be connected to wastewater treatment plants. At the same time, 5% of the rural areas will be connected to wastewater treatment plants by 2025 and 70% by 2050. The sludge resulting from the wastewater treatment will be used in agriculture or will be dried and used as energy source in the cement industry.	historical emissions will be used for electricity production (25% by 2030) b. Flaring – 55% of the emissions from the non-recycled waste plus the historical emissions will be used for flaring in 2050. 5. Incineration / co-incineration – The volume of municipal waste incinerated / co-incinerated will increase to 500kt in 2030 and to 900kt in 2050, with the option of this waste being used for energy recovery in recovery facilities and/or in cement plants. 6. Wastewater treatment a. 75% of the rural population will be connected to the sewage network by 2050. b. By 2030, all urban areas will be connected to wastewater treatment plants. At the same time, 5% of the rural areas will be connected to wastewater treatment plants by 2025 and 70% by 2050. The sludge resulting from the wastewater treatment will be used in agriculture or will be dried and used as energy source in the cement industry.	historical emissions will be used for electricity production (30% by 2030) b. Flaring – 60% of the emissions from the non-recycled waste plus the historical emissions will be used for flaring in 2050. 5. Incineration / co-incineration – The volume of municipal waste incinerated / co-incinerated will increase to 500kt in 2030 and to 900kt in 2050, with the option of this waste being used for energy recovery in recovery facilities and/or in cement plants. 6. Wastewater treatment a. 90% of the rural population will be connected to the sewage network by 2050. b. By 2030, all urban areas will be connected to wastewater treatment plants. At the same time, 5% of the rural areas will be connected to wastewater treatment plants by 2025 and 70% by 2050. The sludge resulting from the wastewater treatment will be used in agriculture or will be dried and used as energy source in the cement industry.

1. EU CLIMATE POLICIES AND TARGETS

EU and its MS are fully committed to the Paris Agreement and its long-term goals and demand urgently enhancing the global ambition in light of the latest available scientific evidence published by the IPCC. The European Council endorsed the objective of achieving a climate-neutral EU by 2050, in line with the objectives of the Paris Agreement.

The endorsement of the climate neutrality objective was reached following an inclusive institutional and societal debate based on the strategic long-term vision proposed by the EC which includes a detailed analysis of solutions that could be pursued for the transition to a net zero GHG emission economy. In accordance with the Paris Agreement, the EU MS deliver on the ambitious social and economic transformation, the EU and its Member States aiming to inspire global climate action and demonstrate that moving towards climate neutrality is not only imperative, but also feasible and desirable. The Long-Term Strategies of each Member State must reflect the need to step up collective ambition and provide the long-term policy guidance necessary to limit the intensifying impacts of climate change.

The transition to climate neutrality will bring significant opportunities, such as potential for economic growth, for new business models and markets, for new jobs and technological development. Forward-looking research, development and innovation (RDI) policies will have a key role. Achieving climate neutrality will however require overcoming serious challenges and encompasses adequate instruments, incentives, support and investments to ensure a cost-effective, just, as well as socially balanced and fair transition, taking into account different national circumstances in terms of starting points. The transition will require significant public and private investments.

All relevant EU legislation and policies need to be consistent with, and contribute to, the fulfilment of the climate neutrality objective. The climate neutrality objective needs to be achieved in a way that preserves EU's competitiveness, by developing effective measures to tackle carbon leakage. Lastly, international engagement will be crucial for the success in addressing climate change.

The Commission's Communication to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions "Next Steps Towards a Sustainable European Future - European Action for Sustainability", from November 2016, presents the EU's response to the "2030 Agenda for Sustainable Development - Transforming the World ours", adopted on 25 September 2015 by the heads of state and government of 193 countries, during the General Assembly of the United Nations (UN) in September 2015. The cited communication confirms the integration of the 17 sustainable development goals (SDGs) of the 2030 Agenda within European policy and current EC priorities, presents the assessment of the situation since its drafting and identifies the most relevant sustainability concerns. Through this communication, the EU commits to sustainable development that "ensures a dignified life for all within the limits of the planet, bringing together economic prosperity and efficiency, peaceful societies, social inclusion and environmental responsibility".

1.1 National Long–Term Strategies

The long-term strategies (LTS) are crucial instruments for performing the economic transformation needed in order to achieve the sustainable development goals, as well as for moving towards the long-term goal set by the Paris Agreement – holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels. Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action, with all its subsequent amendments, sets out the process for drafting the LTS every 10 years (starting from 2020) and, where necessary, update them every five years. The LTS should be consistent with Member States' integrated national energy and climate plans (NECP) and with the relevant national strategies and plans.

The national LTS and EU's strategy need to cover, with a perspective of at least 30 years:

- Total GHG emission reductions and enhancements of removals by sinks
- Emission reductions and enhancements of removals in all individual sectors including energy production, industry, transport, the heating and cooling and buildings sector (residential and tertiary), agriculture, waste and land use, land-use change and forestry (LULUCF)

- Expected progress on transition to a low greenhouse gas emission economy, including greenhouse gas intensity, CO_2 intensity of gross domestic product, related estimates of long-term investment, and strategies for related research, development and innovation
- To the extent feasible, expected socio-economic effect of the decarbonisation measures, including, inter alia, aspects related to macro-economic and social development, health risks and benefits and environmental protection
- Links to other national long-term objectives, planning and other policies and measures, and investment.

The Commission supports Member States in preparing their LTS by providing information on the state of the underlying scientific knowledge and opportunities for sharing knowledge and best practices, including, where relevant, guidance for Member States.

The Commission assesses whether the national LTS are adequate for the EU to collectively achieve the objectives and targets set out in the governance regulation and provide information on any remaining collective gap[2].

1.2 Overview of LTS targets from other EU Member States

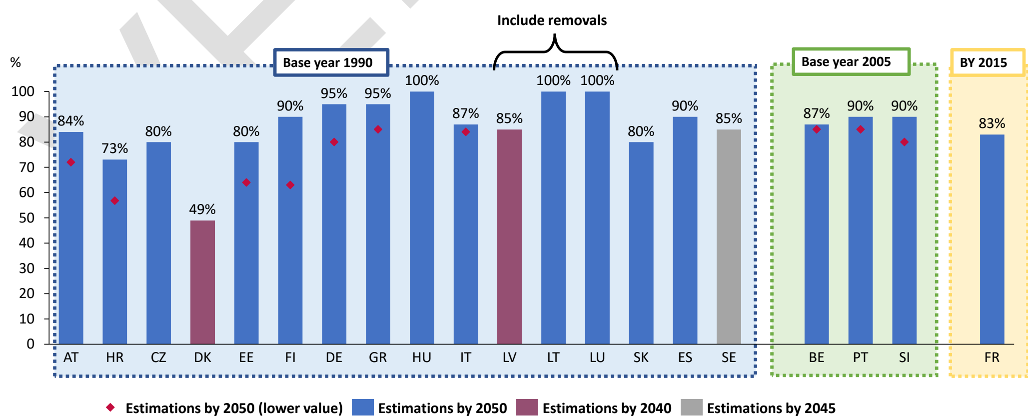
1.2.1 GHG emission reductions

Most of the EU countries include in the LTS the estimated GHG emission reductions by 2050, except Denmark and Latvia which quote estimates by 2040 and Sweden by 2045. Belgium, Portugal, and Slovenia have assessed their emission reduction relative to the emissions level in 2005, and France relative to 2015. The other EU countries use 1990 as the base year against which the emission reductions are evaluated (Figure 5).

Austria, Belgium, Croatia, Estonia, Finland, Germany, Greece, Italy, Portugal, and Slovenia provide a range of GHG reductions that can be achieved, depending on the different modelling scenarios developed by each country. Most EU countries plan to reduce their emission by 80% - 90% by 2050 (or by the last year of the projections) relative to their base year, Germany and Greece by 95%, while Hungary, Lithuania, and Luxembourg by 100%. The estimated emission reductions of Latvia, Lithuania, and Luxemburg include the removals from the LULUCF sector, while the other countries exclude the LULUCF removals from their estimates and Denmark also excludes the ETS sectors. The LTS of Czechia, Estonia, Finland, Germany and Hungary include indicative milestones for 2040 and 2050. The LTS of Luxemburg builds on 2030 and 2040 milestones included in their NECP and national climate law, while the LTS of Sweden provides only intermediate milestones for non-ETS sectors.

Most of the countries included in their LTS the projected emissions by sectors expressed as millions of tons of CO2-eq, while Croatia, Denmark, Latvia, Lithuania, and Slovenia, included the emissions reduction by sector as a percentage compared to 1990 GHG emissions. Due to the diversity of the modelling scenarios by country, a comparison of the emission projections by sectors between countries cannot be performed.

Figure 5. Estimated GHG emission reductions in the LTS of EU countries



[2] National long-term strategies (europa.eu)

1.2.2 RES

Based on the scenarios included in the LTS, the countries that have estimated a higher share of RES in their gross final energy consumption are Austria, Greece, Hungary, Italy, Lithuania, Luxemburg, Portugal, and Spain. Their projections on RES share vary between 80% and 100% in 2050 (Greece even presented a value of 113.8%). The LTS of Croatia, Denmark, Finland, and Slovenia, presented slightly lower estimations of RES share in the gross final energy consumption, which vary between 50% and 80%. The estimates included in the EU countries' LTS represent the RES share in 2050, except for Denmark, which provides the share in 2040. The LTS of Belgium, Czechia, Estonia, France, Germany, Latvia, Netherlands, Slovakia, and Sweden did not include information on RES share in the final energy consumption.

Some of the LTS provide information on the RES share by sectors. For example, Estonia envisages increasing the RES share in energy production to almost three quarters by 2050 (mainly from wind energy and biomass), and the RES share in final energy consumption in transport is projected to be about 26%–52% in 2050 for different scenarios. Latvia also intends to replace fossil energy sources in the energy sector with RES by 2050. Some of the EU countries, like Austria, Denmark, Italy, Netherlands, Spain, and Italy, envisaged that, by 2050, 100% of the electricity production would be realized from RES. Austria plans to achieve this share by 2030, and Sweden by 2040.

1.2.3 Energy Efficiency

The LTS of Croatia, Denmark, Finland, and Portugal include information on the primary energy consumption (PEC) and the final energy consumption (FEC) based on the scenarios developed. The estimations arepresented as absolute values in 2050 (in the case of Denmark for 2040) and as savings (in %) compared to 2005 level of consumption. In the case of Denmark, an increase of 3.7% of FEC is envisaged relative to 2005 due to an expected significant increase in energy consumption in the tertiary sector (particularly new electricity consumption by large data centres).

Greece and Latvia provided only information on the PEC, while Austria, Italy, Hungary, Slovenia, and Spain included only information on the FEC. Italy also presented information on the gross inland energy consumption (GIC), representing the sum of PEC and energy demand for international aviation. Sweden included information on the intensity of FEC as savings (in %) in 2030 compared to 2005.

The LTS of Belgium, Czechia, Estonia, France, Germany, Lithuania, Luxemburg, Netherlands, and Slovakia did not include any information on energy efficiency.

Buildings and transport have the strongest impact on energy efficiency. Energy efficiency measures considered by most countries include moderate or extensive renovation of existing buildings, employing high efficiency processes for homes heating and cooling, use of efficient appliances (for example in Croatia and Spain). Italy and Finland also include measures related to the industrial sector, such as the implementation of advanced technologies (e.g. in electrochemical processes, replacing the use of coke with hydrogen or the electrolytic process in reduction steelmaking processes). Portugal and Slovenia considered strengthening the perspectives of the circular economy and resource use efficiency.

1.3 Summary of the variety of policies, measures and actions proposed by EU member states

This section provides a summary of the various policies, measures and actions proposed by MS in their NECPs and consequently in their LTS. The choice of the countries was made based on several factors, one being the proximity to Romania. For this reason, Romania's EU neighbouring countries are herein included, in addition to the members of the Visegrád Group, except for the Czech Republic. At the same time, the policies and measures adopted by Austria and Belgium are also included.

The analyzed policies and measures follow the 5 dimensions of the Energy Union:

- Decarbonization
- Energy Efficiency
- Security of Energy Supply

- Internal Energy Market
- Research, Innovation and Competitiveness.

The Decarbonization dimension is defined by policies, actions and measures on the national, regional (or provincial) and local levels, which are aimed at reducing the countries' carbon footprint and reaching net – zero emissions in the agreed timelines. Within the parameters of this dimension, the aforementioned countries have provided specific steps and roadmaps for tackling the issue at hand at the sectoral level, with specific policies, actions and measures being provided for the following key (economic) sectors:

- Energy
- Industry (including the energy consuming industry together with industrial processes and product use - IPPU)
- Transport:
  - Road
  - Rail
  - Air
  - Water
  - Multimodal
- Buildings and Heating & Cooling
- Agriculture and Forestry
- Waste.

In addition to this, within the Decarbonization dimension, the countries provide specific actions meant to increase the share of RES-based energy production.

Regarding the Transport sector, the main objective for all the covered countries is to provide the necessary legal framework and to take critical steps in enabling a swift, sustainable and effective transition from (road) vehicles using internal combustion engines and vehicles intended for other purposes (such as aircraft and ships using fossil fuels) to environmentally friendly vehicles, aircraft, trains and ships, which employ electricity and/or other sustainable and renewable fuels (ex. Green hydrogen). All the countries which have been included in this report have taken careful and detailed steps in ensuring this transition is supported on all levels and all plausible risks have been taken into consideration. A list of the proposed policies and measures for the Transport sector are:

- Clean Vehicle Directive (Austrian Chancellery)
- The Federal Government of Austria's Cycling Masterplan for the period 2015 – 2025 (Austrian Chancellery)
- An Electrification plan intended for the Transport sector (Austrian Chancellery)
- Purchase and management of vehicle fleets and building stock in line with climate and energy neutrality objectives by 2040 (Belgian Federal Government)
- Investing in accessibility by focusing on demand (Flemish Region's Government – Kingdom of Belgium);
- Creating the spatial conditions for environmentally friendly mobility and sustainable accessibility (Flemish Region's Government – Kingdom of Belgium)
- Controlling the development of mobility (Flemish Region's Government – Kingdom of Belgium)
- Preparing transport networks for the future (Flemish Region's Government – Kingdom of Belgium)
- Development of low emission transport, including electromobility (Polish Government)
- Establishing Low-emission zones (LEZ) in large urban agglomerations following the National Air Pollution Control Program 2020-2030 (Bulgarian Government)
- Measures in the transport sector (Slovakian Government):
  - Increasing the minimum share for fuel suppliers
  - Increasing the contribution of advanced biofuels
  - Increasing the share of biofuels in transport

Within the Buildings and Heating & Cooling sector, the main focus is the overall improvement in the efficiency in all the buildings, including the older buildings, by measures and actions for renovation and/or additional improvements to the existing structures. Policies, actions and measures address both the public and commercial sectors, as well as for the residential sector. Heating & cooling of buildings is also addressed. The countries have outlined concrete steps and actions aimed at increasing the diversity of technologies and fuels used in the heating & cooling processes and reducing the use of natural gas and other fossil fuels. Some of the policies which the considered countries have decided to adopt are presented hereafter:

- The thermal quality of buildings built after 2020 – which will therefore not undergo thorough renovation before 2050 – must be raised to a cost-optimal level in accordance with the EU Energy Performance of Buildings Directive (Austrian Chancellery)
- By 2030, liquid fossil fuels will no longer be used in federal and provincial public buildings (owned and used) (Austrian Chancellery)
- Measures intended for thermal buildings renovation (Austrian Chancellery)
- The scope of the 6% reduced VAT rate on the demolition and rebuilding of private dwellings, which is currently in place in 32 municipalities, could be extended if the EC finds that this measure is making a significant contribution to the Belgian energy efficiency target (Belgian Federal Government)
- Entry into force on 1 January 2019 of an optional scheme for charging VAT on new buildings leased for commercial purposes where the lessee is a Belgian taxpayer (Belgian Federal Government)
- A plan for setting-up an environmental energy tax will be drawn up in consultation with the federal and regional governments (Belgian Federal Government)
- Implementation of the Green District Heating Program (Hungarian Government)
- Reduction of CO_2 emissions in the construction sector (Polish Government)
- Reduction of CO_2 emissions in the energy production sector through actions envisaged by the State Environmental Policy 2030 and other strategic documents for the energy sector (Energy Policy of Poland until 2040) (Polish Government):
- Development of energy-efficient heating systems and of low-emission individual heating systems (Polish Government)
- District heating optimization (Slovakian Government)
- Gradual decommissioning of solid fossil fuel heating plants after 2025 (Slovakian Government).

The main focus within the Agriculture and Forestry sector is aimed towards reducing GHG emissions in the sector, given the EU regulations. Some of the proposed policies for this sector are:

- Improve dosing to suit requirements by means of fertilizer needs planning, soil sampling and Agriculture 4.0 (digital Agriculture) and by increasing the knowledge (building on existing training and advisory services). Reducing losses in mineral and agricultural fertilizers management (Austrian Chancellery)
- Increasing the consumption of energy recovered landfill gas, and using biogas in agriculture (Hungarian Government)
- Austrian Nitrate Action Programme aims at the prevention and/or reduction of the nitrate input in the field of agriculture. (Austrian Chancellery)
- Identifying suitable locations for the construction of biogas plants (close to livestock and other raw material suppliers, possibility of connecting to the gas grid) (Austrian Chancellery)
- Management of agricultural residues (Austrian Chancellery)
- Incentives for cooperation between farm holdings, e.g., by using the same biogas production capacities and farm manure storage facilities (Austrian Chancellery)
- Incentives for the use of crop rotation with a focus on nitrogen-fixing crops (Bulgarian Government)
- Management of degraded agricultural land through (Bulgarian Government):
    - Biological re-cultivation using plants that are indigenous to the area
    - Anti-corrosion and soil erosion prevention methods

- Introducing irrigation and water and energy saving technologies, promoting extensive farming (Bulgarian Government)
- Supporting the development of green infrastructure in rural areas to adapt to climate change (Polish Government)
- Promoting eco-farming, dissemination of environmentally friendly methods of agricultural and fishery production, and management of by-products from agriculture, fishery and agri-food processing (Polish Government)
- Agricultural land - Slovak Government Regulation No 342/2014, laying down rules for granting support in agriculture in the context of decoupled direct payment schemes. The Regulation introduces the efficient use and appropriate timing of use of nitrogen doses within mineral fertilizers (Slovakian Government)
- Sectoral policies and measures in the land use, land-use change and forestry (LULUCF) sector (Slovakian Government);

The waste management sector's policies, actions and measures are focused on developing processes and mechanisms for enabling more efficient waste treating and actions through which the products of waste treatment could be utilized.

The energy sector's targets and objectives are outlined through polices, measures and actions aimed at achieving the agreed targets included in the Paris Agreement, as well as meeting the objectives of the European Union. This includes accelerating and managing the clean energy transition, diversifying the sources of energy, establishing higher interstate cooperation between neighbouring countries, providing financial incenvtives for RES-based investments, transforming the energy markets, etc. Some of the policies, actions and measures proposed under the scope of this sector include the following:

- Basic instruments – market premiums and investment support (Austrian Chancellery)
- '100,000 rooftops' flagship project (Austrian chancellery)
- Develop offshore wind capacity in the North Sea (Belgian Federal Government)
- Build 4 GW of offshore wind capacity by 2030 (Belgian Federal Government)
- Implementation of the measures of the Accelerated Gasification Program (PAG) in Bulgaria (Bulgarian Government)
- Introducing a binding energy efficiency scheme (reducing fuel and final energy consumption) (Bulgarian Government)
- Development of electricity transmission and distribution infrastructure, of smart networks, of storage facilities and interconnectors (Bulgarian Government)
- Support for the introduction of low-power electricity and heat generation installations in family houses and blocks of flats (Slovakian Government)
- Develop 2nd generation biofuels (Slovakian Government)

The Energy Efficiency Dimension includes policies, actions, measures and objectives for increasing energy efficiency. These include:

- Setting-up new energy efficiency obligation schemes and financing plans
- New legislation to significantly improve the energy efficiency of public buildings
- Financial and other type of support aimed at aiding the general public invest more in energy efficient technologies
- Increasing the public awareness and level of knowledge and education on the energy efficiency topic
- Introducing and implementing energy audits.

For the Energy Security Dimension, the focus is on the process of ensuring higher energy security for the national energy systems. In this regard, policies, actions and measures have been proposed through which the energy supply is diversified in the dependence on imports of (all kinds of) energy is decreased, in parallel with supporting the development of the internal energy production capabilities. In addition to this, policies, actions and measures have been proposed, through which improved demand response, coupling of electricity markets and efficient and sustainable energy storage technologies are introduced and integrated in the national grid. It is also important to underline that a notable effort has been placed in emphasizing the potential of (Green) Hydrogen in this regard.

The Internal Energy Market Dimension provides a set of policies, actions and measures which are aimed at achieving higher interconnectivity of the electricity grid, whilst taking into account the predefined EU interconnectivity targets, improvement of the energy transmission grid and further advanced energy market adaptation and integration. Another important component tackled here is Energy Poverty. Some of the countries have adopted policies and have taken on steps to combat this issue in the coming years. Lastly, it is important to also mention that within this dimension, the countries have drafted policies, actions and measures aimed at increasing their energy systems flexibility with regard to RES integration, the integration of smart grids energy systems, aggregation, energy storage, distributed generation (DG), mechanisms for dispatching and curtailment, real – time pricing and etc.

Within the context of the Research, Innovation and Competitiveness Dimension, the countries have proposed actions, policies and measures aimed at developing new green and efficient technologies. The countries have identified and defined the fields and cross – sectional fields of the energy sector which are considered as a priority and focused their RDI effort in those areas. Some countries have also included measures for overseeing the process and ensuring transparency. Lastly, measures to support and stimulate the innovation in domestic industries relevant for LTS have been introduced.

2. OVERVIEW AND PROCESS FOR DEVELOPING THE STRATEGIES

2.1 Legal and policy context

The structure of **Romania's Long-Term Strategy (LTS)** follows the **EU Regulation 2018/1999**, which, through Article 15, sets for each Member State to describe how it will contribute to achieving the objectives of the **Paris Agreement**. The LTS has to indicate how the Member State will contribute to the long-term European goals so that the EU can achieve climate neutrality as soon as possible and achieve a highly energy-efficient system, largely based on energy from renewable sources.

At EU level, the European **Energy Strategy**[3] has 5 dimensions: (1) energy security, (2) the internal energy market, (3) energy efficiency, (4) decarbonising the economy and (5) research, innovation, and competitiveness. The key tools for implementing the strategy are the National Energy and Climate Plans (NECP). which cover periods of ten years starting from 2021-2030, together with the EU and national long-term strategies (LTS), which cover a 30 years period of time.

Regulation (EU) 2018/841 of the European Parliament and of the Council of 30 May 2018 on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework, and amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU is one of the key-elements for the implementation of the Union's commitments under the Paris Agreement.

Regulation (EC) No 401/2009 of the European Parliament and of the Council of 23 April 2009 on the European Environment Agency and the European Environment Information and Observation Network includes provisions aimed at achieving the objectives regarding environmental protection. According to the Commission's assessment elaborated in September 2020[4], Romania's NECP is not ambitious enough. Based on the Commission's recommendations, the policies and measures developed to achieve the decarbonisation target need more clarity.

Regulation (EU) 2018/1999, Regulation (EU) 2018/841 and Regulation (EC) no. 401/2009 were subsequently amended by **Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law')**[5] which aims to achieve zero net GHG emissions for all Member States by 2050, mainly by regulating GHG emissions union-wide, by investing in green technologies and protecting the natural environment. The Romanian 2021-2030 NECP will be updated in 2023 to reflect the above-mentioned provisions. The measures and policies in the updated NECP, together with the ones in the LTS, will need to observe the following targets stipulated in Regulation (EU) 2018/841:

- **Zero net emissions** must be reached by **2050** the latest, with the target of achieving a negative emissions balance subsequently, by taking the necessary measures at Union and national level (Article 2).
- To achieve climate neutrality in 2050, the Union's mandatory climate target for 2030 is a national reduction in net GHGs emissions (emissions after deductions) by at least **55% by 2030 compared to 1990 levels**. **The contribution of net removals** for 2030 are limited to 225 million tonnes of CO2 equivalent net carbon sink. The LULUCF threshold (restraints) ensures that increased ambition in the LULUCF sector will not lead to a decrease in ambition in the ETS and ESR sectors. The intermediate climate target will be set for **2040** at Union level, and the Commission will publish the Union's estimated indicative budget for GHGs for the period 2030-2050 (Article 4).
- The assessment of the Union's progress and of the national measures will be based on an **indicative, linear trajectory**, setting out the path to reducing net emissions at Union level and linking the **Union's 2030, 2040 and 2050 climate neutrality targets** (Articles 6,7 and 8).
- Regarding climate change adaptation (Article 5), similar to other Member States, Romania is working on drafting the 2022-2035 National Strategy on Disaster Risk Reduction and has adopted the National Disaster Risk Reduction and Management Plan (adopted by decision of General Inspectorate for

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[3] https://energy.ec.europa.eu/topics/energy-strategy_en
[4] https://ec.europa.eu/energy/sites/default/files/documents/staff_working_document_assessment_necp_romania_en.pdf
[5] Regulamentul (UE) 2021/1119 al Parlamentului European și al Consiliului din 30 iunie 2021 de stabilire a cadrului pentru atingerea neutralității climatice și de modificare a Regulamentului (CE) nr. 401/2009 și (UE) 2018/1999 („Legea europeană a climei").

Emergency Situations (IGSU)), within a technical assistance service agreement between IGSU and the World Bank. The Agreement on Reimbursable Technical Assistance Services (SATR), "Strategy for Disaster Risk Reduction for Romania", entered into force on 30 June 2020 and includes measures to adapt to climate change. The recommendations on the draft proposal of the 2022-2035 National Strategy on Disaster Risk consolidates the complex vision, general objectives and principles, directions of action (measures), expected results, ways of implementation, monitoring and evaluation and the financial means necessary for the implementation of such a strategy.

The legislative framework relevant for the accomplishment of the energy and climate LTS strategic objectives includes, among others, the legislation presented in Table 3:

Table 3. Other EU legislation relevant for the deployment of the LTS

Legislation	Main aspects relevant for achieving the objectives
Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC	The Directive establishes a greenhouse gas emission allowance trading system (hereinafter referred to as the "Community scheme") to promote the reduction of greenhouse gas emissions in a cost-effective and economically efficient way. The directive was transposed into national law by GD no. 780/2006 (scheme for trading GHG emission certificates), with subsequent amendments and additions. The fourth phase of the EU ETS will run from 2021-2030 with two allocation periods 2021-2025 and 2026-2030. Operators must report the requested data annually, within the commercialization period.
Commission Regulation (EU) No 601/2012 of 21 June 2012 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council	The Regulation sets-ip the monitoring and reporting of greenhouse gas emissions in accordance with Directive 2003/87/EC.
Regulation (EU) 2018/842 of the European Parliament and of the Council of 30 May 2018 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement and amending Regulation (EU) No 525/2013	The regulation stipulates that Romania must achieve a mandatory reduction of greenhouse gas emissions from non-ETS (Effort Sharing Regulation (ESR)) sectors, such as transport, buildings, agriculture and waste, industrial processes, and product use. The annual reduction is mandatory for the member states in the period 2021-2030.
Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014 amending Directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large undertakings and groups	The directive introduces a non-financial declaration for large enterprises and groups. Starting from 2017, public interest companies with more than 500 employees at the balance sheet date were required to publish a non-financial statement in the directors' reports. From 2019, the scope of non-financial information was extended to all categories of companies exceeding the criterion of more than 500 employees during the financial year. The presentation of information on energy transition and climate is not standardized or mandatory. Consequently, the data presented are minimal and are not collected at national level.
Commission Delegated Regulation (EU) 2021/2139 of 4 June 2021 supplementing Regulation (EU) 2020/852 of the European Parliament and of the Council by establishing the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to climate change mitigation or climate change adaptation and for determining whether that economic activity causes no significant harm to any of the other environmental objectives	The Regulation specifies the technical examination criteria according to which certain economic activities qualify as activities that contribute substantially to climate change mitigation and adaptation, as well as the criteria for economic activities that cause significant damage to any relevant environmental objective. Companies report the share of eligible/taxable activities in turnover, capital expenditure and operating expenditure.
Communication from the Commission to the European Parliament, the Council, the	Hydrogen is a key priority for the European Green Deal. The Strategy's vision for a climate-neutral EU is expected to increase the share of hydrogen in the European energy mix to 13-14% by 2050.

European Economic and Social Committee and the Committee of the Regions "A hydrogen strategy for a climate-neutral Europe" - COM(2020) 301 final, 08.07.2020	
Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and The Committee Of The Regions "A Green Deal Industrial Plan for the Net-Zero Age" - COM(2023) 62 final, 01.02.2023	The plan aims to establish a framework of measures to strengthen the European ecosystem for manufacturing products with net zero emission technologies
Proposal for a Regulation of the European Parliament and of the Council on establishing a framework of measures for strengthening Europe's net-zero technology products manufacturing ecosystem (Net Zero Industry Act)	The Net Zero Industry Act is under development
Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe's recovery	To align with the goal of becoming the first climate-neutral continent by 2050, European industry will need a secure supply of clean and affordable energy and raw materials. The updated version of the new Industrial Strategy 2020 addresses building a stronger single market to support Europe's recovery.
Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC	The directive was transposed into national legislation by Law 12/18.072014 on energy efficiency, with subsequent amendments and additions, which creates the legal framework for the development and application of the national policy in the field of energy efficiency
Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources	The directive was transposed into national legislation by GEO 163/29.11. 2022 for the completion of the legal framework for the promotion of the use of energy from renewable sources, as well as for the modification and completion of some normative acts, which complete the legal framework necessary for the promotion of energy from renewable sources
Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings	The directive was transposed into national legislation by Law no. 372/2005 on the energy performance of buildings, republished, with subsequent amendments and additions
Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU	The draft law on transposition into national legislation was submitted to public consultation.
Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Next steps for a sustainable European future, European action for sustainability, COM(2016) 739 final - 22.11.2016	The Communication confirms the integration of the 17 SDGs of the 2030 Agenda within the framework of European policy and the current priorities of the EC, presents the assessment of the situation at the time of its elaboration and identifies the most relevant concerns regarding sustainability. Through this Communication, the EU commits to sustainable development that "ensures a dignified life for all, respecting the limits of the planet, bringing together economic prosperity and efficiency, peaceful societies, social inclusion and environmental responsibility"

Fit for 55 package	The "Fit for 55" package is a set of interlinked legislative proposals that, applied together, can meet the Union's 2030 binding climate target of reducing domestic net greenhouse gas emissions (emissions net of removals) by at least 55 % by 2030 compared to 1990 levels. More details about this package are given below this table.

The "Fit for 55" package of the European Green Deal includes several additional amendments and revisions, mainly for the following acts:

- Directive 2012/27/EU (on energy efficiency) at the proposal stage [6]
- Directive (EU) 2018/2001 (on renewable energy) at the proposal stage [7]
- Regulation (EU) 2018/1999 (on the Governance of the Energy Union and Climate Action) at the proposal stage
- Proposal for a Regulation of the European Parliament and of the Council amending Regulations (EU) 2018/841 as regards the scope, simplifying the compliance rules, setting out the targets of the Member States for 2030 and committing to the collective achievement of climate neutrality by 2035 in the land use, forestry and agriculture sector, and (EU) 2018/1999 as regards improvement in monitoring, reporting, tracking of progress and review
- Regulation (EU) 2018/842 of the European Parliament and of the Council of 30 May 2018 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement and amending Regulation (EU) No 525/2013
- Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union, Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and Regulation (EU) 2015/757
- Proposal for a Regulation of the European Parliament and of the Council establishing a carbon border adjustment mechanism
- Proposal for a Regulation of the European Parliament and of the Council amending Regulation (EU) 2019/631 as regards strengthening the CO2 emission performance standards for new passenger cars and new light commercial vehicles in line with the Union’s increased climate ambitio

Other relevant proposed legislation at EU level includes:

- Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC as regards aviation's contribution to the Union’s economy-wide emission reduction target and appropriately implementing a global market-based measure
- Proposal for amending Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings. Currently, the procedures at the level of the European Parliament are expected to be completed in order to be able to start the consultation process between the Parliament, the Council and the Commission.
- Proposal for a decision of the European Parliament and of the Council amending Decision (EU) 2015/1814 as regards the amount of allowances to be placed in the market stability reserve for the Union greenhouse gas emission trading scheme until 2030
- Proposal for a Regulation of the European Parliament and of the Council on ensuring a level playing field for sustainable air transport
- Proposal for a Regulation of the European Parliament and of the Council on the use of renewable and low-carbon fuels in maritime transport and amending Directive 2009/16/EC

[6] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0558
[7] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0557

- Proposal for a Regulation of the European Parliament and of the Council on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU of the European Parliament and of the Council
- Proposal for a Council Directive restructuring the Union framework for the taxation of energy products and electricity
- Proposal for a Regulation of the European Parliament and of the Council establishing a Social Climate Fund
- Proposal for a new corporate sustainability reporting Directive[8], which extends the applicability and introduces more detailed reporting requirements and a reporting requirement in line with mandatory EU reporting standards.
- Proposal for a Complementary Climate Delegated Act , which adds, under strict conditions, specific nuclear and gas energy activities in the list of economic activities covered by the EU taxonomy[9].

At the level of national legislation, the main strategies, national plans and normative acts with an relevant for the implementation of the LTS are presented in Table 4.

Table 4. National Legislation relevant for the implementation of the LTS

Document	Main aspects
Romania's National Recovery and Resilience Plan (PNRR) approved by the EU Council (October 28, 2021)	Regulation (EU) 2021/241 establishing the Recovery and Resilience Mechanism and the National Recovery and Resilience Plan (PNRR) also covers the ecological transition that must be supported through reforms and investments in green technologies and capacities, including biodiversity, energy efficiency, building renovation and the circular economy.
National Energy and Climate Plan (NECP) for 2021-2030	Approved by GD 1,076 / 2021, the NECP will be updated in 2023
2014-2020 National Programme for Rural Development (PNDR)	Approved by European Commission Decision C(2015)3508/ 26.05.2015
Strategic Plan of Common Agricultural Policy 2023-2027 (2023-2027 CAP SP)	Approved by European Commission Decision C(2022)8783/ 07.12.2022
National Long-Term Renovation Strategy to support the renovation of the national stock of residential and non-residential buildings, both public and private, and its gradual transformation into a real estate stock with a high level of energy efficiency and decarbonization by 2050 (SNRTL)	Approved by GD no. 1034 of November 27, 2020.
National Integrated Urban Development Strategy for resilient, green, inclusive and competitive cities 2022-2035 (Urban Policy of Romania)	Approved by GD no. 1575/2022
Sustainable Urban Mobility law proposal	Approved by the Government in December 2022, it is currently under debate in the Parliament (Chamber of Deputies, decision-making chamber)
2021-2025 Restructuring Plan of the Oltenia Energy Complex (CEO) with a 2030 perspective	The plan was approved.
GEO 21/2022 of 10.03.2022 regarding setting-up the legal framework for granting restructuring state-aid to CEO	The GEO approves the granting of restructuring aid in favour CEO, as authorized by European Commission Decision no. C(2022)553 final, 26.01.2022
GEO 108/2022 of June 30, 2022 on the decarbonization of the energy sector, with subsequent amendments and completions	The GEO establishes the general legal framework for the phasing out of the energy mix of electricity the production based on lignite and coal
GEO 175/2022 of December 14, 2022 for the establishment of measures regarding the investment objectives for the realization of hydropower facilities in progress, as well as other projects of major public interest that use renewable energy, as well as for the modification and	The GEO includes the list of investments for the construction and commissioning of new electricity production capacities from hydro sources, as well as the new electricity and thermal energy production capacity from Iernut

[8] https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en#review
[9] https://ec.europa.eu/info/publications/220202-sustainable-finance-taxonomy-complementary-climate-delegated-act_en

completion of some normative acts, with subsequent amendments and completions	
National Forest Accounting Plan of Romania [10] for the first commitment period (2021-2025)	The plan was published by the Ministry of Environment, Waters and Forests (MMAP)
National Strategy for the Sustainable Development of Romania 2030 (SNDDR 2030) and National Action Plan for implementing the SNDDR 2030	Approved by GD no. 877 of November 21, 2018, with subsequent amendments and additions The strategy presents Romania's progress regarding the implementation of the 17 Sustainable Development Goals (SDGs) included in the "2030 Agenda for Sustainable Development - Transforming our World" of the UN
National Strategy for the Circular Economy in Romania	Approved by GD no. 1,172/2022
Law no. 184/2018 on the system for the promotion of energy from renewable energy sources, with subsequent amendments and completions	The law lists measures to increase the share of RES in gross final energy consumption
Law no. 293/2018 on the reduction of national emissions of certain atmospheric pollutants, with subsequent amendments and completions	Directive (EU) 2016/2284 on the reduction of national emissions of certain atmospheric pollutants was transposed by Law no. 293/2018 on national emission reduction commitments for anthropogenic atmospheric emissions of sulfur dioxide (SO2), nitrogen oxides (NOx), non-methane volatile organic compounds (VOCnm), ammonia (NH3) and fine particles in suspension (PM2, 5).
GD no. 1076/2004 on establishing the procedure for carrying out the environmental assessment for plans and programs (SEA Directive), with subsequent amendments and completions	Directive 2001/42/EC was transposed into Romanian legislation by GD no. 1076/2004. The NECP was subject to the SEA procedure.
Law 292/2018 of December 3, 2018 on the assessment of the impact of certain public and private projects on the environment (EIA Directive), with subsequent amendments and completions	The law transposing the new EIA Directive 2014/52 / EU has a potential impact on investment projects planned in Romania. The climate impact of new investments is assessed during the EIA procedure, which includes public consultation.
GEO 57/2007 (Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds and Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora - Natura 2000 Directives), with subsequent amendments and completions	The Natura 2000 directives were transposed into Romanian legislation also through GEO 57/2007 regarding the regime of protected natural areas. The act has a potential impact on planned major investments, including those in the field of SRE (wind power, hydropower, etc.). The procedure includes public consultation.
GD no. 219/2007 on the promotion of cogeneration based on useful thermal energy, with subsequent amendments and additions	The GD establishes the support scheme for the promotion of high-efficiency cogeneration.
GD no. 203/2019 on the approval of the National Energy Efficiency Action Plan, with subsequent amendments and completions	According to the National Energy Efficiency Action Plan, policies and measures are reflected in the implementation of 11 National Energy Efficiency Programs.
Law no. 220/2008 for setting-up the system for the promotion of energy production from renewable energy sources, with subsequent amendments and completions	Green certificates, which certify the production of electricity from renewable energy sources, can be traded, separately from the amount of electricity they represent, on an organized market, under the terms of the law and represent the support scheme for the promotion of energy production from sources renewable.
GD no. 666/2016 for the approval of the strategic document Master General Transport Plan of Romania, with subsequent amendments and completions	The GD approves the strategic document on the development of the national transport infrastructure in the period 2016-2030
Government Decision no. 1312/2021 regarding the amendment of Government Decision no. 666/2016 for the approval of the strategic document Master General Transport Plan of Romania, with subsequent amendments and completions	The GD includes the Investment Program (PI) for the development of transport infrastructure for the period 2021-2030, a programmatic reference document for the relevant public policies in achieving the national transport infrastructure objectives

[10] http://www.mmediu.ro/app/webroot/uploads/files/National%20forestry%20accounting%20plan%20of%20Romania_RO.pdf

2.2 Public consultations and involvement of national and EU entities

After finalizing the development, calibration and optimization of the LEAP_RO model, in the process of developing the LTS, 8 preliminary scenarios for the energy and climate evolution of Romania until the year 2050were developed in the summer of 2022. Following the consultations carried out with the Ministry of Energy (ME) and the Ministry of the Environment, Water and Forests (MMAP), a first draft version of the LTS was elaborated in November 2022, including a number of 3 scenarios. The main targets and hypotheses of the 3 scenarios were presented during the meetings on 12.12.2022 and 27.02.2023 of the Interministerial Committee on Climate Change (CISC). Following the integration of the comments received from the institutions represented in the CISC, on 31.03.2023, the first full preliminary version of the LTS was finalized. Its main targets and hypotheses were presented during the CISC meeting of 11.04.2023.

Between 31.03 and 12.04.2023, consultations took place with the institutions represented in the CISC. During this period, written comments were submitted, which were included in a new preliminary version of the LTS that was drafted on 18.04.2023. Based on it, bilateral meetings were held with expert teams from the Ministry of Transport and Infrastructure (MTI), the Ministry of Economy (MEc), the Ministry of Agriculture and Rural Development (MADR) and the Ministry of Development, Public Works and Administration (MDLPA). Following the new round of consultations, the current version of the LRS was ellaborated on 23.04.2023 and was presented and approved at the CISC meeting on 24.04.2023.

Public consultations, including the private sector, were launched on 18.04.2023, when the LTS was published on the MMAP website, a first round of consultation being scheduled on 27.03.2023 at the MMAP premises.

At the same time, in February and March 2023, 3 training sessions on the LEAP_RO model were organized. They were attended by 53 representatives from ME, MMAP, Ministry of Transport and Infrastructure (MTI), National Company for Road Infrastructure Administration (CNAIR), National Company for Rail Transport (CFR SA), National Institute of Statistics (INS), National Commission for Strategy and Prognosis (CNSP), Ministry of Agriculture and Rural Development (MADR), Ministry of Research, Innovation and Digitalization (MCID), Ministry of Development, Public Works and Administration (MDLPA), Ministry of European Investments and Projects (MIPE), Ministry of Economy (MEc), Ministry of Labour and Social Protection (MMSS), Presidential Administration of Romania, and Chancellery of the Prime Minister.

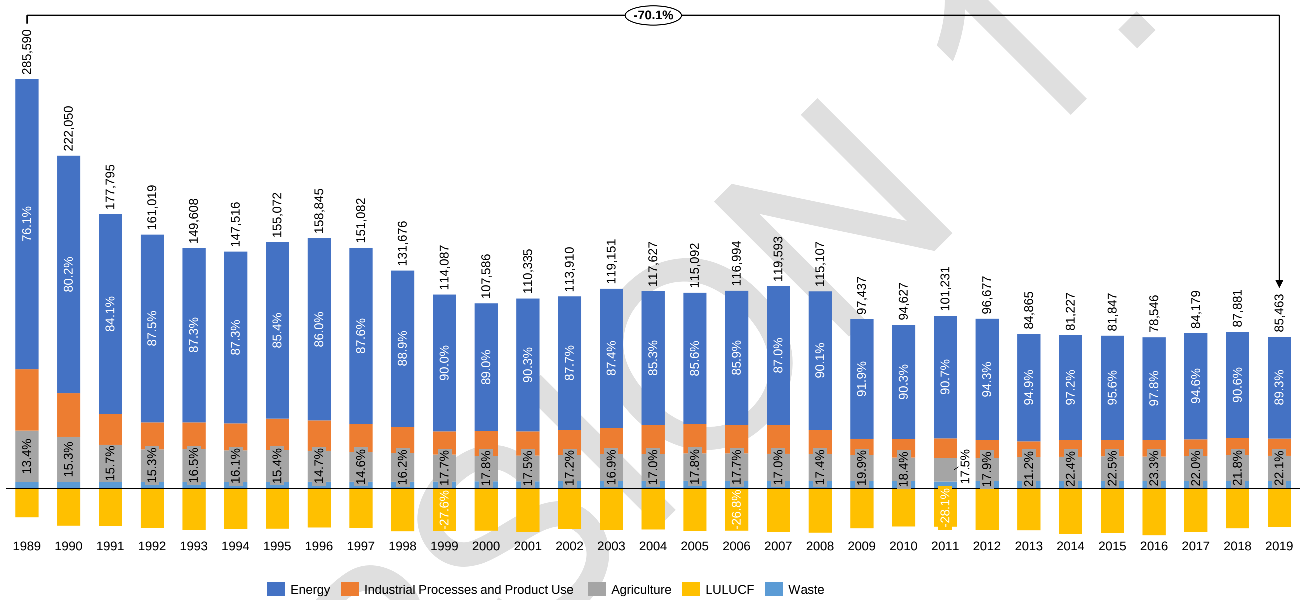
3. TOTAL GHG EMISSION REDUCTIONS AND ENHANCEMENTS OF REMOVALS BY SINKS

3.1 Economy-wide trajectories

3.1.1 Historical trends in GHG emissions and removals

The GHG emission and removals that Romania reports to UNFCCC in the National Inventory of GHG (INEGES) are divided into the following main sectors: Energy (including Transport), Industrial Processes and Product Use (IPPU), Agriculture, Land Use, Land Use Change and Forestry (LULUCF) and Waste. The Inventory is prepared in line with the 2006 IPCC GHG Inventory Guidelines, and each sector comprises individual categories and subcategories identified as sources (or sinks) of emissions. According to the INEGES, the total GHG emissions and removals (net emissions, including the LULUCF sector) were 85.46 Mt CO_2-eq in 2019 (Figure 6), which represents a reduction of 70% compared to emission level in 1989.

Figure 6. GHG emissions and removals (net-emissions) by sector (in kt CO_2-eq), 1989-2019



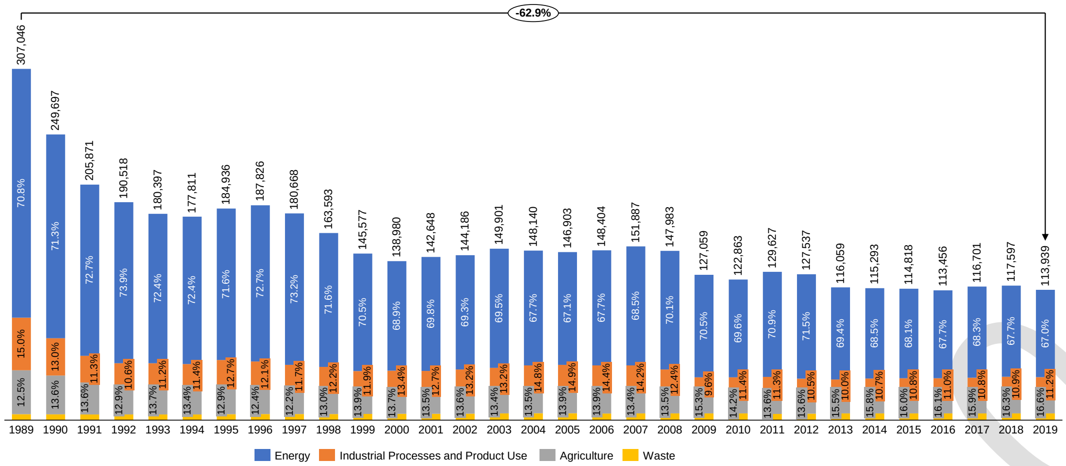
Source: INEGES Submission of Romania to UNFCCC (National Inventory Report - NIR and Common Reporting Format - CRF)

If the removals from the LULUCF sector are not accounted for, then the total GHG emissions in 2019 were 113.94 Mt CO_2-eq (63% less compared to 1989) (Figure 7). The prevailing share of emissions originated from the Energy sector (throughout the entire 1989-2019 period), accounting for total emissions 67% in 2019, followed by Agriculture, with nearly 17%, IPPU sector with around 11% and Waste sector with 5% share (Figure 7).

The GHG emissions trend reflected the economic development of the country. In the period 1989 – 2000, the transition of Romania from a centralized economy to a free market economy, the reorganization of all economic sectors, closing inefficient industries and start of the operation of the first two units of the Cernavoda nuclear power plant caused a massive reduction of the GHG emissions by more than 50%. Between 2000 and 2008, the GHG emissions slightly increased and stabilized because of the economic revitalization. Another decrease in the GHG emissions occurred in the period 2009 - 2012 due to the global financial and economic crisis. After 2013, the GHG emission level remained rather constant.

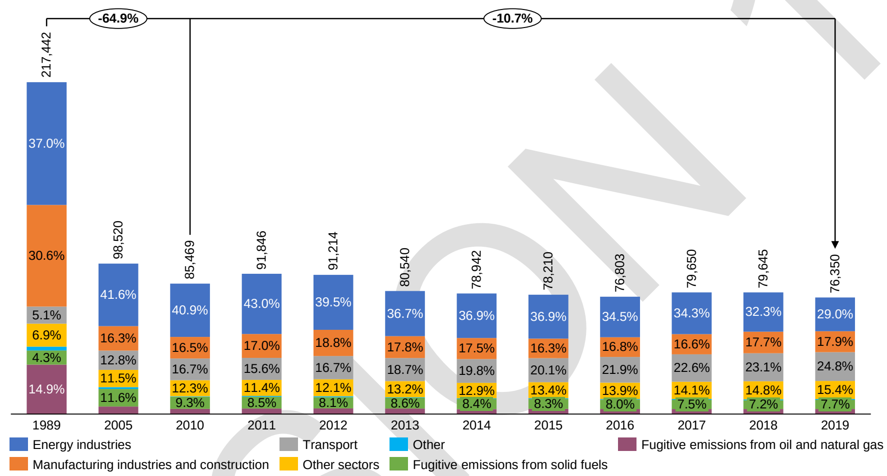
In the Energy sector, the main sources of emissions are the energy industries (electricity and / or heat production plants) and the transport, which accounted for 29% and 25%, respectively, of the total emissions in 2019 (Figure 8). Per comparison, in 1989, the manufacturing and construction sector were second to the energy industries in terms of contribution to the total GHG emission level. In the analysed period, the largest increase in emission share was encountered by the transport sector, from 5% in 1989 to 25% in 2019. During 2010-2019, the GHG emission from the energy sector decreased by approximately 11%.

Figure 7. GHG emissions by sector (in kt CO_2-eq), 1989-2019



Source: National Inventory Submission of Romania to UNFCCC in 2021 (National Inventory Report - NIR and Common Reporting Format - CRF)

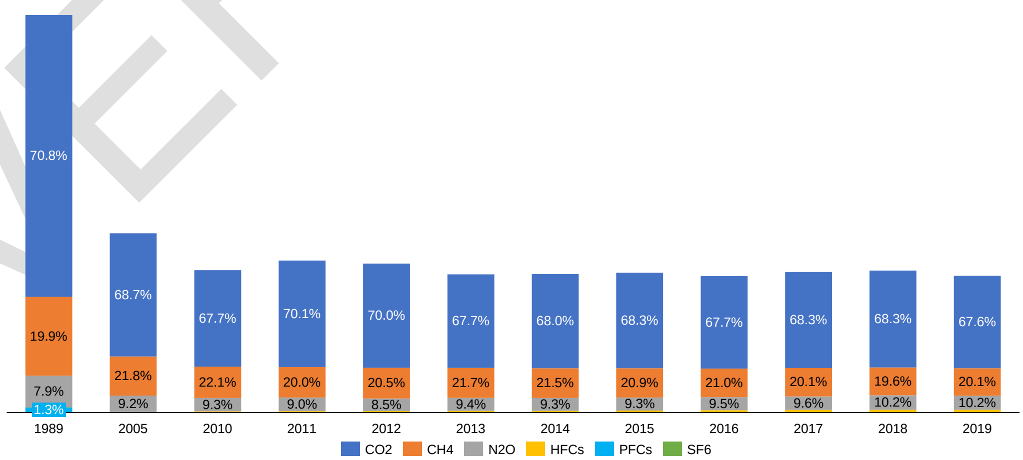
Figure 8. GHG emissions in Energy sector, by category (in kt CO_2-eq)



Source: National Inventory Submission of Romania to UNFCCC in 2021 (National Inventory Report - NIR and Common Reporting Format - CRF)

Concerning the emissions by type of gases, in 2019, approximately 68% of the emissions were CO_2 emissions, followed by CH4 emissions, 20%, and N2O emissions, approximately 10%. The remaining GHGs (HFCs, PFCs, SF6) accounted for approximately 2% of the total GHG emissions (Figure 9).

Figure 9. GHG emissions by gas (% share in total)



Source: National Inventory Submissions to UNFCCC in 2021 (National Inventory Report - NIR and Common Reporting Format - CRF)

3.1.2 Decarbonization pathway until 2050 under 3 different scenarios

In this LTS, three scenarios are analysed.

The RO Neutral scenario anticipates climate neutrality of Romania, i.e., 99% net emission reductions in 2050, when compared to 1990.

According to the RO Neutral scenario, Romania need to lower its net emissions by 78% by 2030, or its emissions (excluding LULUCF) by 67% from 1990 levels, in order to become climate neutral in 2050 (Figure 10 and Figure 11). On the other hand, the REF scenario anticipates 85% net emission reductions in 2050 when compared to 1990 levels. In 2030, net emissions must be lowered by 67% and emissions (excluding those from the LULUCF sector) must be decreased by 71% from 1990 levels to meet the objectives of the REF scenario. In comparison to the Romanian NECP, where it is predicted that emissions (excluding LULUCF) will be 118.35 Mt CO_2-eq in 2030, the REF scenario target for 2030 is slightly more ambitious. The Middle scenario falls between the REF and the RO Neutral scenarios, as its name indicates: compared to 1990 levels, the target for 2050 is 94% net emission reduction, while for 2030 is 77% of net emissions reduction.

The RO Neutral scenario is with 91% more ambitious in terms of net emissions compared to the REF scenario. Figure 12 displays a summary of the net emission reductions for all three scenarios, together with the historical values for 1990, 2005, and 2019.

Figure 10. Decarbonization pathways until 2050 by sectors – REF, Middle and RO Neutral scenarios

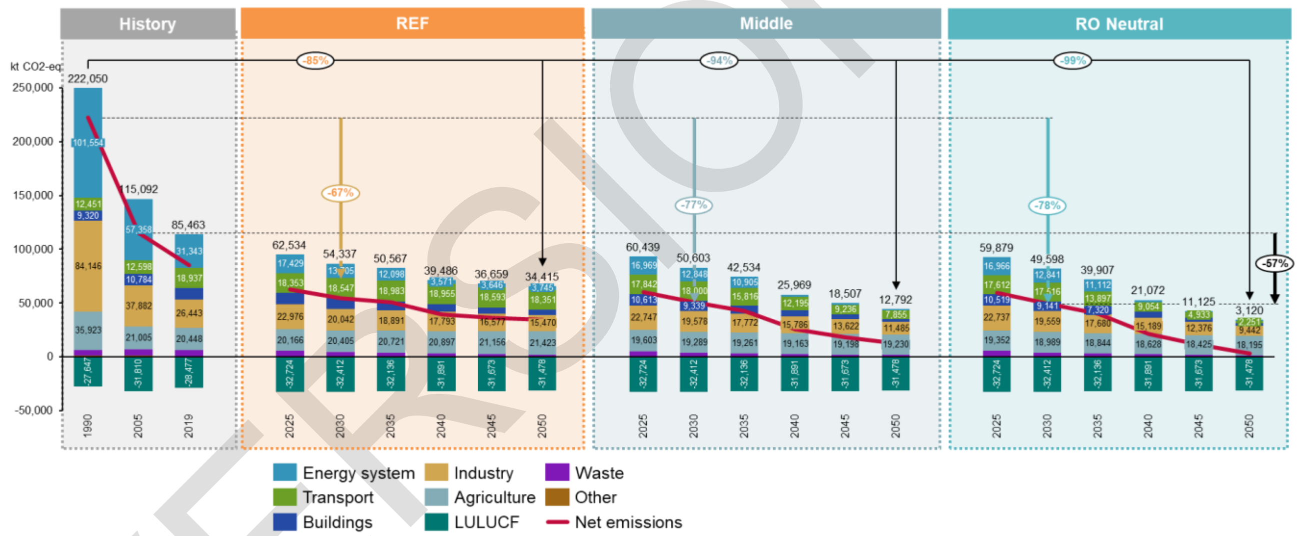


Figure 11. Decarbonization pathways until 2050 without LULUCF by sectors – REF, Middle and RO Neutral scenarios

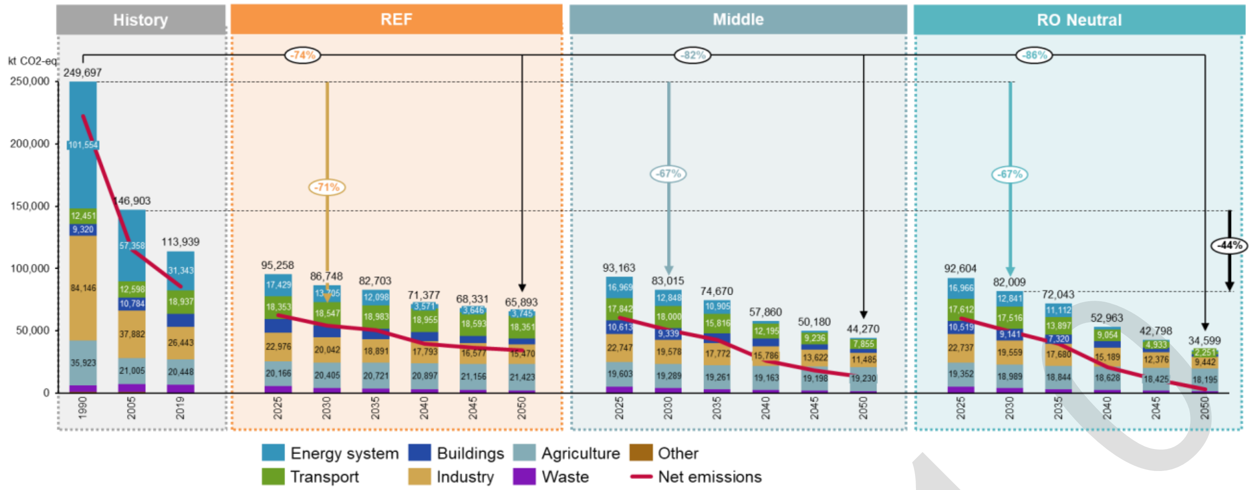
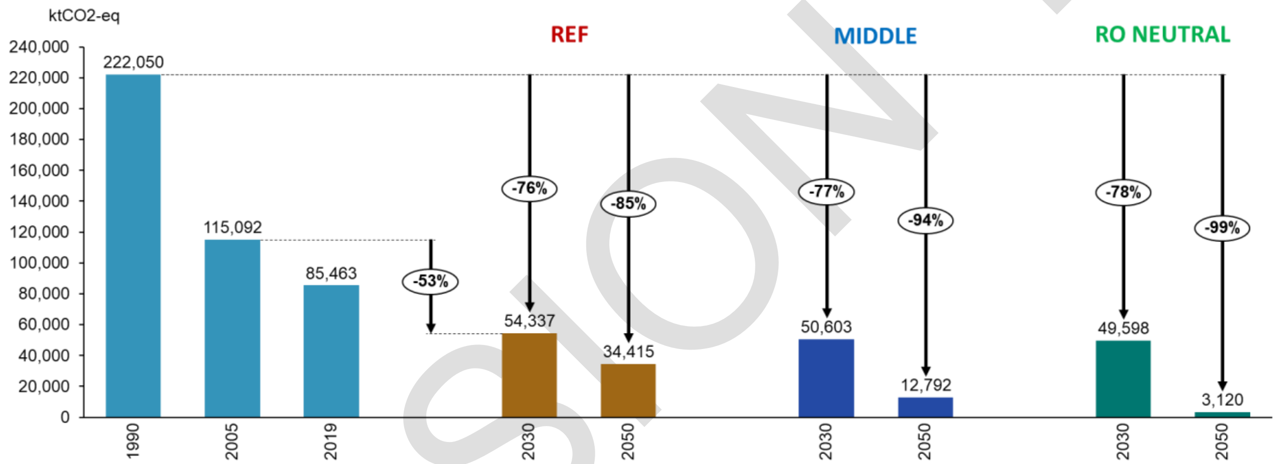
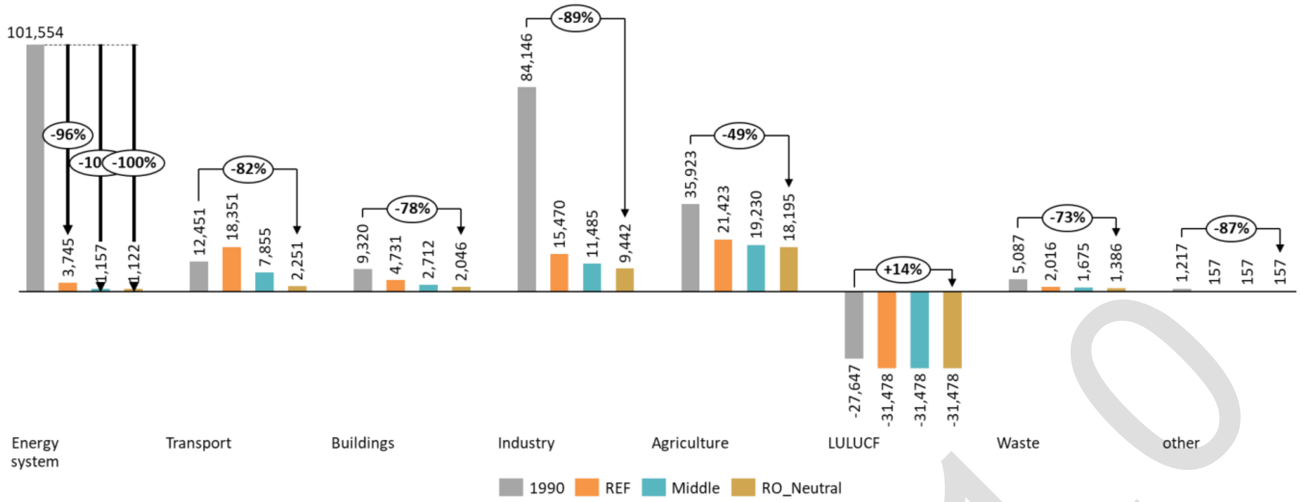


Figure 12. Summary of decarbonization goals of net emissions in 2030 and 2050 – REF, Middle and RO Neutral scenarios (ktCO2-eq)



The emission reduction that should be achieved in each sector is presented in Figure 13 and the details are presented in the following sections. The highest targeted emission reductions concern the Energy system (electricity and heat production sector). The next most significant effort for performing the decarbonization concerns the Industry sector, which includes the emissions from the energy demand in the Industry and the emissions from IPPU as substitutes for ozone depleting substances (ODS). The Transport, Buildings (which includes the residential and commercial sectors), Waste and Agriculture sector have also great contribution for achieving the emission lowering targets at national level. The LULUCF sector, on the other hand, is the only one with net absorptions and it is crucial for reaching carbon neutrality since it has to balance out the emissions from all the other sectors. As a result, in order to reach climate neutrality, the LULUCF absorptions should be at least 14% larger in 2050 compared to 1990.

Figure 13. Summary of decarbonization goals by sectors in 2050 – REF, Middle and RO Neutral scenarios (ktCO2-eq)



3.1.3 National targets and indicative milestones by 2050 for the chosen scenario

Romania chooses the **RO Neutral** scenario for establishing its LTS national targets and milestones, with the aim of becoming climate neutral in 2050, targeting **99% net emission reduction in 2050** compared to 1990. As shown in Figure 14, Romania has already started the decarbonization process by reducing emissions in 2019 by 62% as compared to 1990. However, further efforts are needed for reaching carbon neutrality. The first milestone to reach is reducing emissions by 78% in 2030 relative to the 1990 level. Only by putting in place the necessary policies and measures in each sector (Table 2) and adhering to the goals set forth in each of them, as shown in Table 5 , will the RO Neutral goals be achieved. Some sectors, marked by X, require more effort than others in order first stop the rising emission trend, and then to trigger the decreasing trend.

Figure 14. National target for net emissions and indicative milestones by 2050 (RO Neutral scenario)

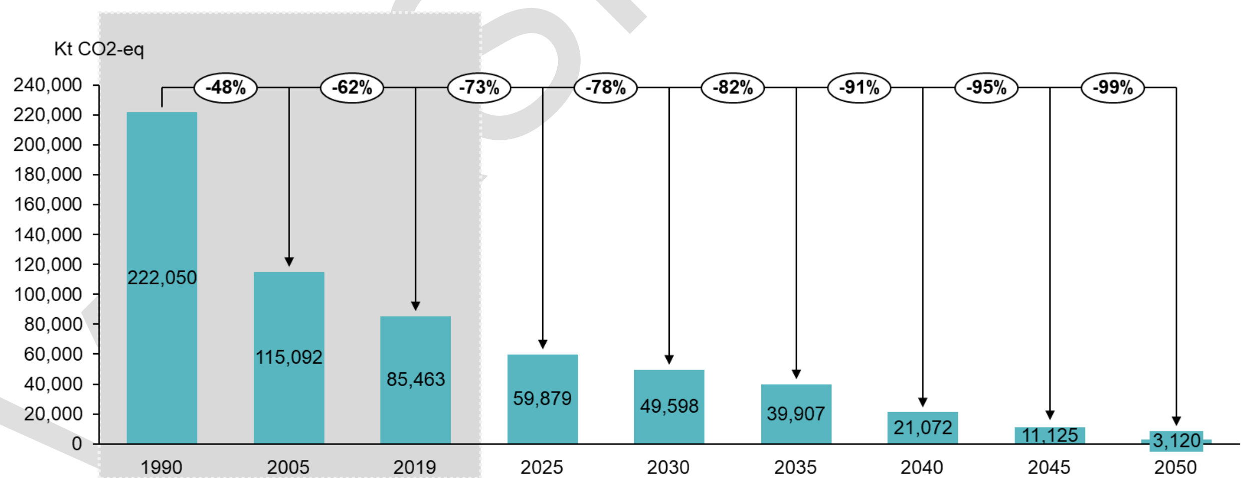
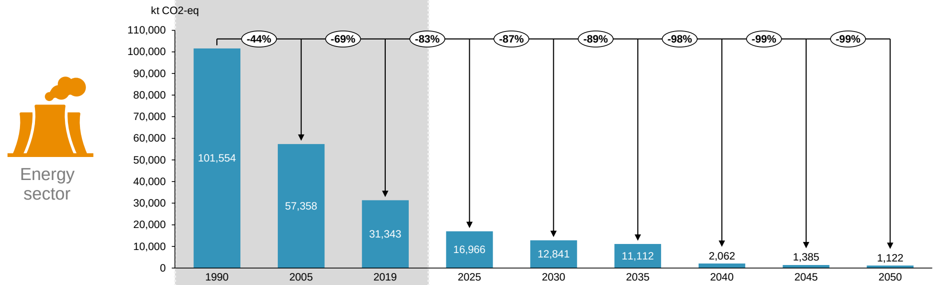
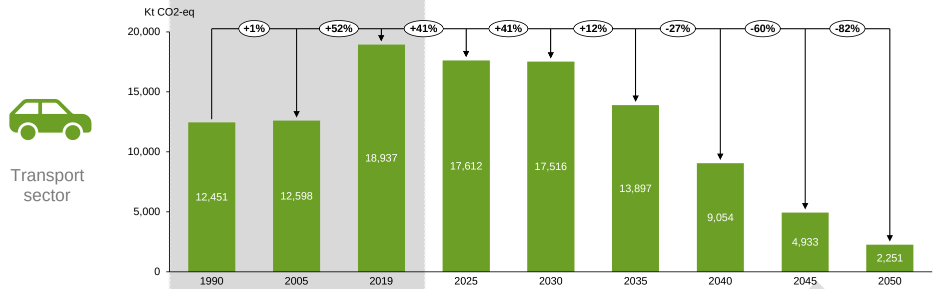


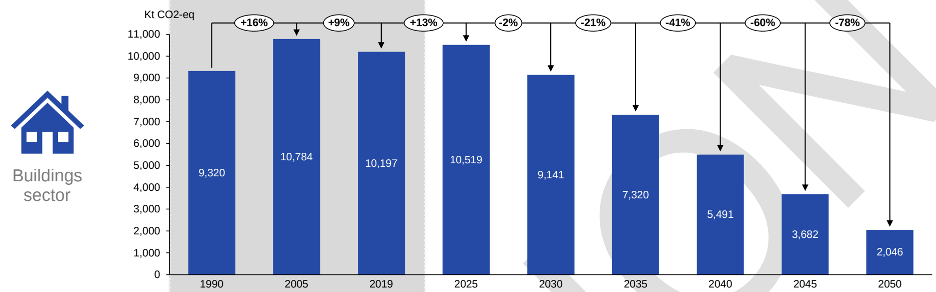
Table 5. Sectoral targets and milestones for emission reductions by 2050 (RO Neutral scenario)



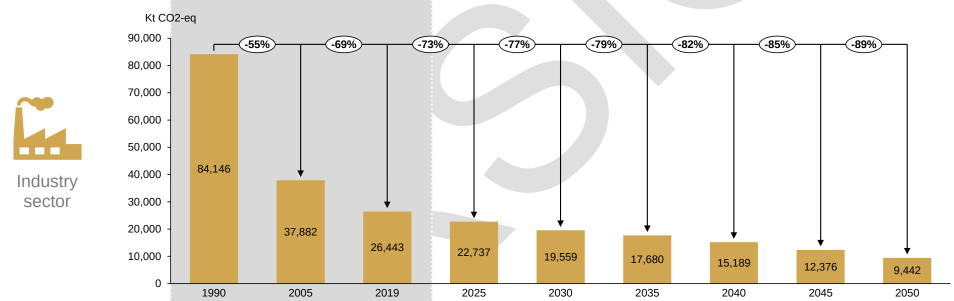
√ The decarbonization of the energy sector has already started. In 2019, 69% of the 2050 goal was already achieved. By 2035, 98% of this goal will have been achieved.



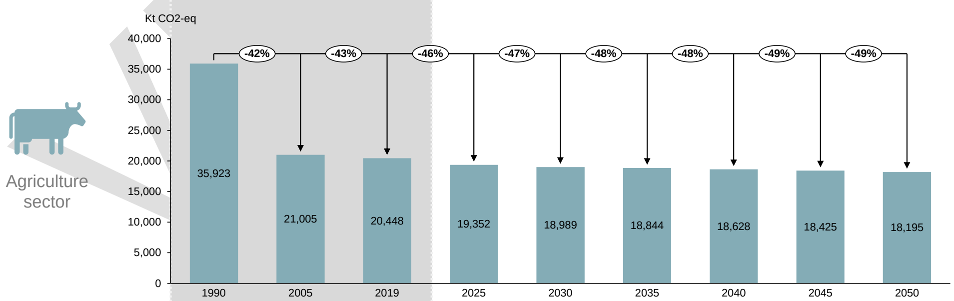
X In the period 1990-2019, the transport emissions increased by 41%. The goal is to reach 82% reduction in 2050 compared to 1990. This can be done by first stopping the increasing trend by 2035.



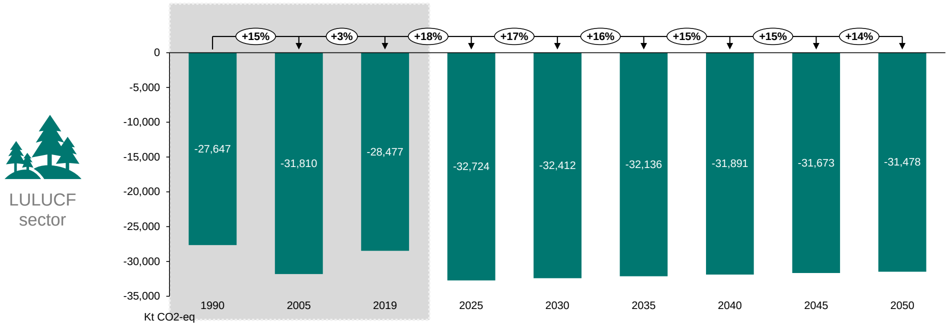
X The emissions from the Buildings sector grew by 9% from 1990 to 2019 and are predicted to continue raising until 2025. After 2025, according to the RO Neutral scenario, the emissions will start lowering and will be, in 2050, 78% lower than they were in 1990.



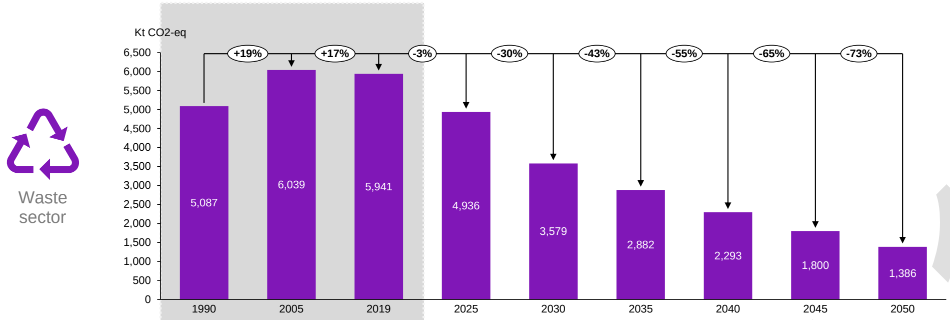
√ The Industry sector has already attained 73% of emissions reductions in the period 1990–2019. The 2050 target is to reduce emissions by 89% compared to 1990 level.



√ The 2050 goal for Agriculture is to reduce the emission level by 49%, when compared to 1990. In 2019, a reduction of 43% compared to 1990 was obtained.



√ The 2050 goal LULUCF is to increase the absorption level by 14% compared to 1990, a target similar to the level which was already achieved in 2005.



X The 2050 target for the Waster sector is to reduce the emission level with 73% compared to 1900. However, in the period 1990-2005, the sectoral emissions increased by 19%. Further, on, the trend slightly decreased by 2019. This trend should continue, at a much faster rate, by 2050.

3.2 Adaptation policies and measures

On 24 February 2021, the European Commission published the Communication on the new EU Strategy on Adaptation to Climate Change (COM(2021) 82 final[11]). The new document builds on the EU's 2013 Adaptation Strategy and is one of the key actions identified in the European Green Deal.

In this context, Romania is revising its National Strategy on Adaptation to Climate Change for 2022-2030 (2022-2030 SNASC) and it is developing the National Action Plan for the implementation of the SNASC in the period 2023-2030 (PNASC 2022-2030). These two documents ensure the continuity and coherence of the previously developed adaptation component, within the "National Strategy on Climate Change and Economic Growth Based on Low Carbon Emissions for the Period 2016-2030".

SNASC and PNASC aim at sectoral development in accordance with the principles of the EU Strategy on Adaptation to Climate Change and integrate the global adaptation objective of Article 7 of the Paris Agreement, including the target of Sustainable Development Goal 13 – Climate Action.

SNASC will be the comprehensive document of public policies, basic strategic guidelines for Romania's adaptation to the effects of climate change and examples of proactive adaptation measures. The 2022-2030 SNASC is complemented by the 2023-2030 PNASC, which details specific measures implemented at the level of Romania's public institutions, required during the adaptation process.

Both documents are in the final stage of elaboration and during the second quarter of 2023 they will be advanced for the adoption stage, after having gone through a full and complex period of consultation with public institutions and civil society, including strategic environmental assessment.

Climate variability, particularly in terms of the frequency and intensity of extreme weather events and climate change, are fundamental challenges faced by the society at the beginning of the 21st century. Climate warming, reflected by increasing temperatures or increasingly frequent and intense heat waves, changes in the atmospheric precipitation regime, either through their increased occurrence in extreme events (floods) or their absence over long periods (droughts), anomalies regarding the seasons in regions with temperate climate, are leading to major changes in the interactions between society and the natural environment, both globally and regionally or locally.

All the above transform the efforts to adapt to climate change and to seize new opportunities, needed in all sectors of activity, in a top priority meant to increase the resilience against climate change of the society, of the natural

[11] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2021%3A82%3AFIN

environment and of the economy. It is highly important that adaptation efforts become increasingly ambitious on medium and long term and complement actions to mitigate GHG emissions.

Based on the expected impact at sectoral level, the Strategy sets sectoral policy objectives, which consider the current context and requirements and are in line with the provisions of strategic European-level legislative documents, such as the European Green Gren, the new EU Strategy on Adaptation to Climate Change and the European Climate Law.

Thus, SNASC proposes a systemic sectoral and cross-sectoral approach with objectives aligned with EU-wide targets and aims to adapt to the effects of climate change in 13 key sectors as follows: Water resources; Forests; Biodiversity and ecosystem services; Population, public health and air quality; Education and awareness; Cultural heritage; Municipalities; Agriculture; Energy; Transport; Tourism and recreation; Industry; Insurance.

The achievement of the objectives included in the SNASC and PNASC will also have a significant economic impact by exploiting the opportunities arising in the economic sectors. The sectoral benefits will create the necessary framework for increased business opportunities in all economic sectors, in particular by means of innovation and research, but also through appropriate management of climate change risks.

Increasing the adaptive capacity and the implementation of early warning systems also aims to reduce the number of people and communities vulnerable to extreme events, such as floods or flash floods occuring in risk areas.

SNASC has an important component regarding communication, awareness and public participation in climate action. The public is an important stakeholder in the adaptation process, which requires transparency and social involvement to achieve the objectives.

Disadvantaged groups in local communities benefit from climate change adaptation measures, thereby increasing social cohesion and protecting fundamental human rights and freedoms.

Achieving the objectives of the SNASC and accelerating the process of adaptation to climate change also aims to make a significant contribution to the transition towards a circular economy and a resilient economic environment, in line with the ambitions of Romania and the European Union.

In addition to the actions in the SNASC and PNASC, specific adaptation actions are also included in other plans, programmes and strategies related to different economic sectors, such as: the National Strategy for the Sustainable Development of Romania 2030 (SNDDR 2030), the National Recovery and Resilience Plan (PNRR), the REPowerEU Plan, or the National Plan for Disaster Risk Management.

The strategic objectives in the SNASC are reflected in the PNASC through concrete measures that will lead to their effective and efficient implementation. The plan includes actions for each sector and objective, together with full details of the associated deadlines, the responsible institutions (by identifying the authority responsible for coordinating the implementation and the authorities responsible for implementation and/or support), the identified sources of funding (which may change over time), estimates of investments, as well as result indicators associated with each action.

The strategic objectives (SOs) for adaptation to the impact of climate change at national level, formulated for the 13 key sectors defined within SNSAC, together with examples of specific actions, are presented below:

1. Water resources

SO.1.1 Reduce the risk of water resources deficit

SO.1.2 Reduce the risk of flooding

SO.1.3 Increase the safety level of dams and dykes

The objectives of the „Water resources” sector will be achieved through the implementation of various actions, such as updating the policy and institutional framework for the promotion of specific legislation, carrying out periodic quantitative and qualitative assessments of water requirements by type of use, analysis of climate factors, etc.

2. Forests

SO.2.1 Adaptation of forests and the forest sector to the impacts of climate change, through sustainable management of forest resources, management of disasters and of other emergencies generated by specific risk factors, increasing the resilience of forests

SO.2.2 Expansion of forested areas

SO.2.3 Stimulate forest bioeconomy within the limits of sustainability and support the socio-economic functions of forests and of forest products with long life span

SO.2.4 Adapting forest regeneration/restoration practices to the requirements imposed by the climate change

SO.2.5 Minimise the risk of climate change regarding and through forests.

The objectives of the 'Forests' sector will be achieved by updating the policy framework, conducting research studies and improving forest-related knowledge.

3. Biodiversity and ecosystem services

SO.3.1 Improve and disseminate knowledge on biodiversity and climate change and promote the role and contribution of biodiversity in climate change adaptation

SO.3.2 Support the conservation, restoration and enhancement of the continuity and connectivity of habitats and ecological networks, building on green-blue infrastructure and agroecology infrastructures

SO.3.3 Support/promote the use of best practices in agriculture, pisciculture, aquaculture and forest management

SO.3.4 Support the development of a coherent, connected and representative network of protected areas implementing adaptive management

SO.3.5 Integrate ecosystem resilience issues (linked to water availability) into all relevant public policies and sectoral schemes of economic activities.

The objectives of the "Biodiversity and ecosystem services" sector will be achieved through the implementation of various actions, such as through the development and implementation of biodiversity specific climate products and services, updating of policy frameworks, including natural area management plans, or through concrete investments in biodiversity conservation.

4. Population, public health and air quality

SO.4.1 Setting-up the National Observatory for Climate and Health within the Ro-ADAPT platform in order to inventory, monitor and quantify climate risks on public health, select adaptation solutions and assess the impact of their implementation

SO.4.2 Develop a framework coordinated with the European and international framework to ensure resilience to transboundary climate risks that may affect the population, the health system and air quality

SO.4.3 Protect citizens' health from the impacts of disasters by strengthening the national emergency management system and connecting it to the National Observatory for Climate and Health within Ro-ADAPT and other relevant platforms.

The objectives of the "Population, Public Health and Air Quality" sector will be achieved through the implementation of various actions, such as the development of various national studies on the impact of climate change on public health and the development of the legislative framework.

5. Education and awareness

SO.5.1 Increase the level of public information and awareness on climate change impacts and adaptation

SO.5.2 Improve citizen education on climate change adaptation

SO.5.3 Actively involve citizens in the climate change adaptation process, including relevant decision-making

SO.5.4 Promote scientific research and innovation related to climate change adaptation.

The objectives of the "Education and Awareness" sector will be achieved through the implementation of various actions such as information and awareness raising campaigns and the promotion of climate change issues through the introduction of specific subjects in the school curriculum, as well providing support for research activities in this field.

6. Cultural heritage

SO.6.1 Detailed, systematic and relevant climate monitoring of cultural heritage

SO.6.2 Protect cultural heritage from the combined impacts of climate change, associated risks and local pollution

SO.6.3 Develop a national integrated cultural heritage management plan in relation to climate change impact.

The objectives of the "Cultural Heritage" sector will be achieved by carrying out various risk and vulnerability assessment studies on the effects of the climate change, deploying information campaigns and developing and promoting public policies and regulations specific to this sector.

7. Municipalities

Increasing the climate resilience of municipalities through:

SO.7.1 Development of local action plans for adaptation to climate change

SO.7.2 Improving existing design codes and technical regulations in the field of construction or other codes or norms relevant to the field, in order to increase resilience to the effects of extreme climate events

SO.7.3 Adaptation to climate change of risk analysis and coverage plans and of emergency situations plans

SO.7.4 Develop/implement education, research, information and public awareness programmes.

The objectives of the "Municipalities" sector will be achieved through the implementation of various actions, such as the implementation of the measures at local level included in the plan for adaptation to climate change, the updating of general urban planning plans and sustainable mobility plans, the integration of nature-based solutions, by carrying out campaigns to raise awareness of the issue of climate change and developing various studies on the impact of climate change on municipalities.

8. Agriculture and rural development

SO.8.1 Develop an adaptation strategy in agriculture

SO.8.2 Perform effective management of agricultural lands

SO.8.3 Improve the knowledge level in agriculture and related to its connection with climate change

SO.8.4 Increase awareness regarding risk management and access to risk management tools.

The objectives of the „Agriculture and Rural Development” sector will be achieved through the implementation of various actions, such as drafting specific studies addressing climate change in agriculture and rural development and the promotion of environmentally friendly agricultural practices.

9. Energy

SO.9.1 Increase the resilience of the energy sector

SO.9.2 Increase the resilience of the heating and cooling sector

SO.9.3 Develop educational, information and awareness programmes to increase energy resilience

SO.9.4 Identify the critical infrastructure in the energy systems and implement measures to address the impact of extreme events.

The objectives proposed of the „Energy” sector will be achieved through the implementation of various actions, such as setting-up research programmes to identify optimal technical solutions to increase end-user resilience.

10. Transport

SO.10.1 Consolidate land infrastructure (road, urban, rail)

SO.10.2 Consolidate air transport infrastructure

SO.10.3 Consolidate water transport infrastructure

SO.10.4 Asses the vulnerability â of the transport sector;

SO.10.5 Integrate climate change considerations into planning and decision-making processes.

The objectives of the „Transport" sector will be achieved by carrying out studies addressing climate change issues and improving the capacity to prevent possible negative impact of climate change within the transport sector.

11. Tourism and leisure activities

SO.11.1 Protect and expand natural recreational areas in cities

SO.11.2 Develop tourist destinations less dependent on climate change

SO.11.3 Long-term planning for seasonal eco-friendly mountain resorts

SO.11.4 Adapting and protecting coastal tourism infrastructure to climate change

SO.11.5 Long-term policy, planning and education to adapt the sector to climate change

SO.11.6 Adaptation of tourism service providers to climate change

SO.11.7 Staff and tourists' management and behavioural change

The objectives of the "Tourism and Recreation" sector will be achieved through the implementation of actions aimed at protecting and preserving tourist attractions, developing urban and peri-urban parks and consolidating the infrastructure.

12. Industry

SO.12.1 Become aware of the climate risks for industry, drafting adaptation strategies and business plans for the industrial ecosystems, business/company level adaptation

SO.12.2 Reduce specific energy consumption of industrial consumers and increase energy resilience

SO.12.3 Long-term policies and planning for climate change adaptation

SO.12.4 Reducing risks in the supply and distribution chain for supporting the circular economy

SO.12.5 Support the increased use of insurances for industrial losses caused by extreme events and climate change.

The objectives of the "Industry" sector will be achieved through the implementation of various actions, such as increasing awareness of climate change issues within the sector and developing specific studies and implementing specific adaptation measures.

13. Insurance

SO.13.1 Increase the use of and access to insurance products against extreme events associated with climate change

SO.13.2 Increase the institutional capacity of the insurance sector to develop insurance products for climate change adaptation specific to all sectors.

The objectives of the „Insurance" sector will be achieved by carrying out information campaigns and encouraging the use of insurance services.

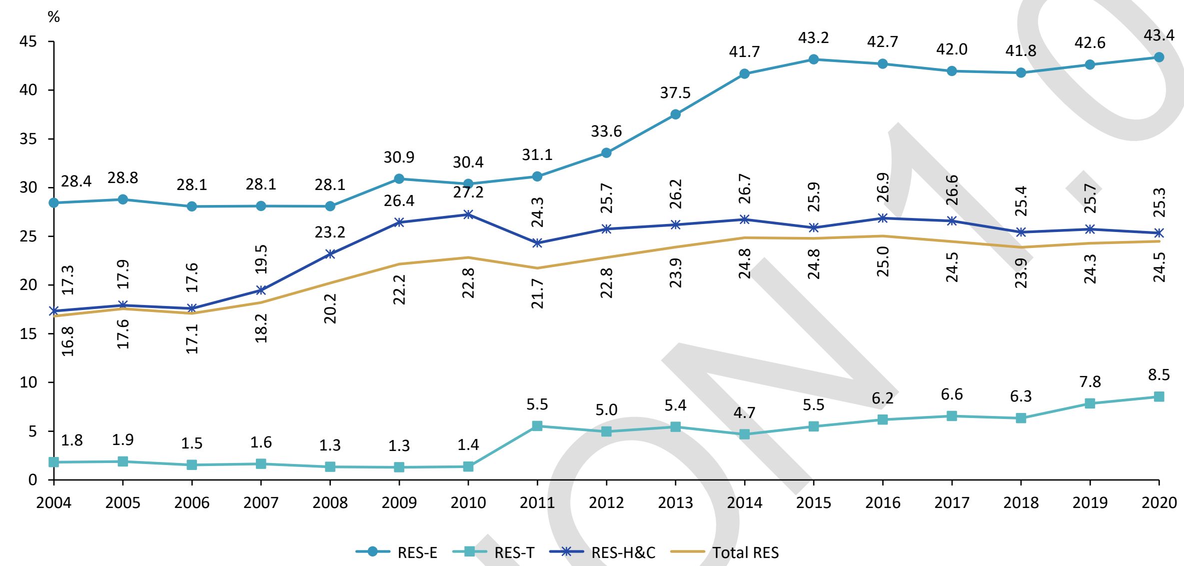
The consistent and coherent implementation of the adaptation policy objectives and their coordination with other policies and strategies that address fundamental issues for Romania's sustainable development, such as resilience of the energy system, lowering the risk for disaster occurrence or water resources management, is a prerequisite for the adaptation of Romanian society to climate change and mitigation of its medium and long-term impact.

4. RENEWABLE ENERGY

4.1 Historical trend in RES share

The historical trends show constant increase of the RES share in the gross final energy consumption during 2004-2020 (Figure 15). The highest increase in the RES share occurred in the electricity sector, from 30.4% in 2010 to 43.4% in 2020, as a result of the decrease of the electricity production from coal fired power plants, on one hand, and of the increase in the share of wind and solar power plants on the other hand. Due to the increased use of biofuels, the RES share in transport increased from 1.4% in 2010 to 8.5% in 2020. The RES share in the heating and cooling (H&C) sector was almost constant during 2010-2020.

Figure 15. RES share in gross final energy consumption/transport/electricity/ heating and cooling



4.2 RES share vision by 2050

The vision for 2050 shows the increase of the RES share in the gross final consumption in all 3 scenarios (Figure 16).

The RES share in the gross final energy consumption, in the RO Neutral scenario, should reach 89.9% in 2050 and 36.3% in 2030.

All three scenarios target a similar share of RES in 2030: 34.3% in the REF, 35.9% in the Middle, 36.3% in RO Neutral. In contrast to the REF scenario, which targets a RES share of 56.9% in 2050, and the Middle scenario, which aims for a RES share of 76.9% by 2050, the growth in the RES share is more significant in the RO Neutral scenario: 89.9%. At the same time, the gross final energy consumption will decrease in all three scenarios (Figure 17). In terms of technologies, by 2050, the most important role will be played hydrogen, solar and wind in all three scenarios, as well as biomass, especially in the REF scenario.

Figure 16. RES share in gross final energy consumption – REF, Middle and RO Neutral scenarios

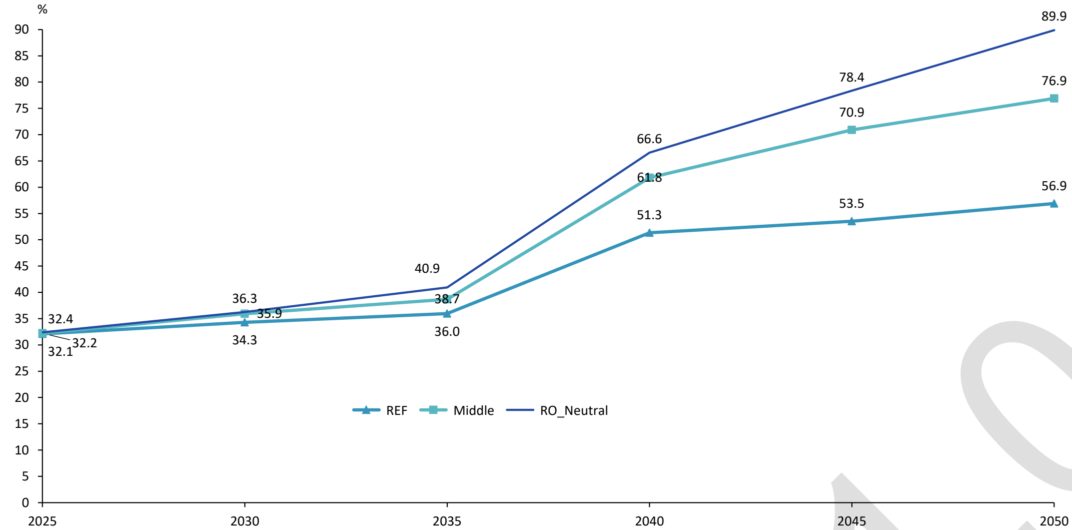
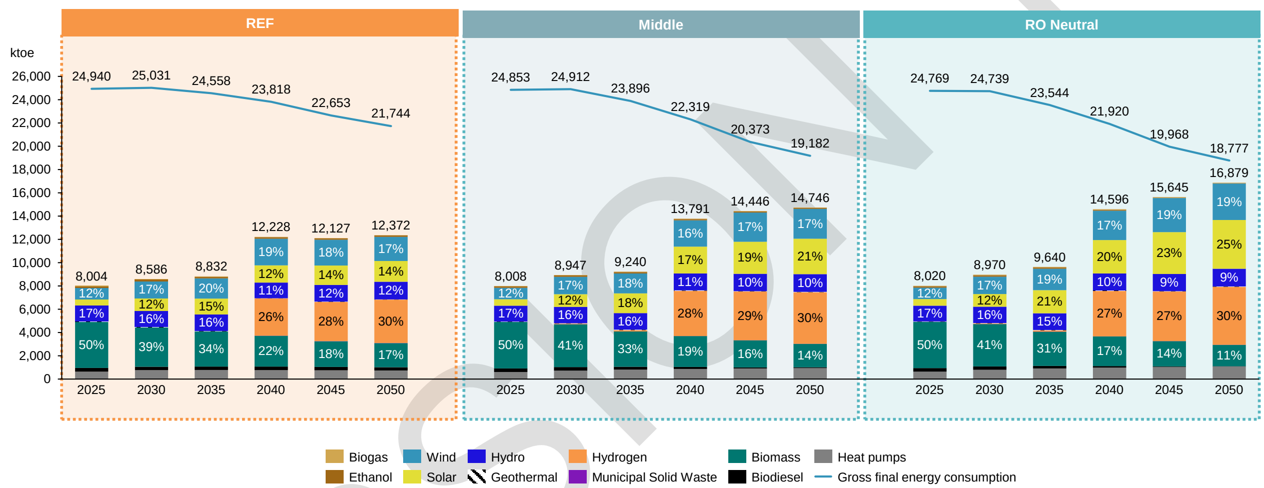
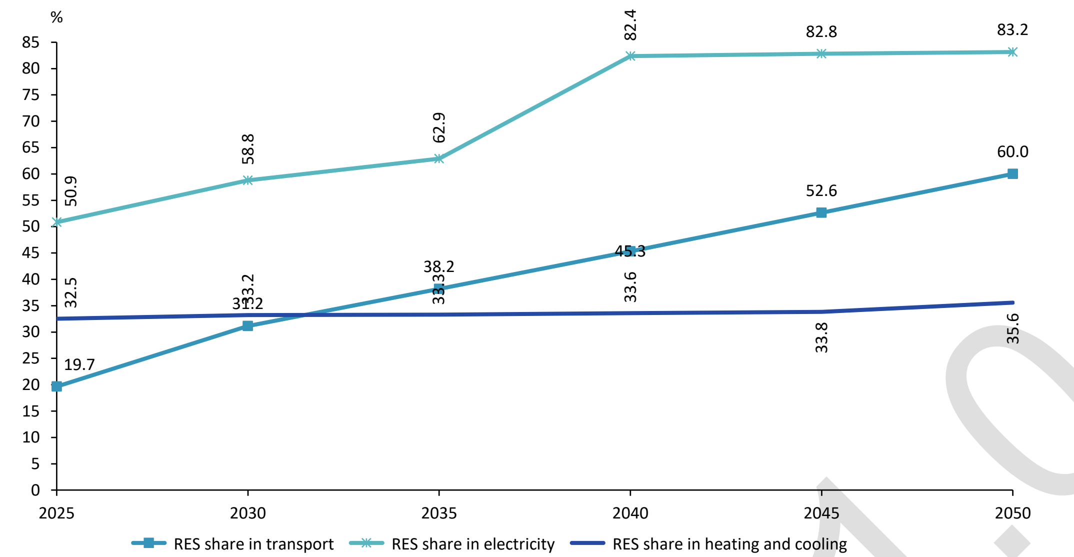


Figure 17. RES in gross final energy consumption by fuels – REF, Middle and RO Neutral scenarios



In the REF scenario, the overall RES share in the gross final energy consumption will increase with a much smaller rate than in the other two. The increased use of electricity in the transport sector will mainly contribute to achieving around 60% RES share in 2050. The RES share in the electricity sector will also increase by 2050, but not as much as in the other two scenarios, since, in the REF scenario, the electrification of the demand sectors will much lower than in the other 2 scenarios. On the other hand, due to the decreased use of biomass, especially in the rural areas, which will replaced by cleaner technologies, the RES share in the heating and cooling sector will be almost constant throughout the whole analysed period, reaching 35.6% in 2050. Although the biomass is considered as renewable source, it is envisioned that its consumption will be reduced since conservation of LULUCF absorptions is of great importance, as well as due to the adverse air quality consequences of biomass consumption.

Figure 18. RES share in transport/electricity/heating and cooling final energy consumption – REF scenario



The Middle scenario is much more ambitious than the REF scenario. The RES share in the transport sector is scheduled to reach approximately 160% in 2050, as a results of the increased use of electricity and hydrogen. This percentage is larger than 100%, since, according to Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources, the electricity consumption in the transport is counted with a factor higher than 1 (for example, 4 for road transport and 1.5 for rail transport). The increased electricity generation from wind and solar power plants will contribute to reaching a RES share in the electricity sector of approximately 90%. The increased use of heat pumps, solar thermal collectors and hydrogen will raise the RES share in the heating and cooling sector at 77.5% in 2050.

Figure 19. RES share in transport/electricity/heating and cooling final energy consumption – Middle scenario

4.3 RES share national target and indicative milestones by 2050

As RO Neutral is the chosen scenario, the LTS national target is the RES share in the gross final energy consumption will be **89.9% in 2050**. As a milestone, in **2030**, the RES share should reach **36.3%.**

In this scenario, there will be an increase in the gross final energy consumption from RES in all three sectors – transport, electricity and heating and cooling (Figure 20). The RES share in the transport sector will be around 243% in 2050, as a results of the increased use of electricity and hydrogen (Figure 21). The significant increase of electricity production from wind and solar power plants, as well as from hydrogen, will contribute to the RES share in the electricity sector to reach around 107.5% in 2050 (Figure 22). This percentage will be higher than 100% since part of the electricity that will be produced from RES will not be directly consumed, but it will be used for hydrogen production, so the electricity generation from RES is greater than the gross final energy consumption. The much higher rate of usage of heat pumps, solar thermal collectors and hydrogen will increase the share of RES in the final energy consumption from the heating and cooling sector to around 97.5% (Figure 23).

Figure 20. RES share in transport/electricity/heating and cooling final energy consumption – RO Neutral scenario

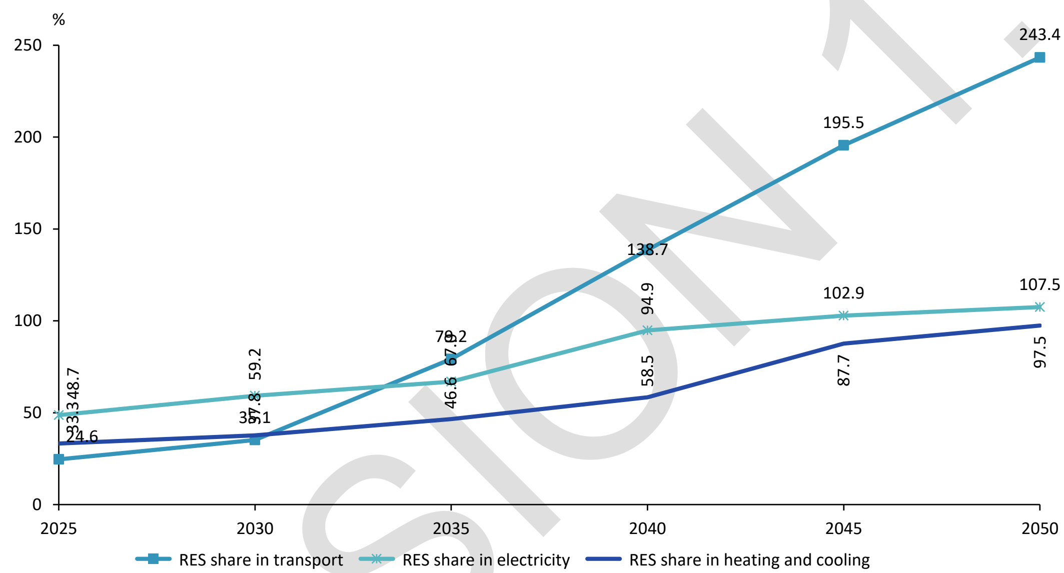


Figure 21. RES in final consumption in Transport sector by fuels

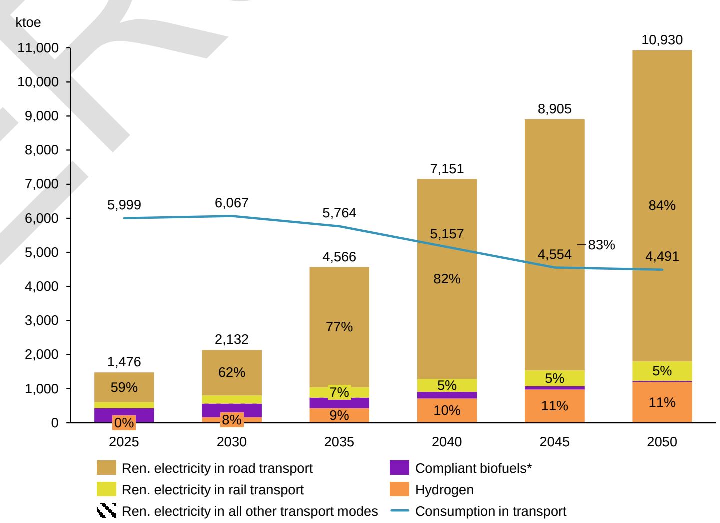


Figure 22. RES in gross final electricity consumption by fuels

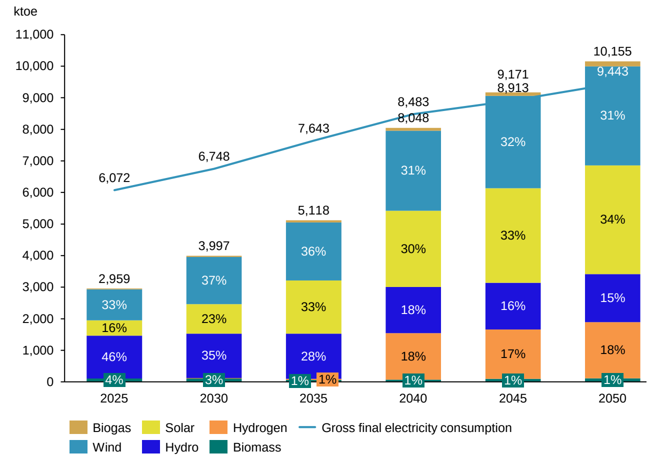
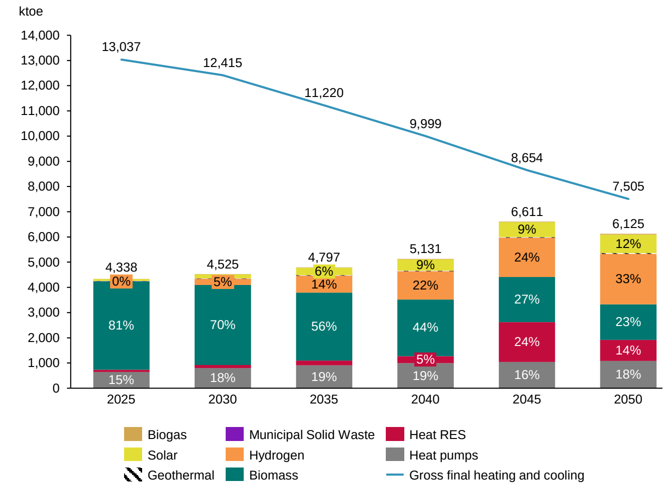


Figure 23. RES in gross final energy Heating and cooling consumption by fuels

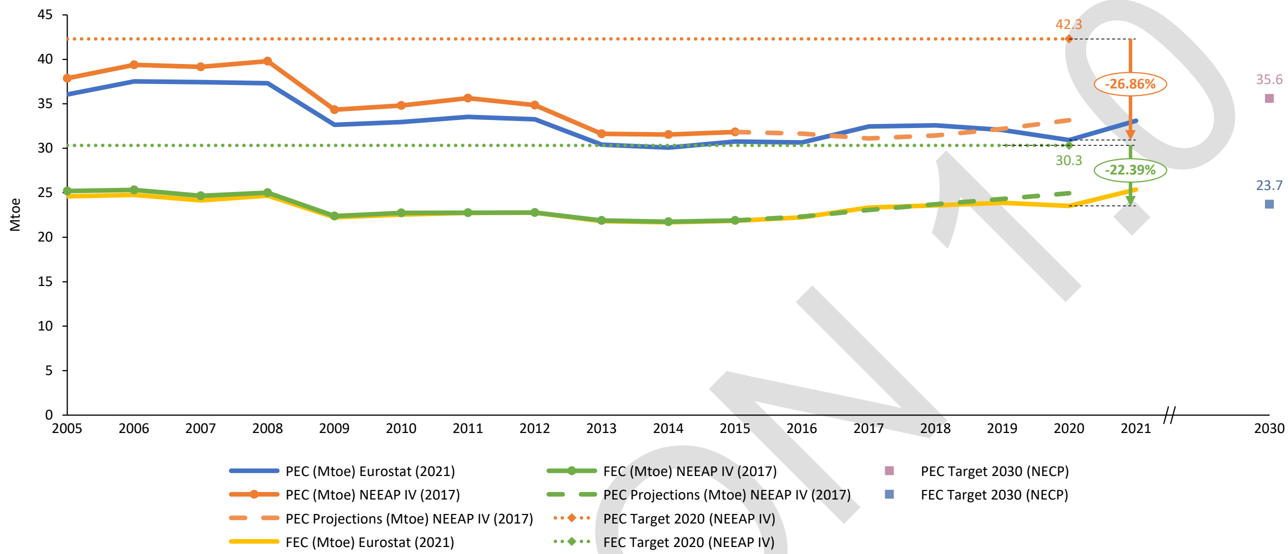


5. ENERGY EFFICIENCY

5.1 Historical trend in EE

When analyzing the historical trend in terms of energy efficiency, it can be concluded that the targets set for the year 2020 in the National Energy Efficiency Action Plan, 2017 (NEEAP IV) were accomplished (Figure 24). The primary energy consumption (PEC) in 2020 was with approximately 27% lower that the target, while the final energy consumption (FEC) was with approximately 22% lower than the target.

Figure 24. Historical trend in EE



Note: PEC = Primary Energy Consumption; FEC =Final Energy consumption
Source: Eurostat Database (Energy Indicators - Energy efficiency [NRG_IND_EFF]); National Energy Efficiency Action Plan, version of 2017 (NEEAP IV), Integrated Energy and Climate Plan (NECP)

5.2 EE vision by 2050

The energy efficiency first principle ("taking utmost account of cost-efficient energy efficiency measures in shaping energy policy and making relevant investment decisions"[12]) was applied while computing the energy consumptions levels by 2050 in all three scenarios (Figure 25 and Figure 26).

In the RO Neutral scenario, in 2030, the primary and the final energy consumption should be reduced by 46% and 45%, respectively, when compared to the reference 2030 emissions from the Primes model.

In order to achieve carbon neutrality in the **RO Neutral scenario**, the primary energy consumption should be additionally reduced by 11% in **2050**, compared to 2030, and the final energy consumption should be reduced by 26% in the same period. This will be achieved by employing the most efficient technologies and by enhancing building performances. When compared to the REF scenario, the primary energy consumption in 2050 in the RO Neutral scenario will be 6% lower, while the final energy consumption will be 15% lower. The Middle scenario will be similar primary and final energy consumption as the RO Neutral scenario.

[12] https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficiency-targets-directive-and-rules/energy-efficiency-first-principle_en#:~:text=The%20%E2%80%9Cenergy%20efficiency%20first%20principle,and%20making%20relevant%20investment%20decisions.

Figure 25. Primary energy consumption trajectory – REF, Middle and RO Neutral scenarios

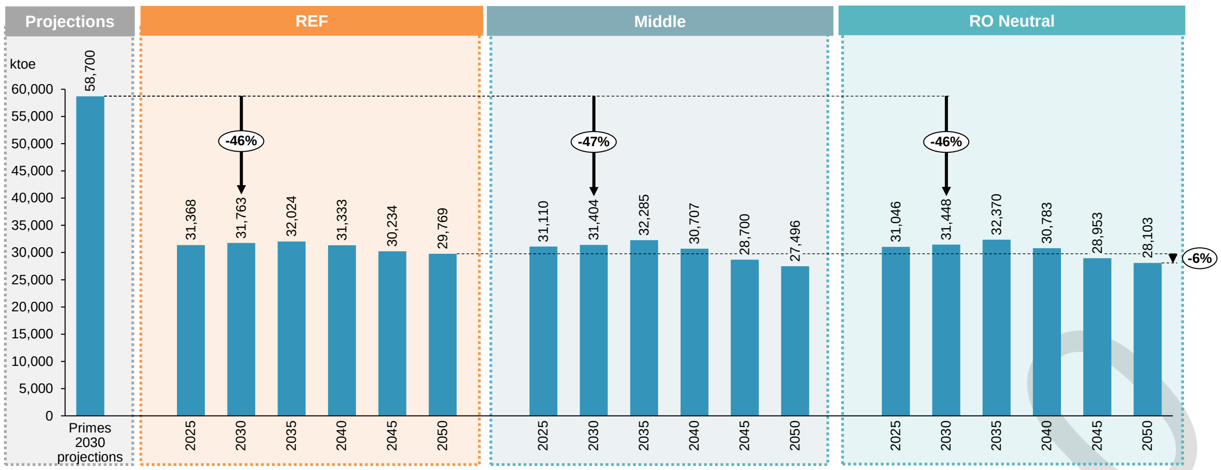
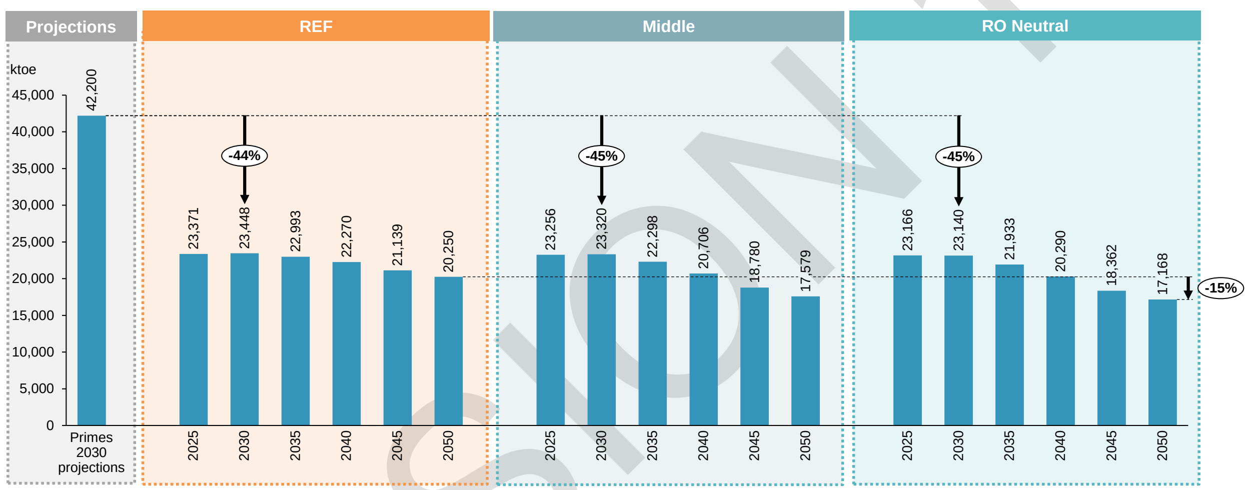
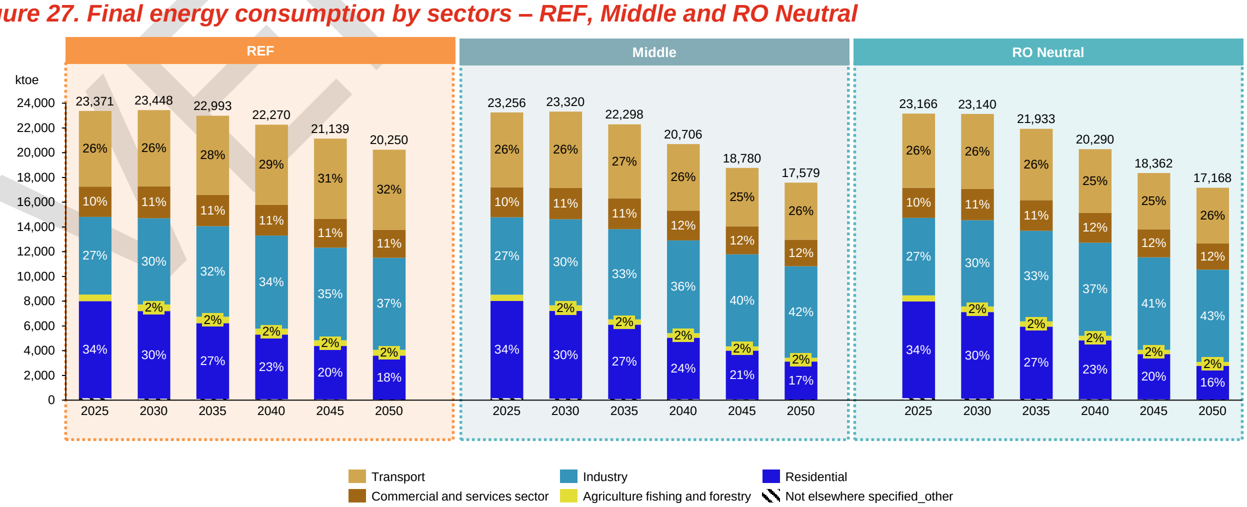


Figure 26. Final energy consumption trajectory – REF, Middle and RO Neutral scenarios



Regarding the final energy consumption by sectors, in 2050, the Transport and the Residential will play much more important roles in the REF scenario than in the other 2 scenarios (Figure 27). At the same time, in all three scenarios, the Industry sector will have the largest final energy consumption in 2050, which will not be the case in 2025.

Figure 27. Final energy consumption by sectors – REF, Middle and RO Neutral



5.3 EE national target and indicative milestones by 2050

As the energy efficiency target of Romania will be set according to the **RO Neutral scenario**, the target for **2030** is to reach **46%** and **45%** reductions of the **primary** and the **final** energy consumption, respectively, when compared to the reference 2030 target from the Primes model (Figure 28 and Figure 29). For 2050, the primary energy consumption will be additionally reduced by 11%, while the final energy consumption by 26%, in both cases compared to the 2030 levels. By comparing the 2030 Primes projections with the 2050 level, the primary energy consumption will be lowered with 52%, while the final energy consumption will be lowered with 59%.

Figure 28. EE national target and indicative milestones for primary energy consumption

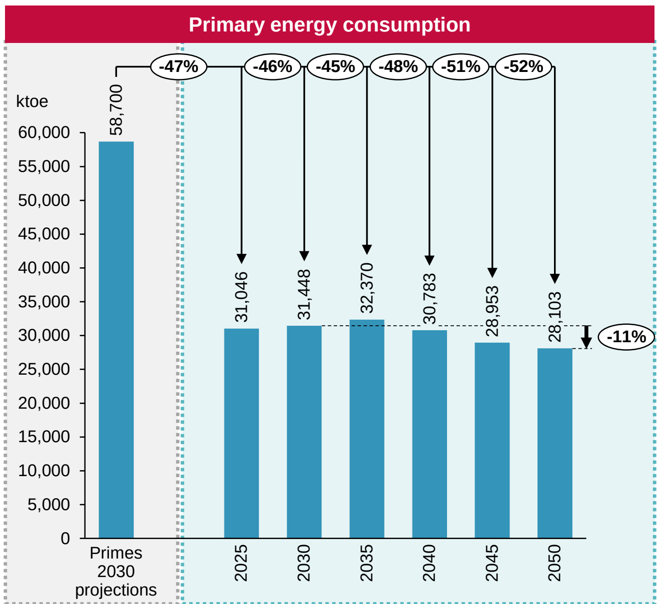
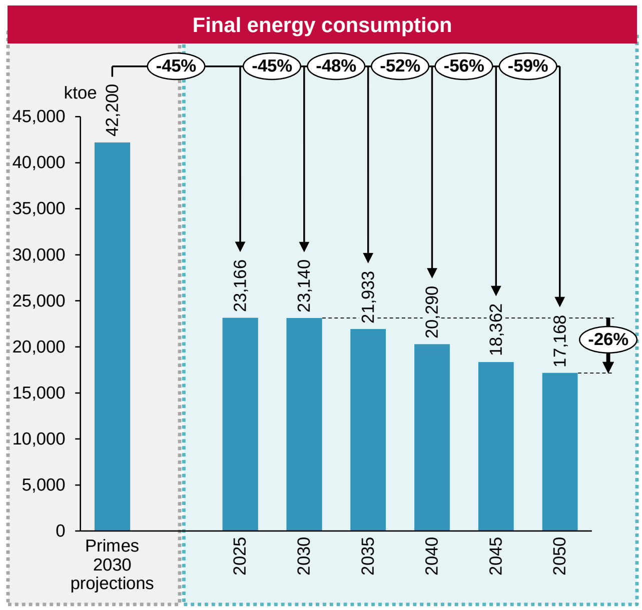


Figure 29. EE national target and indicative milestones for final energy consumption



6. SECTOR-SPECIFIC TARGETS AND TRAJECTORIES

6.1 Energy system

6.1.1 Expected emissions trajectory

In this sector, the emissions objective is presented in Figure 30 and Figure 31:

In all three scenarios, electricity and heat generation will completely be decarbonized by 2050

The emissions from the Electricity generation are due mainly to the coal and natural gas power plants. Due to the assumption that no more coal-based electricity will be produced starting from 2027 and no more natural gas-based energy will be produced from 2036, emissions from this sector will be reduced to zero in all three scenarios significantly before 2050. Due to the fact that, in the RO Neutral scenario, the rate of electrification in most demand sectors in will be much higher than in the other two scenarios, which it will lead to higher overall electricity demand, the emissions due to natural gas plants will be slightly higher (approx. 2%) in the RO Neutral than in the REF scenario.

Regarding heat generation (produced by heat and autoproducer plants), no coal or natural gas fired heat plants will be used starting from 2046 in the RO Neutral and the Middle scenarios, therefore the emissions from this sector will also be reduced to zero. At the same time, no coal or natural gas based-CHPs on coal and natural gas will be used starting from 2037. After 2036, the heat will be produced by biomass, biogas and hydrogen-based CHPs and will be used in all sectors, including industry.

When compared to 1990, in 2030 the emission reduction in the Electricity and heat generation sector will be reduced by 85% in all three scenarios. Almost 100% of the emissions will be CO_2 during the whole analysed period (Figure 31).

Figure 30. Trajectory of emissions by source in the Electricity generation sector – REF, Middle and RO Neutral scenario

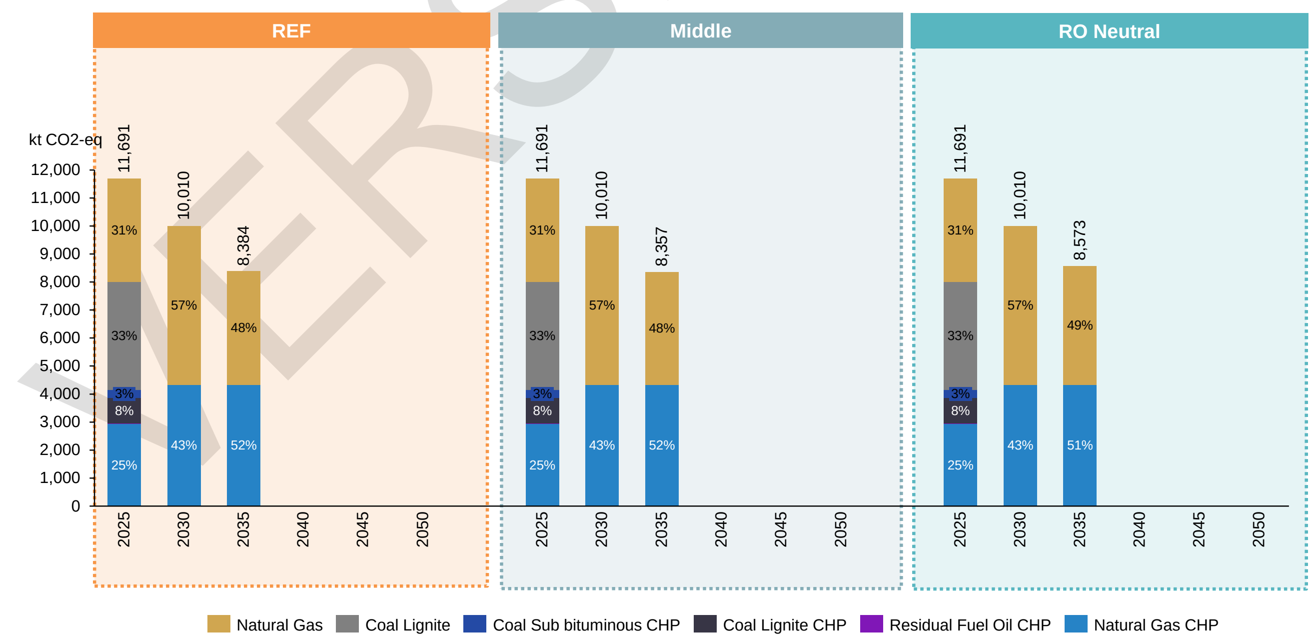
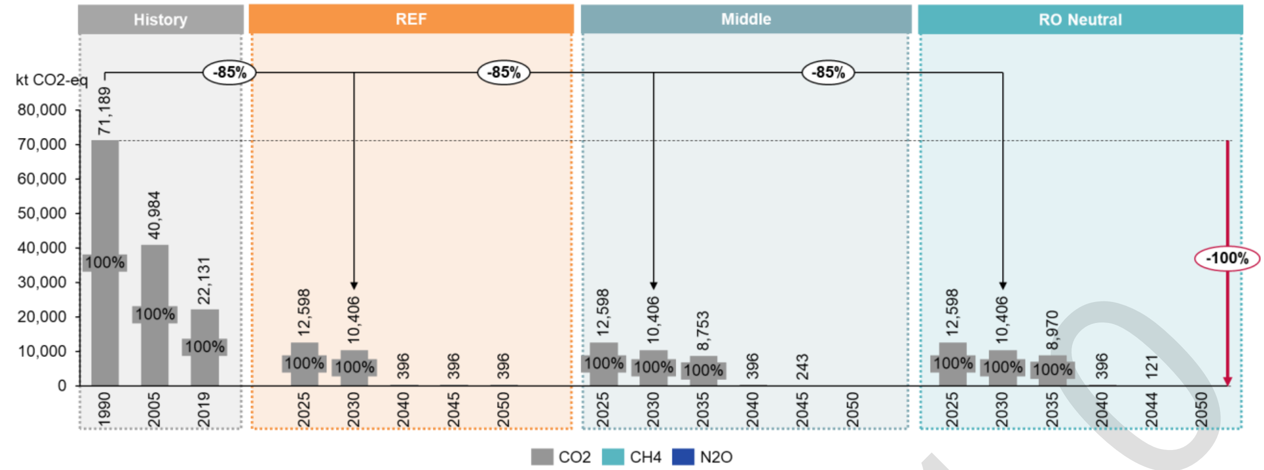
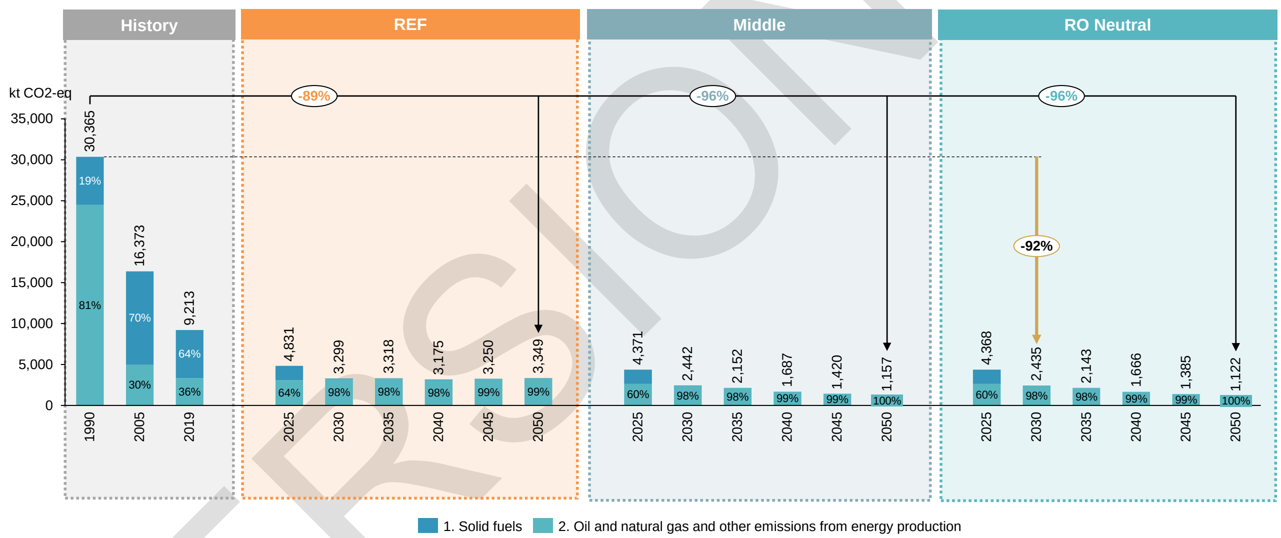


Figure 31. Trajectory of emissions by GHG in the Electricity and heat generation sector – REF, Middle and RO Neutral scenario



Concerning fugitive emissions from fuels, which are mainly due to the coal mining, natural gas and oil exploration, production, transport and distribution, as the usage of these fuels will be reduced, fugitive emissions will be reduced by 96% in 2050, when compared to 1990, in the RO Neutral scenario (Figure 32). In 2050, the fugitive emissions will be mainly due to the non-energy use of natural gas.

Figure 32. Trajectory Fugitive emissions from fuels by source – REF, Middle and RO Neutral scenario



6.1.2 General description of main drivers and decarbonization options

Regarding the electricity and heat generation, in all three scenarios, the following capacities were available to the model:

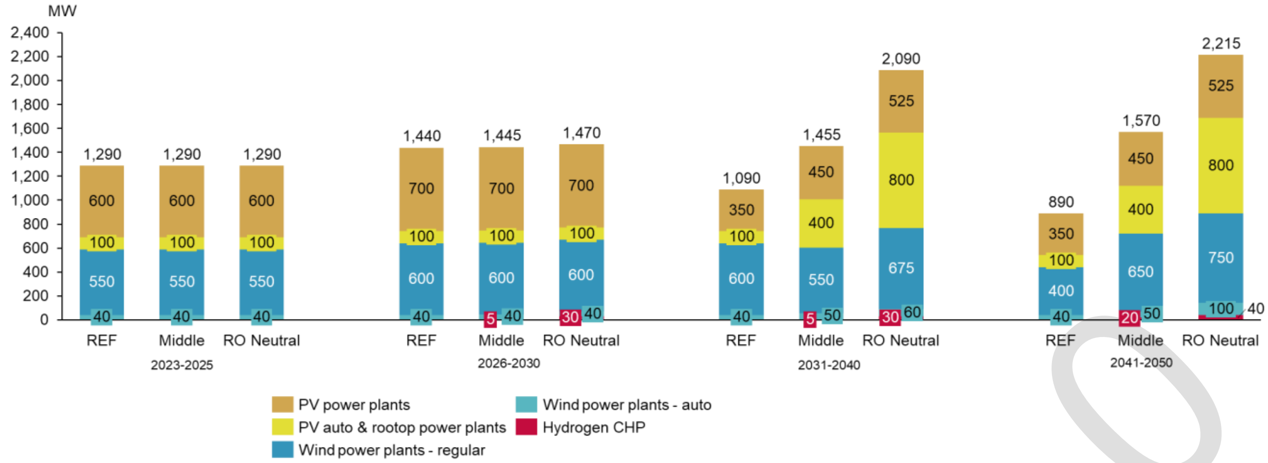
- **Nuclear capacities**:
  - Currently, Romania has in place, operating, U1 (CANDU) – 700 MW and U2 (CANDU) – 700 MW
  - U1 will be repowered during 2027-2029
  - U2 will be repowered during 2036-2038
  - New nuclear capacities:
    - 462 MW starting from 2029 in all 3 scenarios
    - 700 MW starting from 2030 in Middle and RO Neutral scenarios

        - 700 MW starting from 2031 in Middle and RO Neutral scenarios

- **Coal and lignite-powered capacities** – all will be closed by the end of 2031
    - 1,695 MW were closed on 31.12.2021.
    - 660 MW were scheduled to be closed on 31.12.2022.
    - 1,425 MW will be closed on 31.12.2025.
    - 1,140 MW will be closed / placed in stand-by on 31.12.2026.
- **Natural gas-powered plants** (CCGT, CHP)
    - All natural gas-powered capacities will be 100% ready for renewable gases (green hydrogen) by 2036.
    - New CCGT capacities:
        - 430 MW starting from 2024
        - 430 MW starting from 2025
        - 430 MW starting from 2026
        - 1,325 MW starting from 2027
    - New CHP capacities:
        - 80 MW starting from 2024
        - 52 MW starting from 2025
        - 365 MW starting from 2026
        - 50 MW starting from 2027
        - 200 MW starting from 2028
        - 200 MW starting from 2029
- **Hydro power plants**:
    - 65 MW starting from 2024
    - 12 MW starting from 2025
    - 148 MW starting from 2027
    - 50 MW starting from 2028
    - 29 MW starting from 2030
- **Biomass CHP** – new biomass CHP capacities available to the model: 10 MW each year by 2050
- **Biogas CHP** – new biogas CHP capacities available to the model: 5 MW each year by 2050
- **Biogas PP** – new PP biogas capacities available to the model: 5 MW each year by 2050

The availability of hydrogen CHPs in the Middle and RO Neutral scenarios, as well as the pace at which solar and wind capacities will be built and installed, are the key differences between the three examined scenarios. The annual availability of PV and wind power plants and hydrogen CHPs is displayed in Figure 33.

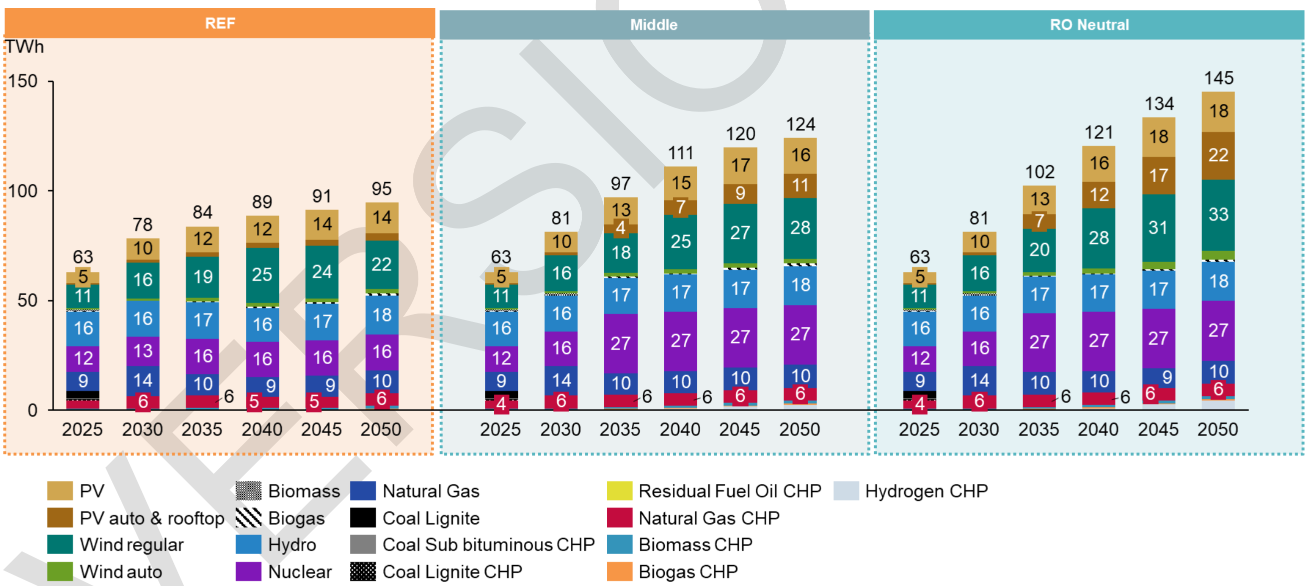
Figure 33. Yearly availability of new PV and wind power plants and hydrogen CHPs



*Note: Hydrogen is available from 2027 in the Middle and the RO Neutral scenarios

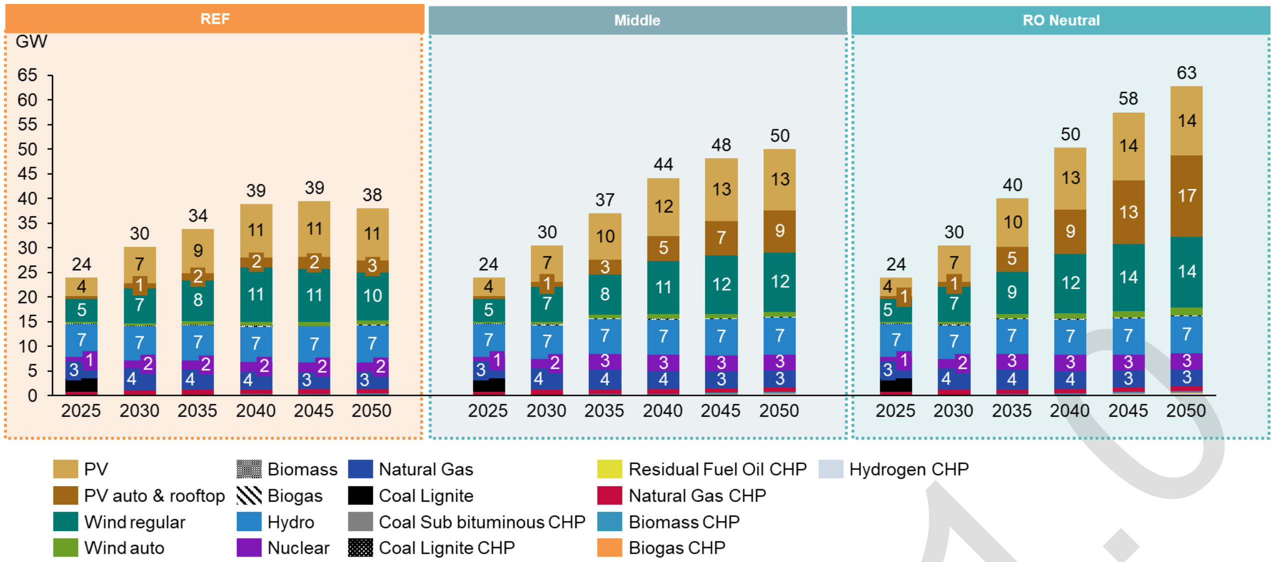
For each of the three scenarios, Figure 34 and Figure 35 display the electricity production and installed capacity by source. Due to the electrification and the increased rate of usage of hydrogen, the electricity production, as well as the installed capacity in the Middle and the RO Neutral scenario, will be significantly higher than in the REF scenario. The main distinction between the three scenarios is related to the level electricity production based on PV and wind, as well as to nuclear power facilities, which, although available to the model in the REF scenario, are not required, in contrast to the situation from the other two scenarios. Construction of new hydrogen CHPs is another noteworthy distinction between REF scenario on one hand, and the Middle and RO Neutral scenario, on the other.

Figure 34. Electricity generation by source – REF, Middle and RO Neutral scenarios



**Note: Starting from 2036, natural gas-powered plants will be operated 100% on hydrogen. However, in the above Figure, they are still being represented being powered by natural gas*

Figure 35. Installed capacity by source – REF, Middle and RO Neutral scenarios



**Note: Starting from 2036, natural gas-powered plants will be operated 100% on hydrogen. However, in the above Figure, they are still being represented being powered by natural gas*

6.2 Transport

6.2.1 Expected trajectory of emissions, energy consumption and sources by transport type

The objective of the emissions in the Transport sector is presented in Figure 36:

In the RO Neutral scenario, the reduction of the GHG in the Transport sector will be 82% in 2050 compared to the 1990 level. At the same time, the sectoral emission will be in 2030 41% higher when compared to 1990

In the REF scenario, the level of GHG emissions will increase by 47% in both 2030 and 2050 when compared to 1990. The RO Neutral is with 88% more ambitious than the REF scenario.

The Transport sector is very complex and its decarbonization requires special attention. As REF scenario shows, with moderate measures, the emissions will still increase in the analysed period, although with a much smaller rate compared to a scenario with no measures. In the RO Neutral scenario, drastic hypotheses are considered, including high share of electric and hydrogen vehicles in 2050 and faster retirements of old vehicles, which will lead to 82% reduction of the emissions in the period 2019-2050.

The highest share of the emissions in the Transport sector are historically and currently due to the Road Transport (around 96% in 2019). As the emissions from the Road transport will be reduced, the share of the Aviation sector will increase to approximately 15% in 2050 in the RO Neutral scenario. More than 90% of the emissions in the Transport sector are and will be due to CO_2 (Figure 37).

Figure 36. Trajectory of emissions by source in the Transport sector – REF, Middle and RO Neutral scenario

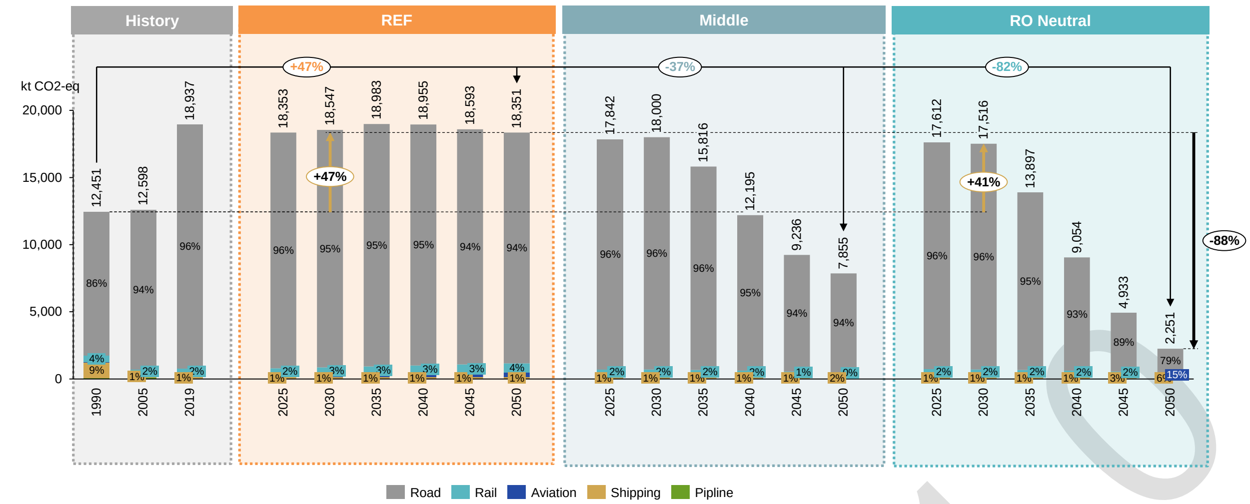
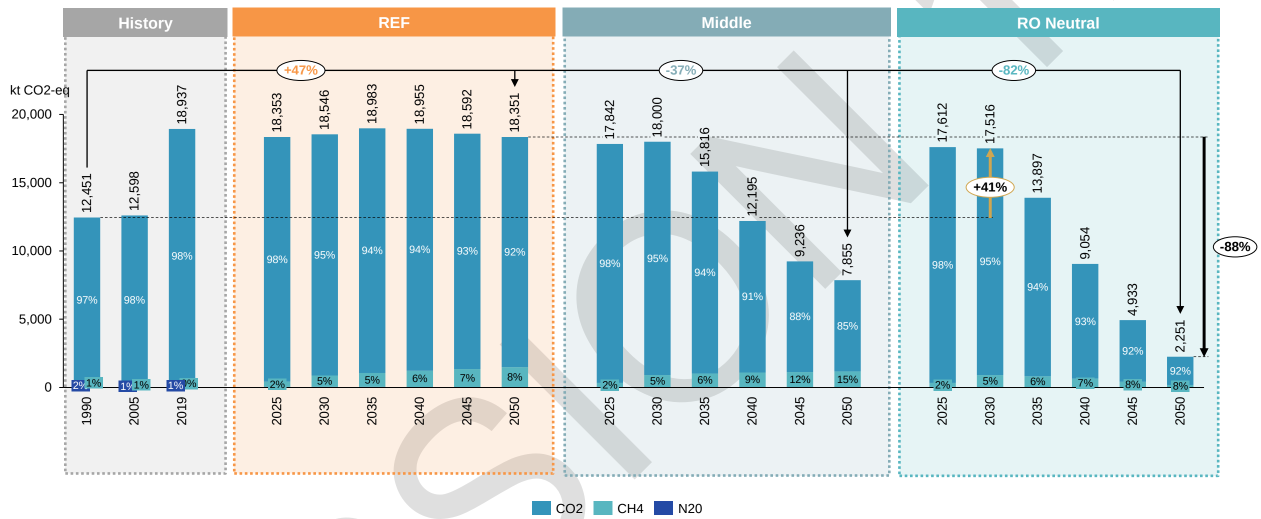


Figure 37. Trajectory of emissions by GHG in the Transport sector - REF and RO Neutral scenario



6.2.2 Decarbonisation options for the transport sector

The transport sector is one of the most difficult to decarbonize since there will be a significant rise in its emissions level if no policies and measures will be implemented. As a result, particular consideration should be given to this sector in order to reach the LTS overall targets.

Urban transport is a major source of emissions. This is mainly caused by the fact that road trips in 1-person cars accounts for the majority of the general transport movements in the Romanian cities, with over 76% of the country's population residing in urban areas. However, the share of urban transport in the national level of emissions is difficult to assess due to the lack of standardized and consistent data at the urban level.

An important factor for the steep increase in GHG emissions in the urban transport sector which occurred in the last decades is the significant increase in the number of registered vehicles. Although Romania is still below the EU average, the number of vehicles per 1,000 inhabitants has steadily increased over the last 20 years, reaching 261 cars per 1,000 inhabitants in 2018 (the EU average being 505 cars per 1,000 inhabitants). In addition, the moving vehicles in cities are old and inefficient in terms of fuel consumption. This contributes to increased GHG emissions and has a negative impact on the overall air quality. In 2017, Romania imported 520,000 second-hand vehicles that do not comply with EU environmental regulations. Between 2011 and 2017, the number of second-hand registered vehicles increased by 450%. Consequently, in 2019, over 74% of all cars registered in Romania had a lifespan of over 10 years, corresponding to Euro 4, 3, 2, 1 or even 0 emission standards. Only 16% of all cars registered in 2019 complied with Euro 6 emission standards.

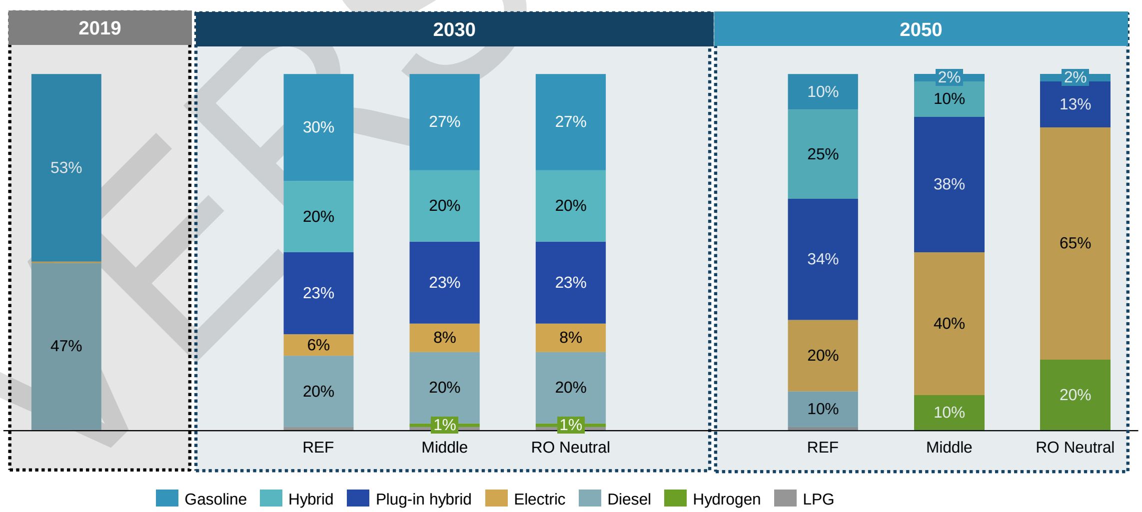
At the same time, road traffic congestion is a growing problem in large Romanian cities, as the number of vehicles increases. This is another cause for increased GHG emissions. One of the major causes of traffic jams in large urban agglomerations is the lack of integrated transport and urban planning.

The entry into force of a law on sustainable urban mobility represents a milestone included in Component 10 – Local Fund from the National Recovery and Resilience Plan (Reform 1 - Setting-up a framework for sustainable urban mobility). The draft law was approved in December 2022 by the Government and is currently in the parliamentary adoption procedure (the Chamber of Deputies is the decision-making chamber. The draft law will establish as a field the sustainable urban mobility, which up to now has been in the niche area between urban planning and transport. The purpose of the law is to establish the necessary conditions for the realization and implementation of a sustainable, fair, efficient and inclusive mobility system in order to create better mobility conditions in urban areas, reduce the level of GHG emissions due to transport and increase road safety in urban areas, by using green and digital solutions.

The significant share of old cars with high emissions (NOx, CO, HC, PM) is one of the main factors that determine the poor air quality in Romanian cities. Cities such as Bucharest, Iași, Brașov are already subject of procedures of investigation initiated by the EC for exceeding the maximum level of emissions for several GHGs. Even though many cities in Europe (Madrid, London, Milan, Stockholm, etc.) have already implemented low-emission zones, this type of measure has not been put into practice in Romanian cities so far due to the lack of a regulatory framework at the national level. In the cited draft law, it is proposed to establish low-emission areas that must be implemented by the municipalities, within a maximum of 2 years, in the areas where the maximum legal emission levels are exceeded.

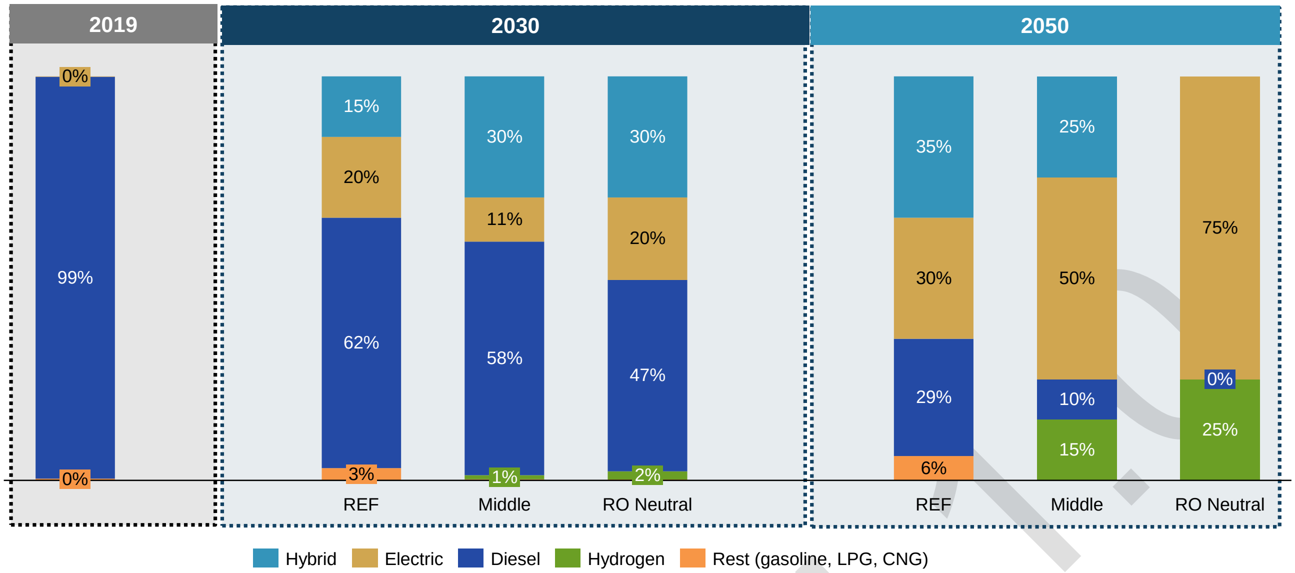
Figure 38 indicates that, in the RO Neutral scenario, in 2030, just 47% of cars will be powered by gasoline or diesel, compared to more than 99% in 2019. In the REF scenario, the gasoline & diesel share for cars will not be significantly higher, 50%, the other 50% of vehicles being hybrid, plug-in hybrid, or electric. The share of gasoline cars in 2050 will be as low as 10% in the REF scenario and 2% in the RO Neutral scenario. There will be no diesel cars in 2050 in the Middle and the RO Neutral scenarios. Another major difference between the RO Neutral and the Middle scenario, on one hand, and the REF scenario, on the other, is that hydrogen cars are considered in the first two mentioned scenarios, their share reaching 20% in 2050 in the RO Neutral scenario. All the above suggests that the cars distribution by type of fuel will be altered significantly not only by 2050, but already by 2030. At the same time, the targets may be accomplished only by lowering the lifetime of cars from 20-25 years, currently, to approximately 15 years.

Figure 38. Cars share by fuel type – REF, Middle and RO Neutral scenario



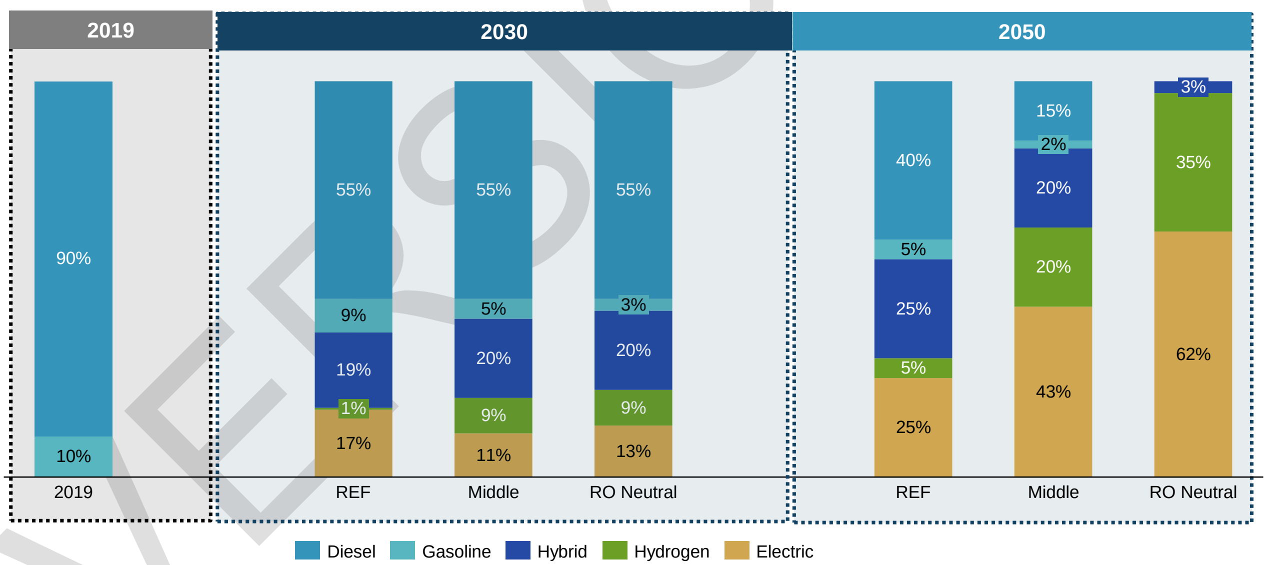
The passenger road transport vehicles fleet also requires radical reforms. In 2019, diesel powered 99% of the passenger road transport vehicles. In the REF scenario, the maximum percentage of diesel passenger road transport vehicles will fall to 62% in 2030 and subsequently to 29% in 2050. Under the RO Neutral scenario, there will be no diesel passenger road transport vehicles in 2050. On the other hand, considerable penetration of electric and hybrid passenger road transport vehicles is envisaged, aiming for 75% of passenger road transport vehicles in 2050 in both Middle and RO Neutral scenario. As in the case of cars, hydrogen passenger road transport vehicles will be introduced according to the Middle and RO Neutral scenarios, with a maximum share of 25% by 2050 in the RO Neutral scenario.

Figure 39. Passenger road transport vehicles share by fuel type – REF, Middle and RO Neutral scenario



Similarly, under the RO Neutral scenario, the share of diesel-powered heavy goods vehicles (HGV) and light commercial vehicles (LCV) should decrease from 90% in 2019 to 55% in 2030 and to 0% in 2050. Electric and hydrogen powered freight vehicles will be introduced in all 3 scenarios. Hydrogen is expected to play a significant part in the decarbonization of this type of vehicles, with a contribution of up to 35% in the RO Neutral scenario. The percentage of hydrogen vehicles will be lower in the Middle scenario.

Figure 40. HGV and LCV share by fuel type – REF, Middle and RO Neutral scenario



The analysis carried out for Transport also takes into account the future obligation stipulated in the proposal to amend Directive (EU) 2018/2001 according to which, in 2030, 2.6% of SRE-T must come from hydrogen.

Additionally, as main drivers, the following assumptions were made:

- Occupancy - 1.98 persons for cars, 9.36 persons per passenger road transport vehicles and 3.2-7.3 tonnes per HGV & LCV
- Average km per year – 6,500 km for cars, 64,500 km for passenger road transport vehicles and 8,900 km for HGV & LCV

The process of electrification of road transport is also supported by the national targets regarding the development of electric charging infrastructure for zero-emission road vehicles. In April 2023, nationwide, there were 1,836 charging points. By 2030, the following investments are scheduled:

- 2,896 high-power charging points (at least 50kW) will be installed on the national roads, expressways and highways networks
- 13,200 high-power charging points will be installed in county seat municipalities (4,000), in other municipalities (1,876), in towns (1,600) and in rural areas (5,724)
- Another 12,083 high and normal power charging points will be installed at national level.

The charging points will be installed:

- 85-95 % in public / semi-public areas
- 5-15 % in private buildings

The charging points will be places in areas identified in the general urban plans / sustainable urban mobility plans as residential areas / mixed areas / service areas / commercial areas / transport areas (as close as possible to the inhabitants – to limit the needs of travel). Also, the charging points will be located in the multimodal transport terminals.

6.3 Buildings

6.3.1 Expected trajectory of emissions, energy consumption and fuel types in the buildings sector

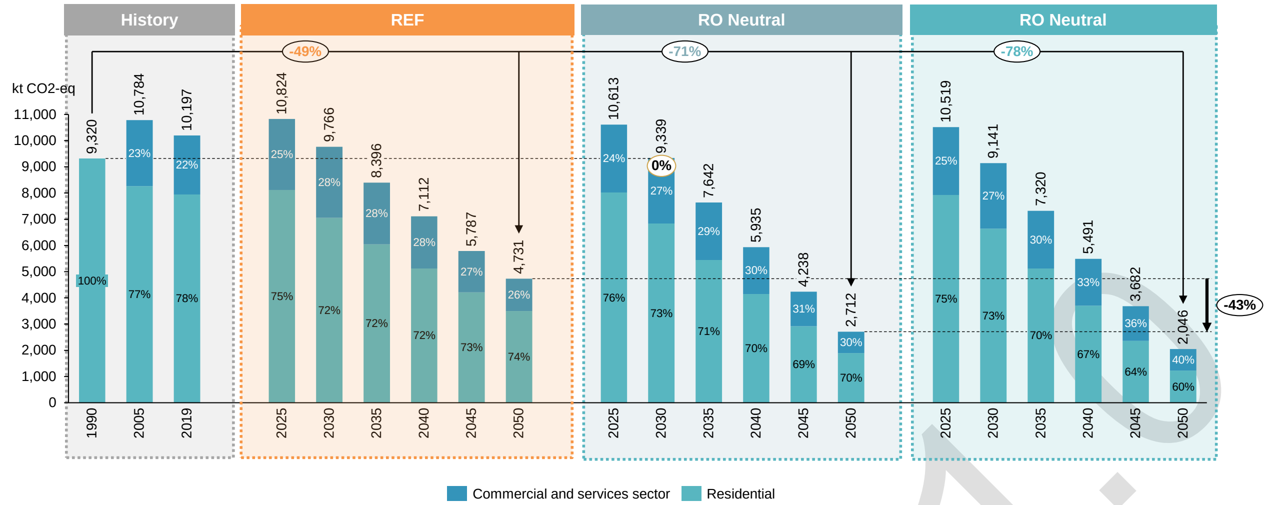
The Buildings sector includes the emissions due to Residential and Commercial sectors. The objective for the emissions in this sector is presented in Figure 41:

In the RO Neutral scenario, the reduction of the GHG in the Buildings sector will be 78% in 2050 and 2% in 2030 compared to 2030 level

In the REF and the Middle scenarios, net GHG emissions will be reduced by 49% and 71%, respectively, in 2050 when compared to the 1990 level, while the emissions in 2030 will be, for both scenarios, almost at the same level as in 1990. When compared to the REF scenario, the RO Neutral scenario is 57% more ambitious in 2050.

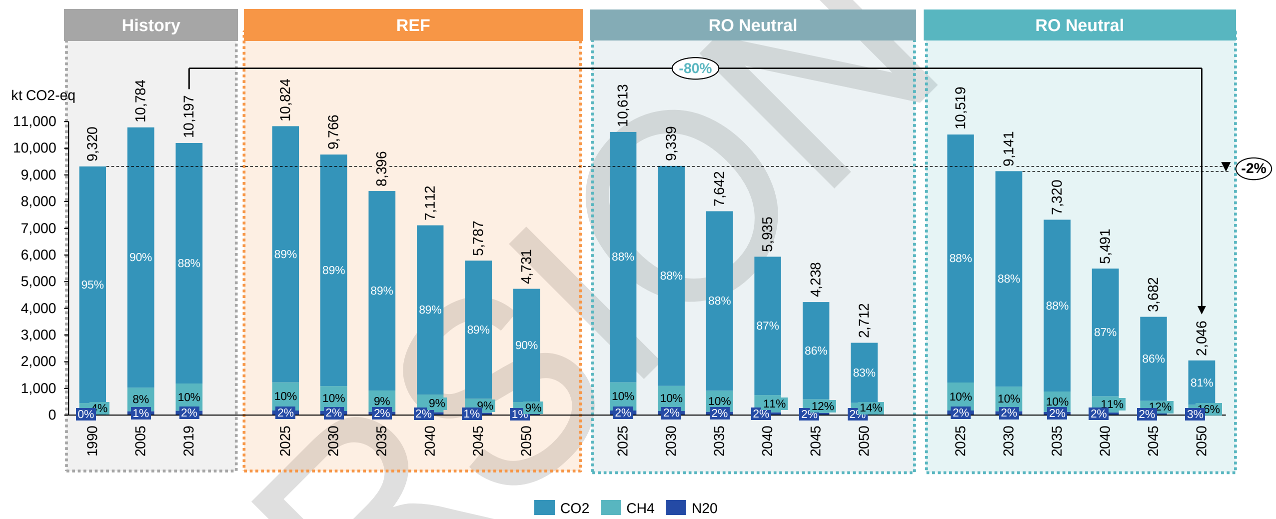
The emissions in the Residential sector will be reduced by 64% in 2050, when compared to 2019 in the RO Neutral scenario, due to the employment of more efficient technologies, as well as due to the improvement of the energy performances of the buildings. On the other hand, the measures applied in the Commercial sector will contribute to lowering with approximately 85% the emissions level in the period 2019-2050 in the RO Neutral scenario.

Figure 41. Trajectory of emissions by source in the Buildings sector – REF, Middle and RO Neutral scenario



More than 80% of the emissions in the Buildings sector are and will be CO_2 emissions, as shown in Figure 42.

Figure 42. Trajectory of emissions by GHG in the Buildings sector – REF, Middle and RO Neutral scenario



6.3.2 Decarbonisation options in the Buildings sector

The decarbonisation hypotheses which were considered for obtaining the LTS objectives set for the Residential sector are the following:

- Employing high efficiency technologies:
  - for heating &, cooling and heating the water, technology efficiencies according to the JRC model will be adopted
  - for the technologies used for cooking, lighting, and appliances, technology efficiencies according to the PRIMES model will be adopted
- The energy demand will be partially fulfilled by **hydrogen CHP**
- The share of **heat pumps** for heating and cooling will be increased, while reducing the share of biomass and natural gas. The share of the heat pumps in the useful energy demand for heating and cooling will be 15% in 2050 in the REF scenario, 20% in the Middle scenario and 25% in the RO Neutral scenarios
- The share of **solar thermal collectors** from the useful energy demand for heating the water will be significantly increased, while reducing the share of natural gas and district heating. The share of solar thermal collectors for water heating will be the following:

	REF		Middle		RO Neutral	
	2030	2050	2030	2050	2030	2050
Urban	10%	18%	25%	39%	28%	54%
Rural	7.50%	19%	14%	28%	16%	33%

- The use of electricity technologies for cooking will be incresed, which natural gas and biomass-based technologies will be replaced (the use of biomass technologies for cooking in the rural areas will be reduced to 0% in 2050)
- **Annual renovation rates** in accordance with the Scenario 2 of the SNRTL (the same assumption as in the case of the 2021-2030 NECP) will be implemented: gradual increase from 0.69% annual renovation rate la 3.39% during 2021 – 2030, 3.79% annual renovation rate during 2031 – 2040and 4.33% during 2041-2050

For the Commercial sector, the LTS goals can be met by implementing the following measures:

- Employing high efficiency technologies (according to the Primes model)
- The energy demand will be partially fulfilled by **hydrogen CHP**
- Implementation of the **annual renovation rate** in accordance with the Scenario 2 of the SNRTL

6.4 Industry

6.4.1 Expected trajectory of emissions, energy demand and fuel types in the Industry sector

In the Industry sector analysis, emissions both due to energy use and to IPPU are included. The overall objective for this sector is presented in Figure 43:

In the RO Neutral scenario, the net GHG emissions in the Industry sector will be lowered by 89% in 2050 and by 77% in 2030 when compared to the 1990 level

As compared to 1990 levels, in the REF scenario, a decrease of the net GHG emissions by 82% in 2050 and by 76% in 2030 will be achieved, while in the Middle scenario these percentages are 86% in 2050 and 77% in 2030. In relation to the REF scenario, the RO Neutral scenario targets 39% lower emissions in 2050.

This objective in the Industry sector is mainly achieved by decarbonizing the energy consumption (mainly by increasing the energy efficiency and performing the fuel switch), which leads to 93% emission decrease in this sub-sector in the RO Neutral scenario in 2050, compared to 1990 (Figure 44). In the period 2019-2050, the highest share of the emissions from energy use in Industry will be due to Non-metallic minerals, Chemical and Petrochemical, Food and tobacco and Iron and steel industrial areas.

Regarding Industrial processes, the highest share in the emissions will be due to the Mineral and Metal industries. While the emissions from the Metal industry will be reduced by 67% in 2050 compared to 2019 in the RO Neutral scenario, mainly due to employing the more efficient steel manufacturing process, the emissions from the Mineral industry will slightly increase in the same period, due to the increase of the national production index growth, however showing nearly constant emission factors during the whole period. Therefore, in order to reduce these emissions, carbon capture, storage and utilization (CCUS) technology will be employed, so that, by 2050, in the RO Neutral scenario, 2,583 kt CO_2 emissions from the sectoral emissions (including the residual emissions resulting from burning of fuels for the production of thermal energy required for the process) will be captured annually. The implementation of the Kigali amendment to the Montreal protocol will reduce the emissions from the Product uses as substitutes of ozone depleting substances by approximately 7 times in 2050, compared to 2019, in both scenarios.

Figure 43. Trajectory of emissions by source in the Industry – REF, Middle and RO Neutral scenario

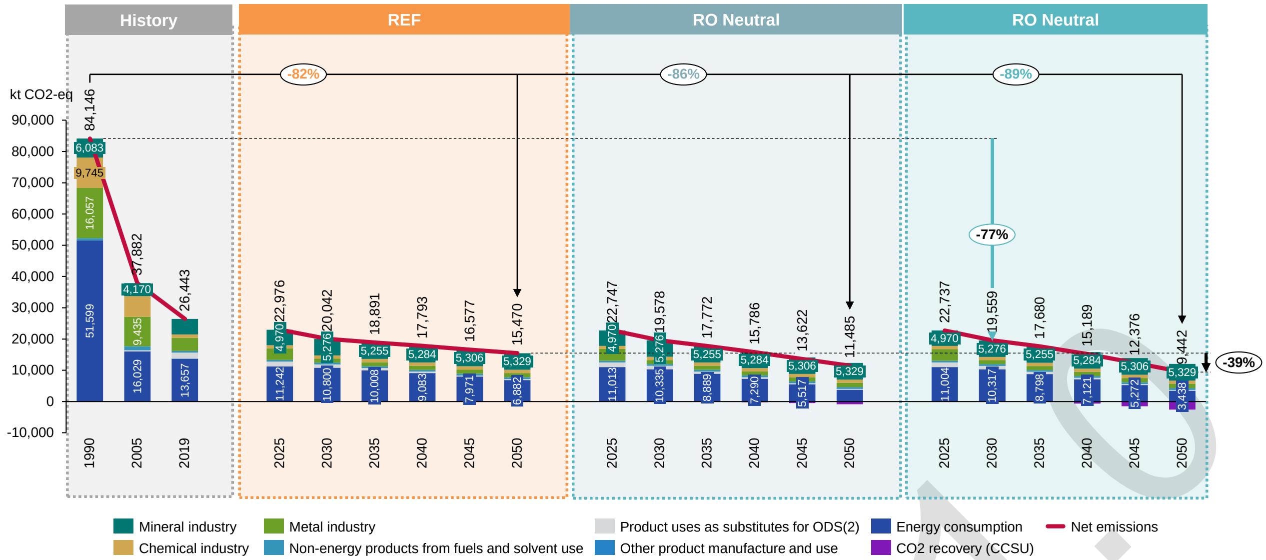
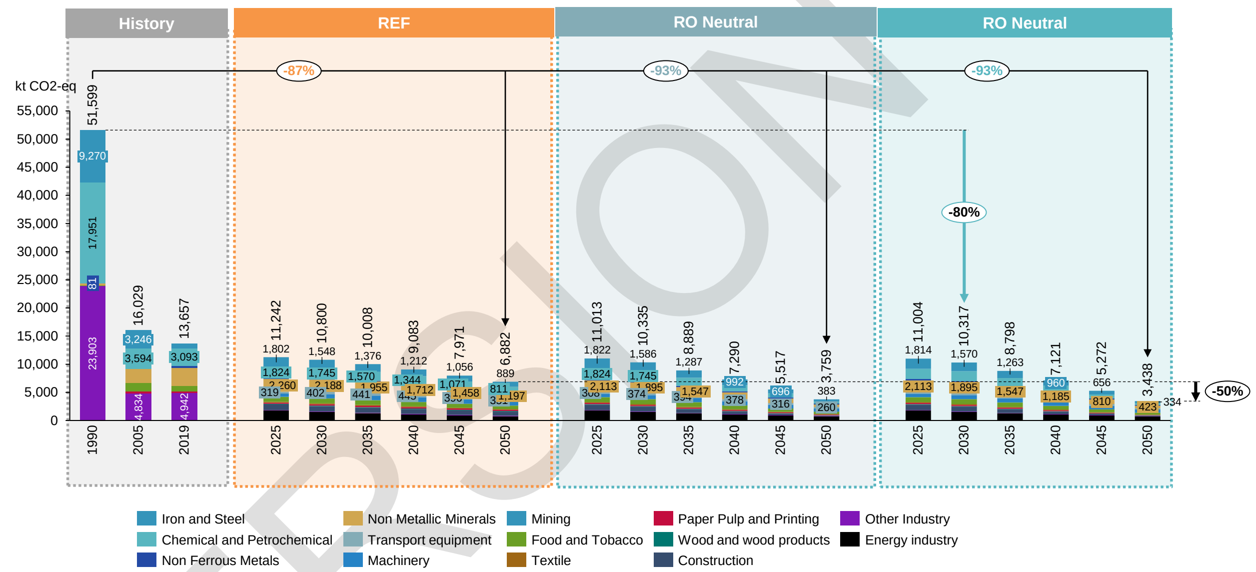
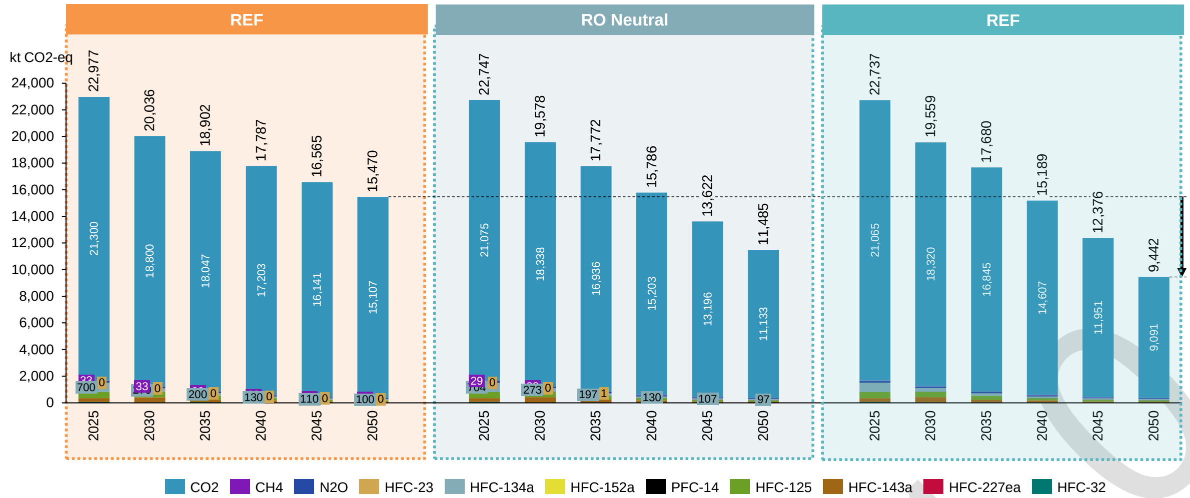


Figure 44. Trajectory of emissions by source from energy use in the Industry – REF, Middle and RO Neutral scenario



As a result of the Product uses as substitutes of ozone depleting substances, F-gases are included in this sector, which will be drastically reduced. As a result, in 2050, more than 96% of the GHG emissions in the Industry sector will be CO_2 emissions, as shown in Figure 45.

Figure 45. Trajectory of the emissions in Industry by type of GHG – REF, Middle and RO Neutral scenario



6.4.2 General overview of the policies, existing plans and measures for decarbonisation as described in point 2.1 of Section A of Part I of Annex I of Regulation (EU) 2018/1999

The general policies and measure applied to the Industry sector (IPPU and energy use in Industry) in all three scenarios include:

- Reduction of the use of fossil fuels (such as natural gas and coal) in all industry branches (Iron and Steel, Chemical and Petrochemical, Non Ferrous Metals, Non Metallic Minerals, Transport equipment, Machinery, Mining, Food and Tobacco, Textile, Paper Pulp and Printing, Wood and wood products, Construction, Other Industry), which will replaced by electricity, hydrogen, energy-reach waste, RES (including biomass) and heat (including heat produced by autoproducers and waste heat from thermal processes, in compliance with the rules regarding environmental protection
- The efficiency of the employed technologies will be increased according to the state-of-the-art of the Primes model
- Implementation of the Kigali amendment of the Montreal protocol in the Product uses as substitutes of ozone depleting substances
- In the cement production, the activity data in 2040 will be in accordance with NC 8 (approx. 8,600kt clinker production), while the process emission factor level (calculated on the basis of CaO and MgO content originating from carbonates) will be lowered from 0.52 to 0.49 tCO2/t clinker, according to NC 8
- The lime production will follow the production index growth trend (in accordance to the data from the National Commission for Strategy and Prognosis) and the emission factors will be in accordance with the BR 4
- The glass production will follow the production index growth trend (in accordance with the data from CNSP) and the emission factors will be in accordance with BR 4
- The level of production and emission in the ceramics industry and in all the other industries employing non-metallic minerals will be in accordance with BR 4
- The annual growth rate of soda ash production will be 1.8%, in accordance with BR 4
- The emission factor in the steel production will lower from1.01 tCO2/t to 0.3 tCO2/t in 2030, as a result of employing electric arc furnace (EAF) and DRI-EAF technologies

The major difference between the scenarios is the different share of fuels used for energy purposes, as well as the introduction of the CCSU technology in the Mineral industry in the Middle and the RO Neutral scenarios. In the Middle scenario, 20% of the emissions from the Mineral industry will be captured by 2050, while 50% of the emissions of the sector will be captured in the RO Neutral scenario. The new provisions stipulated in the proposals for amending Directive (EU) 2018/2001, according to which the share of hydrogen from the RES-based final energy used in industry should be 50% in 2030, is also considered.

6.5 Agriculture and land use, land-use change and forestry (LULUCF)

6.5.1 Expected trajectory of emissions in Agriculture and LULUCF

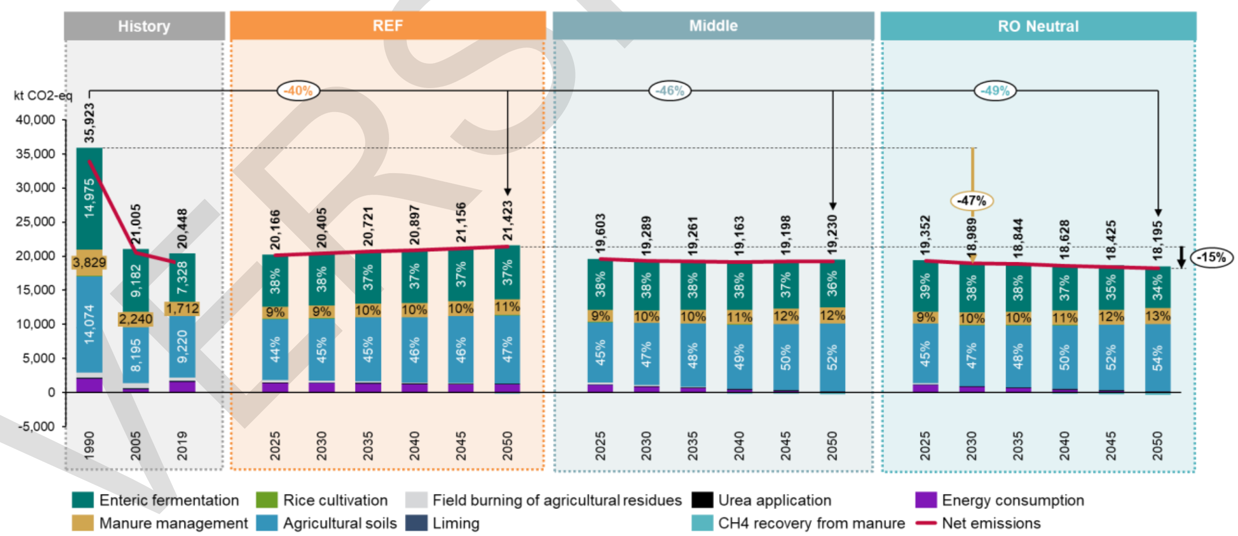
In the Agriculture sector the implementation of the proposed policies and measures lead to the emission trajectories indicated in Figure 46:

In the RO Neutral scenario, the GHG emissions in Agriculture will be lowered by 49% in 2050 and 47% in 2030 when compared to the 1990 level

In the REF scenario, a reduction of the GHG emissions by 40% in 2050 and 43% in 2030 when compared to the 1990 level will be achieved. In relation to the REF scenario, the RO Neutral scenario will accomplish 15% lower emissions in 2050.

The Agricultural soils category has the largest share of emissions in the period 2019 - 2050. Due to the implementation of the policies and measures listed in the in the next section, the emissions will be almost nearly constant throughout the whole analysed period in the RO Neutral scenario. The policies and measures that will be implemented in the area of enteric fermentation, a field that contributes significantly to the level of emissions from Agriculture, will lead to the reduction of emissions by 16% in 2050 compared to the level of 2019 in the RO Neutral scenario, despite the fact that, in general, the livestock will increase in the analysed period. As a result of the livestock increase, emissions from manure management will increase by 37% in 2050 compared to 2019. However, in order to reduce these emissions, energy recovery will be employed. It is estimated that around 340 kt CH4 will be recovered annually by 2050, the obtained energy going to be used in the Agriculture sector. Under the RO Neutral scenario, emissions from field burning of agricultural residues will be reduced to zero starting from 2030.

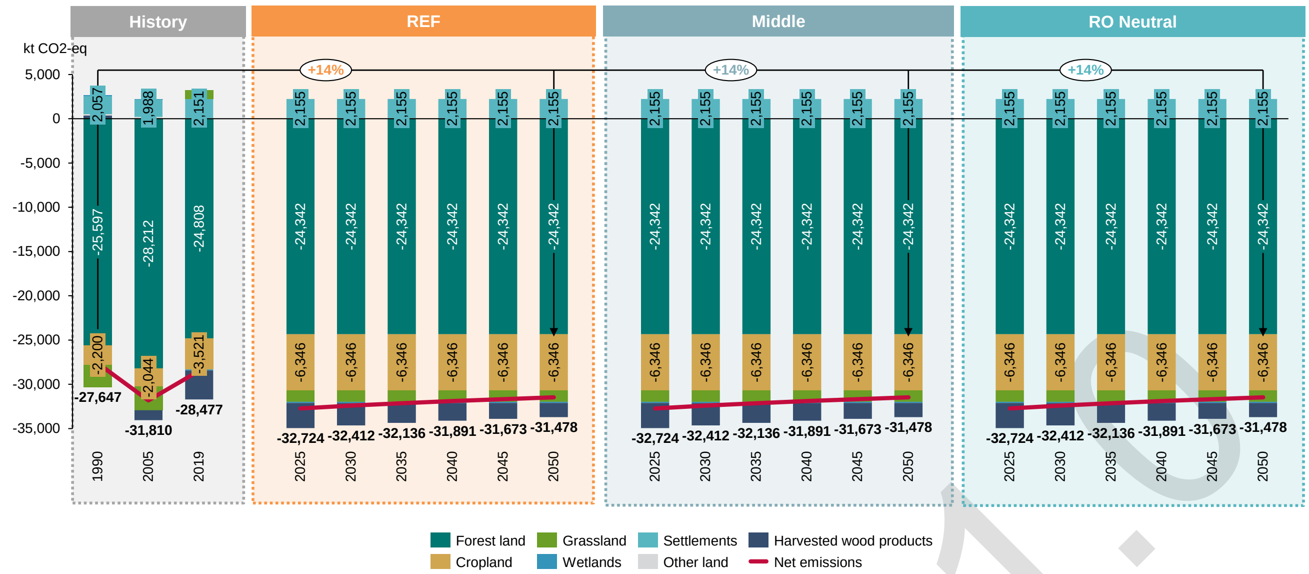
Figure 46. Trajectory of emissions by source in the Agriculture – REF, Middle and RO Neutral scenario



The LULUCF sector has the major role in the absorption of the GHG emissions (Figure 47). Due to the fact that this sector already achieves significant absorptions, it is assumed, in all three scenarios, that the absorptions from LULUCF will be increased by around 14% in 2050, when compared to 1990.

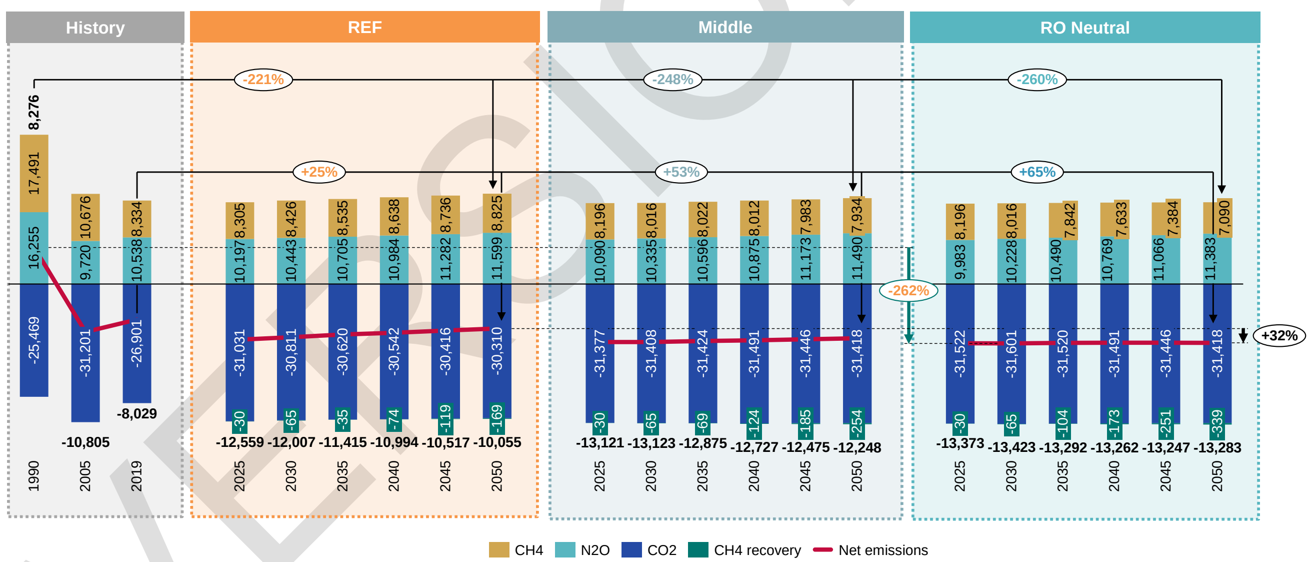
In all three scenarios, the level of GHG absorptions in the LULUCF sector will increase by 14% in 2050 compared to the 1990

Figure 47. Trajectory of emissions by source in the LULUCF – REF, Middle and RO Neutral scenario



As a result of the policies and measures implemented in the Agriculture sector and the continuation of measures leading to GHG absorptions in the LULUCF sector, when analysing these two sectors as a whole, an increase of the total net GHG absorptions will occur in 2050 compared to 1990, in all three scenarios (Figure 48). When compared to 2019, these net absorptions will be increased by 65% in 2050 in the RO Neutral scenario. The RO Neutral scenario is 32% more ambitious than the REF scenario. In terms of individual GHG, the highest share of the absorption concerns CO_2, while the highest share of the emissions is due to N_2O, followed by CH_4.

Figure 48. Trajectory of the emissions by GHG in Agriculture and LULUCF – REF, Middle and RO Neutral scenario



6.5.2 Decarbonization options in Agriculture and LULUCF sectors

Emissions will be reduced in Agriculture and LULUCF by applying the following measures:

- Emissions from enteric fermentation will be reduced by introducing a proper diet. Based on this assumption, the emission factor for enteric fermentation will reduced by 10% in 2030 and by 30% in 2050 in the RO Neutral scenario. In the Middle and REF scenario, these emission factors will be reduced by 10% and 5%, respectively, in 2030 and by 25% and 20%, respectively, in 2050.
- According to the BR 4, agricultural residues will no longer be burned in the fields starting in 2030 in the RO Neutral scenario, 2040 in the Middle scenario, and 2050 in the REF scenario.
- The emission factor of FSN_N in synthetic fertilizer will be reduced by 20% in 2050 in the RO Neutral scenario, and by 10% and 15% in 2050 in the REF and Middle scenarios, respectively.

- In order to reduce the emissions from the manure management, CH_4 recovery is envisioned. The amount of CH_4 emissions that will be recovered will be used as biogas fulfilling of 5% of the energy demand in Agriculture by 2050 in the Middle and RO Neutral scenarios. At the same time, methane capture will lead to manure management emission reduction: 40% in 2050 compared to 2020 in the RO Neutral scenario, 30% in the Middle scenario and 20% in the REF scenario.
- In terms of energy use in the Agriculture, the share of solar energy will increased in all three scenarios to 15% in 2050, while diesel consumption will reduced to zero.
- Regarding LULUCF, it is assumed that the annual average forest burned area by 2050 will be equal to the average forest burned area during 2010-2019 in all three scenarios.

Based on the data for Livestock in the BR 4, on the 2010-2021 historical data and on the sectoral investment plans, projections for the population of each type of Livestock are made, as shown in Table 6, and considered as hypotheses.

Table 6. Livestock population projections

Buffalo	Female	- 0.5%
	Other types of buffalo	- 0.5%
Goats	Dairy goats	+ 1.1%
	Other types of goats	+ 0.4%
Horses	Horses	- 1.1%
Mules and Asses	Mules and Donkeys	+ 0.2%
Poultry	Adult for eggs	+ 0.7%
	For meat	+ 0.7%
Rabbit	Rabbit	+ 0.5%
Cattle	Slaughter calves younger than 1 year	+ 1.1%
	Breeding cattle younger than 1 year	+ 0.65%
	Breeding cattle between 1 and 2 years	- 0.04%
	Slaughter cattle between 1 and 2 years	+ 2.63%
	Breeding bulls older than 2 years	+ 1.1%
	Heifers for breeding older than 2 years	- 0.4%
	Slaughter male and female cattle older than 2 years	+ 0.13%
	For work	+ 0.27%
	Dairy cow	+ 1.1%
Pigs	Under 20 kg	+ 1.85%
	Between 20 and 50 kg	+ 1.85%
	Fattening	+ 1.85%
	Boars	+ 0.5%
	Breeding sows	+ 1.6%
Sheep	Dairy sheep	+ 1.2%
	Rams for breeding	+ 1.2%
	Other types of sheep	+ 1.2%

6.5.3 Links to agricultural and rural development policies

Between 2023-2027, Romania will continue the implementation of the Common Agricultural Policy through the 2023-2027 Strategic Plan (2023-2027 CAP SP), approved by Commission Decision C(2022) 8,783. The main focus of the 2023-2027 CAP SP will be the continuity in implementing of the measures and policies within the

2014-2020 National Programme for Rural Development (PNDR) and providing support for environmental and climate measures meant to promote the voluntary application of agricultural and/or forest management methods (agri-environment and climate, ecological agriculture, areas with natural constraints and other specific constraints, forests environment and climate) addressed to the conservation of biodiversity, by granting compensation payments. Complementary to the PNRR, which aims at the afforestation of other agricultural areas for which it also ensures the financing of the required maintenance works, 2023-2027 CAP SP provides funding agricultural lands forested during PNDR 2007-2013 and PNDR 2014-2020.

At the same time, within 2023-2027 CAP SP, Romania is considering the implementation of some types of interventions that adequately respond to national objectives, such as:

- Supporting investments in the livestock sector that include new investments and/or modernization of livestock farms, namely investments in equipment, adaptation to standards, connections to utilities, procurement of equipment and building modern facilities, for the proper manure management including manure and sewage sludge storage and application, procuring employed for reducing GHG and ammonia footprint, as well as technologies that contribute low-carbon economy, etc.
- Investments in the agri-food sector (vegetables/potatoes, fruit trees, hops, table grapes, large crops, flowers, aromatic, medicinal and ornamental plants) also aim (as a secondary component of an investment project) to produce energy (electric and/or thermal) from renewable sources (solar, wind, geothermal, aerothermal, hydrothermal, etc.) and use it exclusively for self-consumption purposes (without becoming a prosumer). The implementations of these types of investments will contribute to reducing GHG emissions, producing and using RES-based energy.
- The investments made in small farms will contribute to implementing proper manure management and obtaining organic fertilizers from the utilization of biomass, framed as a secondary component of the project.
- Regarding the investments carried out by young established and recently established farmers, actions that contribute to reducing GHG emissions, acquisition of organic fertilizers, production and use of renewable energy from the utilization of biomass are supported as a secondary component of the investment projects.
- Non-productive investments carried out at the farm level, such as planting forest protection curtains, will also contribute to mitigating and adapting to climate change, by reducing GHG emissions and improving carbon capture and sequestration.

6.6 Waste

6.6.1 Expected trajectory of emissions by sources and by individual GHGs

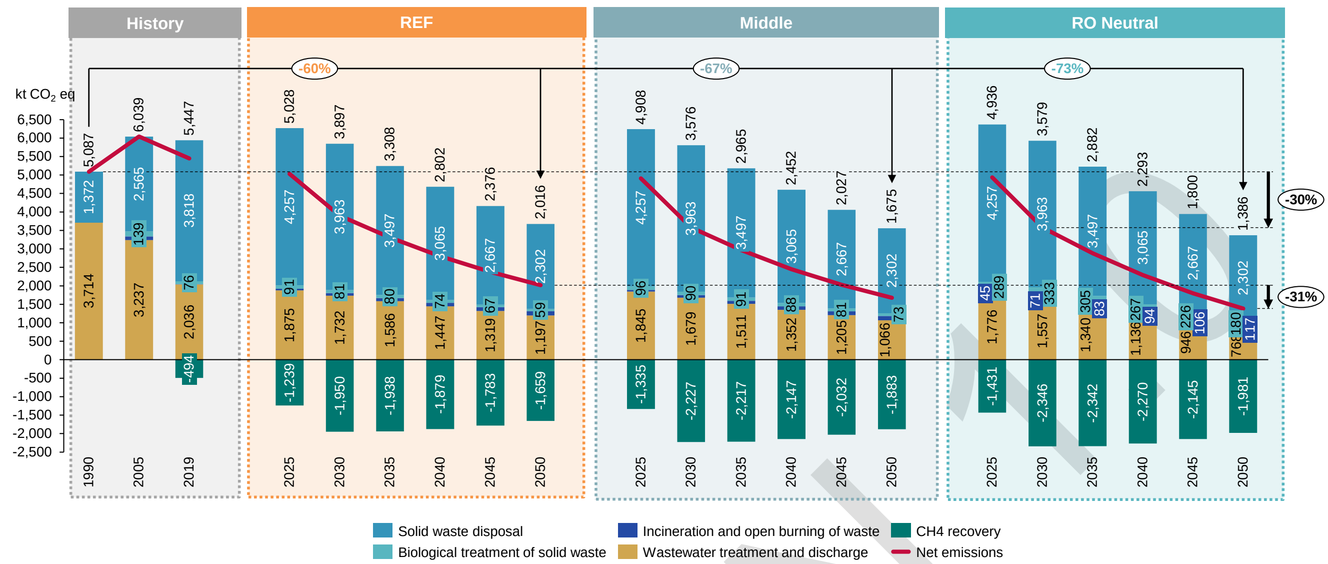
In the Waste sector the implementation of the proposed policies and measures will lead to the emission trajectories presented in Figure 49:

In the RO Neutral scenario, the reduction of the net GHG emissions in the Waste sector will be by 73% in 2050 and by 30% in 2030 when compared to the 1990 level

In the REF scenario, Waste GHG emissions will be reduced by 60% in 2050 and 23% in 2030 when compared to the 1990 level, while in the Middle scenario these percentages will be 67% in 2050 and 30% in 2030. When comparing the scenarios, the RO Neutral is 31% more ambitious than the REF scenario in 2050.

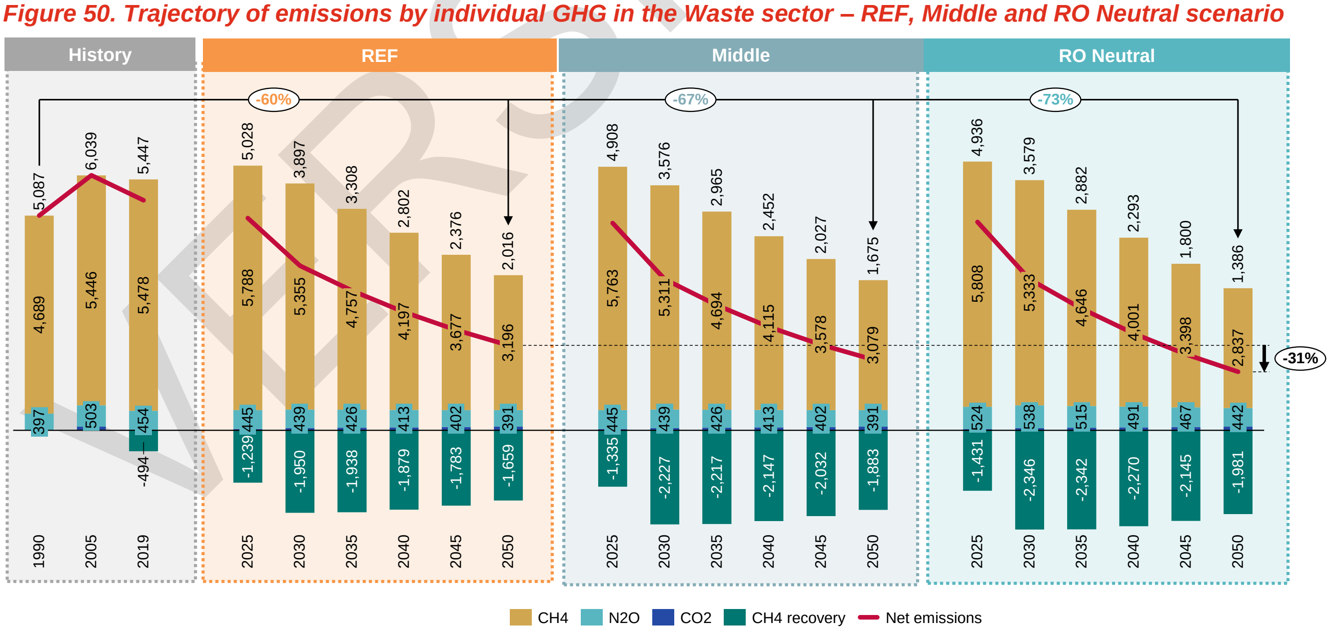
At sectoral level, when compared to 2019, in the RO Neutral scenario, due to the implementation of the measures concerning biological treatment of solid waste and incineration / co-incineration described in the following section, the emissions from these sub-sectors will increase in 2050 compared to 2025. However, at the same time, the policies implemented in these two sub-sectors will lead to drastically reducing the emissions from other two sub-sectors. Namely, the emissions from Solid waste disposal and the Wastewater treatment and discharge will be reduced by approximately 40% and 62%, respectively, in 2050, in the RO Neutral, when compared to 2019. On the other hand, the implementation of the measures for energy recovery, such as flaring and energy production (biogas) will lead to increasing the CH_4 recovered 4 times in 2050 when compared to 2019, in the RO Neutral scenario.

Figure 49. Trajectory of emissions by source in the Waste sector – REF, Middle and RO Neutral scenario



In terms of emissions by individual gases, there will be a significant reduction of the net CH_4 emissions by approximately 83% in 2050, compared to 2019, in the RO Neutral scenario (Figure 50). On the other hand, due to the measures regarding the burning and incineration of waste and methane (which will strongly contribute to the significant reduction of methane emissions), CO_2 emissions will increase approximately 9 times by 2050 compared to 1990 in the RO Neutral scenario. The N_2O emissions will stay almost at the same share in the period 2019-2050 and they will account for around 10% of the total emissions in the Waste sector.

Figure 50. Trajectory of emissions by individual GHG in the Waste sector – REF, Middle and RO Neutral scenario



6.6.2 Decarbonization options in Waste

For the Waste sector, policies and measures are proposed which are in line with the European Green Deal, 2020 Circular economy action plan (2020/2077(INI)), Landfill Directive 1999/31/EC and the Waste Framework Directive (EU) 2018/850. The main EU goal is that only 10% of the residual waste should be landfilled by 2035, which is established in the amended Landfill Directive. For achieving the LTS goals for the waste sector, the following policies and measures, based on the EU Waste Framework Directive of the Waste, will be implemented:

- Residual waste - 10% of residual waste will be landfilled by 2035
- Reduce – minimize the amount of waste produced. By 2030, it is assumed that household waste per capita will be reduced by 10% compared to 2017 (i.e. reduce Municipal Solid Waste (MSW) from the 228 kg per capita recorded in 2017 to 204 kg per capita by 2030). This assumption is consistent with the Romanian Overview of national waste prevention programmes in Europe - Country Profile 2021 by EEA[13]
- Reuse – reuse, repair and repurpose the products in order to avoid disposal. 2020 EU circular economy action plan aims to halve the quantity of municipal waste not recycled or prepared for reuse by 2030, while all EU Member States must recycle or prepare for reuse at least 60% of their municipal waste by 2030.
- Recycle – converting the waste materials to raw materials (such as paper, glass, metal, plastic etc.) and compost, which is a way of recycling organic food and garden waste, which are then used as fertilizers. In this regard, the following minimum requirements for material recovery are envisioned:
    - Wood – 25% in 2025, 30% in 2030 (as in Zero Waste Europe-Policy briefing document[14]) and 50% in 2050
    - Paper and textile – 80% in 2050 (this is in agreement with the Zero Waste Europe-Policy briefing document and the EU Strategy for Sustainable and Circular Textiles)
    - Food and garden waste – 50% in 2030 and 60% in 2050. Food and garden waste will be used in the composting process. Additionally, the emissions factors for composting will be reduced to 3kt CH_4/tonne and 0.24 kt N_2O/tonne in 2050, which is in accordance to the GHG Emission Factors Review – ESA[15].
- Recover energy – converting the non-recycled waste into usable energy. Although the amount of waste going to landfills will be significantly reduced, there will still be a significant amount of emissions produced by the accumulated waste. Therefore, it is important to further reduce these emissions by using two techniques:
    - Energy production – it is assumed that, in 2030, 30% of the emissions from the non-recycled waste plus the historical emissions will be used for electricity production, this share increasing to 60% in 2050, in the RO Neutral scenario. For the Middle scenario, these percentages are 25% in 2030 and 55% in 2050, while for the REF they are 20% in 2030 and 40% in 2050.
    - Flaring – a share of the non-recycled waste plus the historical emissions, excluding the waste used for energy production, will be flared. These shares will be 40% in 2030 and 60% in 2050 in the RO Neutral scenario. For the Middle scenario, the shares will be 40% in 2030 and 55% in 2050, while for the REF scenario they will e 35% in 2030 and 50% in 2050.
- Incineration / co-incineration – The annual volume of incinerated / co-incinerated waste will increase to 500kt in 2030 and to 900kt in 2050 in all three scenarios. Optionally, this waste may be used for energy recovery in recovery facilities and/or in cement factories.

For the Wastewater treatment, it is assumed that:

- 55% of the rural population will be connected to sewage systems by 2050 according to the REF scenario, 75% according to the Medium scenario and 90% according to the RO Neutral scenario.
- All sewage systems in urban areas will be connected to wastewater treatment plants by 2030. 5% of rural areas connected to sewage systems will be connected to wastewater treatment plants by 2030 and 70% by 2050.

[13] https://www.eea.europa.eu/themes/waste/waste-prevention/countries/romania-waste-prevention-country-profile-2021/view
[14] https://zerowasteeurope.eu/wp-content/uploads/2020/07/zero_waste_europe_policy-briefing_achieving-the-eu%E2%80%99s-waste-targets.pdf
[15] https://www.esauk.org/application/files/9616/4268/9204/Appendix_2_ESA_EF_Review_Final.pdf

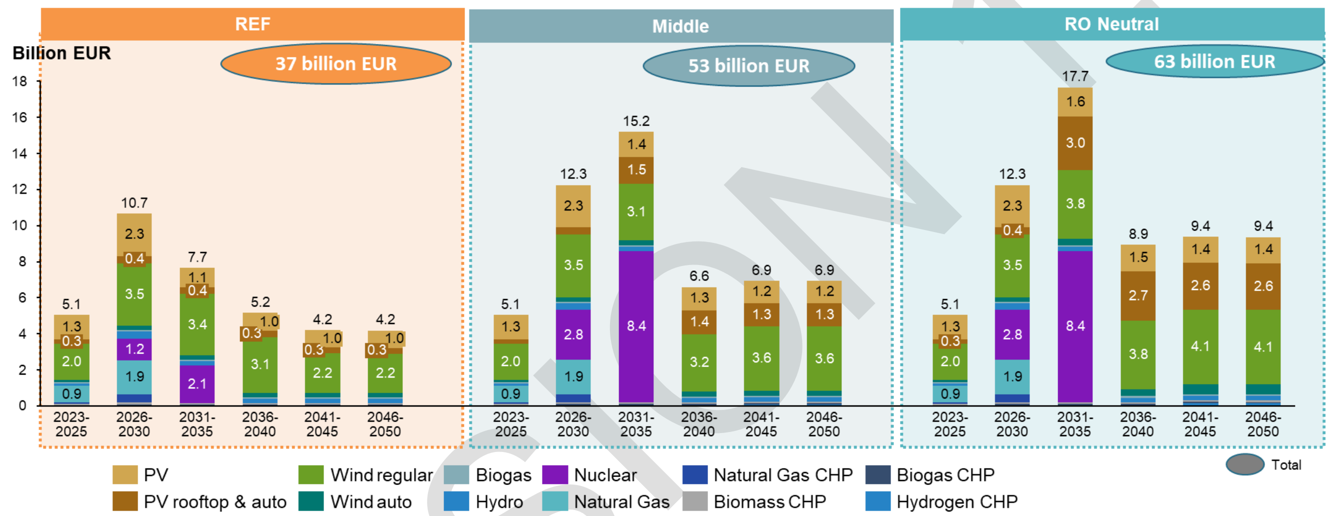
7. COST OF LTS IMPLEMENTATION AND EXPECTED SOCIO-ECONOMY IMPACT

7.1 LTS financing

7.1.1 Estimates of investment needed

In all three scenarios, the investments concerning energy production will target mainly new PV and wind power facilities. At the same time, the RO Neutral and the Middle scenarios include significant investments for the construction of new nuclear power capacities in the period 2026-2035. Furthermore, as indicated in Figure 51, the investments in the RO Neutral scenario for electricity production are more than 1.5 times larger than in the REF scenario. This is due to the RO Neutral scenario's higher rate of electrification of the demand sectors and higher use of hydrogen (which requires RES-based electricity in order to be produced).

Figure 51. The total amount of investments needed until 2050 in for energy production according to the 3 scenarios



The investments needed in the sectors with the largest energy demand (Road Transport, Buildings, Industry) are presented in Figure 52. The road transport sector was selected since it is, by far, the most polluting of all the transport areas and requires the largest amount of investments. For the 3 sectors with the largest energy demand, investments are aimed, mainly, at procuring and installing new, high-efficiency machines, technologies, and equipment (vehicles, heating and cooling equipment, industrial technologies, etc.), as well as performing buildings thermal renovation and performance improvement. The analysis assumes that most technologies will be replaced as they reach end-of-life, which means that investments will be made even in the absence of the LTS implementation (but possibly relying on less efficient or less environmentally friendly solutions). Most of the investments will be made by companies (procurement and installation of high-efficiency equipment and technologies in industry, renovation of commercial buildings, update of vehicles fleet, etc.) and by individuals (purchase of high-performance cars and household appliances, purchase of efficient technologies for heating and space cooling, for water heating, for cooking, for lighting, thermal renovation of houses and apartments, etc.), while the rest will be made by public institutions.

Figure 52. The total amount of investments needed until 2050 in the 3 sectors with the largest energy demand (Transport, Buildings, Industry) according to the 3 scenarios. In the case of the Transport sector, only Road Transport was considered

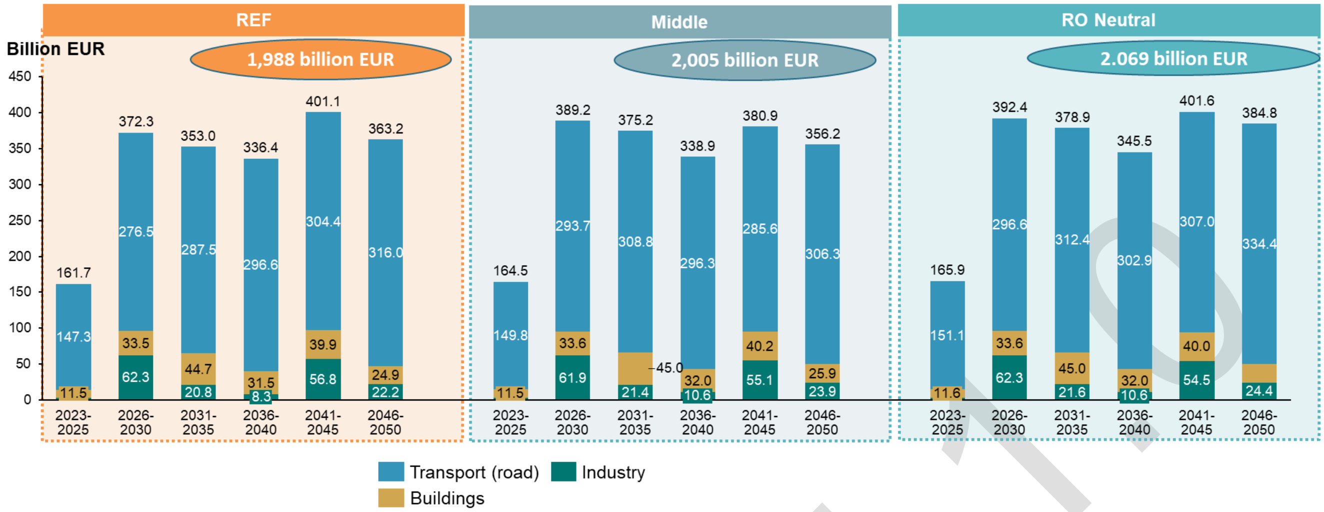
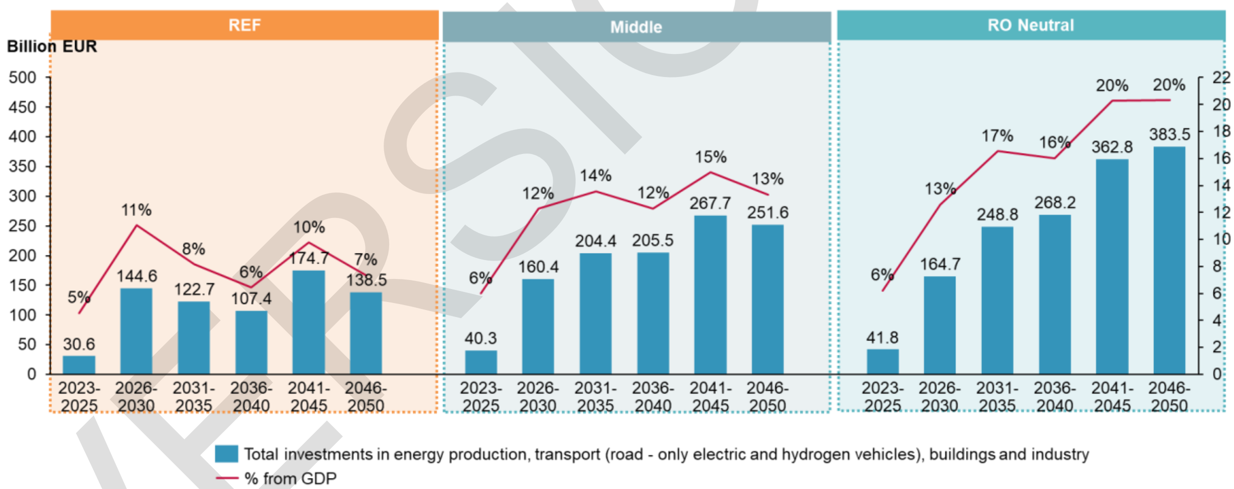


Figure 53 shows the estimation of the total investment required in the energy production sector and in the 3 sectors with the largest energy demand (Road transport – only electric and hydrogen-based vehicles, Buildings, Industry) and the percentage that this amount will represent from the average Gross Domestic Product (GDP) estimated for each of the periods considered. Forecasts regarding the GDP value are presented in Chapter 9.1.

Figure 53. The total amount of investments needed until 2050 in the 3 sectors with the largest energy demand (Transport, Buildings, Industry) according to the 3 scenarios. In the case of the Transport sector, Road Transport (only electric and hydrogen vehicles) was considered



7.1.2 Policies and measures for related research, development and innovation activities

Achieving the decarbonization targets assumed by LTS requires a sustained effort in terms of research, development and innovation (RDI). RDI activities will be carried out both at the level of economic operators and at the level of research organizations (defined according to Ordinance 57/2002 on scientific research and technological development). The support of RDI activities by means of public funding and implementation of fiscal facilities is essential for obtaining results that contribute to the achievement of the decarbonization targets assumed within the LTS.

7.1.2.1 Synergy with the National Strategy for Research, Innovation and Smart Specialization 2022-2027

The **National Strategy for Research, Innovation and Smart Specialization 2022-2027 (SNCISI 2022-2027),** adopted by GD 933/2022**,** includes a list of 4 general objectives (GO) and 5 specific objectives (SO). Most of these aligned with the objectives of the LTS, thus contributing to the process of decarbonization of the national economy.

GO1. The development of the research, development and innovation system includes **SO5. Connecting the research and innovation activities with the societal challenges - The Strategic Research Agenda**, which stipulates, at action A1, connecting research and innovation activities with major societal challenges (demographic changes, climate change, welfare and social inclusion, health, food security, ecological energy, technological changes, etc.). Action A1 will be carried out both by funding projects aimed at societal challenges (support for organizing open calls for projects and benchmark for participation in international initiatives), and by supporting developing solutions to clearly identified problems.

3 of the 6 areas targeting societal challenges, identified within the Strategic Research Agenda, have an essential role in achieving the targets assumed by LTS:

- Digitalization, industry and space
- Climate, energy and mobility
- Food, bioeconomy, natural resources, biodiversity, agriculture and environment.

Among the societal challenge priorities included in the Strategic Research Agenda, the following contribute to achieving the LTS objectives:

- **Open strategic autonomy in digital and emerging technologies and their human centricity** (Collaborative robotics for an agile and resilient economy, supporting the society; New generation computing (edge, neuromorphic, bioinspired, nano, quantum, photonic, HPC); New materials for strategic sectors, resilient to extreme operating environment conditions; Sensors and biosensors; Biotechnologies with industrial or environmental applications; Mentally and physically non-invasive technologies in industry, health, education, communications and housing, etc.).
- **Clean industry, circular economy and security of supply of raw materials** (Greening of highly polluting economic sectors; Decarbonisation of production processes; Development of cost-effective green manufacturing technologies; Industrial value chains based on local resources, including opportunity niches generated by climate change; Shortening and diversifying supply chains including the use of 4R solutions; New business models in the circular economy; Product lifecycle management; Products/technologies with a long shelf life and high recycling rate; Servitization of business models and systems; Advanced recycling of end-of-life materials; Raw materials from natural residues; Non-polluting industrial processes for obtaining raw materials from various sources; New energy efficient economic processes; Sustainability of supply of critical materials; Transparent and consolidated value chains).
- **Energy sector transition towards climate neutrality and resilience** (Development of environmentally friendly technologies for obtaining new energy storage solutions; New methods and technologies for producing energy from renewable resources with a low carbon footprint and their large-scale implementation; Development of efficient technologies for producing hydrogen from abundant, renewable sources; Innovative methods and technologies to reduce the carbon footprint of energy production systems; Development of cross-sectoral energy efficiency solutions; Use of offshore wind and wave energy; Alternatives for clean electricity production using nuclear technologies; Climate services for energy sector; Capture and storage of greenhouse gases).
- **Accessibility, supply and efficient use of energy** (Integration of renewable energy sources in heating and cooling systems; Modernization of energy transport and distribution networks; Development of solutions for thermal insulation and thermal energy storage; Ensuring the raw materials necessary for the expansion of clean energy technologies; Increasing energy storage capacity (Power-to-X Technologies); Streamlining energy consumption; Energy sustainable human communities; Energy-efficient and grid-interactive buildings; Effective and advantageous solutions for turning buildings in prosumers;

Digitalization of the energy system; Promoting and employing decarbonized energy vectors; Architecture of urban space oriented towards setting-up energetically autonomous micro-areas).

- **Towards climate-neutral, resilient and environmentally friendly mobility** (Decarbonization of the transport sector through the use of electrification and other energy vectors with a low carbon footprint (hydrogen, fuels from renewable sources, etc.); Development of production systems and supply networks for alternative fuels; Insufficient implementation of hydrogen-based energy storage applications for transport; Recyclability of materials used in transport systems; Development of zero-emission technologies for mobility; Methods for energy storage on-board of the vehicles; Electrification and the use of railways in freight transport; Changing travel behavior; Increasing the capacity of cities to implement climate-neutral mobility systems; Climate services for the transport sector).
- **Smart mobility systems** (Connected, automated and cooperative Mobility; Big Data and artificial intelligence for smart mobility; Intelligent transport systems for increasing the safety and resilience of the transport infrastructure; Open data platforms for mobility; Promoting mobility as a service; Optimizing multimodal and modal transport systems, by also considering artificial intelligence solutions; Use of drones for food and/or convenience delivery services).
- **Behavioral transformations to reduce the climate footprint** (Reducing the impact of human activities, including food waste, on greenhouse gas emissions; Mitigating climate and water crises by changing and diversifying food habits; Sustainable ways of living in harmony with the environment and the ecosystems that support it; Popularizing and promoting the effects of climate change in Romania; Development of education regarding the human impact on the environment)
- **Increasing the relevance of forests in reducing pollution** (Compensation for massive deforestation and degradation and desertification of soils; Reduction of wood mass consumption; Gradual removal of forests from the forestry circuit; Sustainable management of forests in the context of climate change).
- **Contribution of agriculture to climate neutrality and resilience** (Implementation of agricultural systems that contribute to climate neutrality and biodiversity; Reducing the carbon footprint through innovative agricultural technologies; Conservation and restoration of natural resources used in agriculture (soil, water, biodiversity); Reduction of greenhouse gas emissions generated by animal husbandry; Estimation of emissions/removals from land use, forestry and agriculture; Climate services for the agricultural sector).
- **Biodiversity recovery, conservation and sustainable restoration of ecosystems and ecosystem services** (Conservation and restoration of affected and at risk ecosystems; Conservation of species, connectivity of habitats and ensuring the integrity of ecosystems; Ensuring the efficiency of production systems favorable to biodiversity (low input, ecological); Increasing biodiversity in agri-food systems; Management of genetic resources (animals, plants) in order to maintain biodiversity; Management of insufficiently exploited natural resources (spontaneous flora, microorganisms); Changing people's attitude towards nature and ecology; Control of invasive species; Ensuring coexistence between local communities and fauna; Evaluation and valorization of ecosystem services while ensuring nature conservation; Preventing and combating eutrophication; Restoring wetlands as complex carbon storage areas providing ecosystem services; Development and delivery of knowledge resources regarding the management of protected natural areas; Population awareness and citizen involvement in science).
- **Circular bioeconomy** (Reducing the consumption of plastic packaging and microplastic pollution; Full exploitation, in cascade, of natural resources; Recovery of by-products and waste from the agri-food and non-food industrial sector; Fighting environmental pollution caused by heavy and/or radioactive metals; Climate change-resilient agricultural production and animal husbandry systems; Securing sustainable plant health and modernization of the phytosanitary sector; Reducing the environmental footprint of activities in the bioeconomic sector; Reducing nutrient losses along the food chain; Prevention and combating offshore and onshore oil pollution; Advanced utilization of vegetable residues - circular bioeconomy; Management of water and aquatic resources considering high quality water as a hard-to-renew resource; Advanced utilization of natural resources).
- **Water resources management and sustainable development of fishery and aquaculture** (Integrated management of water resources; Enabling access to drinking water resources; Development of aquaculture and sustainable fisheries; Development of aquaculture in recirculating system, by developing

the complex roles of microorganisms; Development of aquaponics; Sustainable development of irrigation systems; Climate services for the management sector water resources).

- **Food and nutrition security** (Reducing inputs of chemical synthesis in the bioeconomy; Safety and traceability of products on the food chain; Reducing the phenomenon of food fraud; Resilient and sustainable agro-food system to ensure food and nutritional security; Prevention of infectious agents that pass from one species to another and can overcome environmental barriers; Food with superior nutritional characteristics for healthy/personalized diets; Reducing deficient eating behaviors; Ensuring protein independence, diversifying protein sources and increasing the efficiency of their use; Precision nutrition along the food chain; Developing and supporting urban and peri-urban agriculture; Development of the agri-food industry in the rural area).
- **Sustainable, balanced and inclusive development of urban, rural and coastal areas** (Integrated solutions for smart city; Reducing, recycling and recovering municipal waste; Development of green infrastructure in the urban environment; Sustainable and smart rural development; Smart, nature-friendly and adaptive lifestyle; Energy use efficiency and the integration of renewable resources in buildings; Agroecology for sustainable, balanced and inclusive development; Reducing the impact of extreme events on the buildings in rural, coastal and urban areas by using dedicated climate services; Sustainable development by integrating digitalization and artificial intelligence in buildings; Developing high-performance agriculture).
- **Innovative governance models that encourage sustainability and resilience** (Solutions for engaging society and multiple stakeholders in policy decision-making; Innovative models of governance through modeling and forecasting; Increasing the resilience of critical infrastructure through monitoring, modeling, alarming and control; New business and consumption models through innovation and digitalization for sustainability and resilience; Decision support tools for SMEs in the agri-food sector; Supporting the integration of enterprises in global value chains, including through clusters; Assessing the extent to which current policies promote sustainability and resilience; Shaping local and regional development programming by operating at the territory scale).

Within **GO2. Supporting the innovation ecosystems associated with smart specializations**, the national smart specialization areas are defined at. They are split in 7 domains and 36 subdomains. Below, the fields and subfields with a direct impact on achieving the targets assumed by LTS are listed:

- 1. Bioeconomy
    - 1.1 Technologies for the blue economy
    - 1.2 Seeds and breeds improvement
    - 1.3 Technologies for organic farming, agroecology and forestry
    - 1.4 Agriculture 4.0
    - 1.5 Safe and sustainable food for a healthy diet
- 2. Digital economy and space technologies
    - 2.1 Microelectronic devices and systems for smart products
    - 2.2 Networks of the future, communications, Internet of Things
- 3. Energy and mobility
    - 3.1 Green mobility
    - 3.2 Modern energy generation technologies with low or zero emissions
    - 3.3 Digitalization in energy
    - 3.4 Energy storage
- 4. Advanced manufacturing
    - 4.1 Manufacturing technologies for the aeronautical industry
    - 4.3 Advanced manufacturing technologies
- 5. Advanced functional materials
    - 5.1 Optoelectronics

    - 5.2 Smart composite materials
    - 5.3 Recyclable materials and technologies for material recycling
    - 5.4 Materials for electronic, electrical, photonic, magnetic and sensing applications
    - 5.5 Biocompatible materials
    - 5.6 Materials for energy
- 6. Environment and eco-technologies
    - 6.1 Technologies for environmental management, monitoring and depollution
    - 6.2 Technologies for circular economy

Based on the national smart specialization areas, the 8 Regional Development Agencies (ADRs) develop the Regional Smart Specialization Strategies (RIS3).

Within the specific objective SO **2.1. Supporting and encouraging the involvement in smart specialization projects and capitalizing on the results** defined under GO2, action A1. supports setting-up partnerships between research organizations and the private environment to support smart specialization through the development of Innovation and Technology Centers, coordinated by leaders with scientific and/or business experience. At the same time, within specific objective **SO 2.2. Support smart specialization at the level of regions** defined under GO2, action A1. Stipulates increasing funding for the fields and niches of smart specialization for the fruition of the economic potential of competitiveness at regional level by capitalizing on the results of scientific research, the smart specialization fields orientation towards business and economic result and their alignment with sustainable development objectives.

General objective **GO 3. Mobilization towards innovation** supports, through all its 3 specific objectives, the collaboration between research organizations and enterprises, the development of technological transfer and the stimulation of innovation: **SO. 3.1. Supporting and encouraging collaboration between research organizations and the private sector for involvement in innovation projects and capitalizing on results**; **S.O 3.2. Development of technological and knowledge transfer at the national level to increase the visibility of the results and impact in the economic environment**; **SO. 3.3. Supporting innovation entrepreneurship**.

Finally, general objective **GO4. Increasing European and international collaboration** supports, by all its 3 specific objectives, the engagement of research organizations and Romanian companies in RDI activities and projects carried out with partners and European funding: **SO. 4.1. Increasing participation in European Union programs in the field of RDI. Synergies with Horizon Europe and other RDI programs coordinated at European and international level**; **SO. 4.2. Development of bilateral/multilateral collaborations for RDI and RIS3**; **SO. 4.3. Support for participation in European and international projects to strengthen the capacity of RDI actors**.

SNCISI 2022-2027 is implemented through the National Research, Development and Innovation Plan 2022-2027 (PNCDI IV). PNCDI IV is approved by GD 1,188/2022 and ensures the transparency and predictability for funding the national RDI system, with the aim of modernizing, consolidating its excellence and increasing its relevance for the economy and society. PNCDI IV is multi-annual plan comprising 10 programs:

- Program 1: Ideas
- Program 2: Human resources
- Program 3: High performance research organizations
- Program 4: Nucleus
- Program 5: Research infrastructures
- Program 6: Challenges
- Program 7: Partnerships for innovation

- Program 8: European and international cooperation
- Program 9: Research in areas of strategic interest
- Program 10: Science and society

The payments related to the commitments assumed during the implementation period of the programs within PNRDI IV can be scheduled until December 31, 2030. The total maximum budget of PNRDI IV is EUR 60 billion RON (approximately EUR 12 billion).

7.1.2.2 Measures for supporting of RDI activities that will contribute to the achievement of the targets in the LTS

Funding RDI activities, both at the level of the research organizations and of the economic agents, is a key element for the success of LTS implementation. An important percentage of the public funding sources available at national level, via the programs listed below in the current sections and via other programs which will be available by 2050, will have to be dedicated to supporting RDI activities in the field of RES technologies, energy storage, green mobility, increasing energy efficiency in buildings, increasing energy efficiency and reducing emissions in industry, waste management and agriculture, carbon capture, use and storage in industrial processes, and in other areas relevant for the successful implementation of the LTS.

Within **Program 1 (Ideas) of PNCDI IV**, it is necessary to create a platform for advanced studies and research focused on the decarbonization process of the national economy. The platform will include nodes of excellence in scientific research distributed at national level. Within the same Program, calls will be organized for exploratory research projects and complex frontier research projects dedicated to areas of smart specialization with direct relevance to the implementation of LTS, listed in Section 7.1.2.1. The objectives of each call will be correlated with the sectoral and national objectives assumed by LTS.

For the development of the human resources necessary for the implementation of the LTS (including the training for the personnel who will be involved in the transition to a decarbonized economy), calls for European Research Council (ERC)-like research projects will be organized within Program 1 (Ideas), as well as, within **Program 2 (Human Resources) from PNCDI IV**, calls for projects providing PhD scholarship for international mobility, for postdoctoral research and research for the stimulation of young independent teams, calls for mobility projects for researchers, for experienced researchers and for young researchers from the diaspora and for intersectoral mobility. The areas of smart specialization targeted by these calls will be bioeconomy, digital economy and space technologies, energy and mobility, advanced functional materials, environment and eco-technologies. Implemented mainly at the level of research organizations, the calls organized under Programs 1 and 2 will also have an impact for the private sector, that will benefit from the the ideas and human resources developed within these calls.

Within **Program 5 (Research infrastructures) of PNCDI IV**, projects for the accreditation / certification of testing and certifying laboratories for critical areas of the economy and society, such as those involved in the decarbonization process to be implemented via the LTS, will need to be carried out. Such laboratories may target the testing and validation of biofuels and technologies for electric and plug-in hybrid cars, of solutions for the production, storage, transport, distribution and use in industry and domestic use of renewable gases (including green hydrogen), of innovative materials, devices and systems employed for reducing emissions and increasing energy efficiency in multiple economic fields, etc.

Within the framework of **Program 6 (Challenges) of PNCDI IV**, calls for projects will be launched targeting challenges-agile, challenges-change projects and centers of excellence targeting Strategic Research Agenda priorities such as clean industry, circular economy and the security of supply of raw materials, the transition of the energy sector towards neutrality and climate resilience, climate neutral and environmentally friendly mobility, smart mobility systems, contribution of agriculture to climate neutrality and resilience, increasing the relevance of forests in reducing pollution, circular bioeconomy, etc.

Program 7 (Partnerships for innovation) of PNCDI IV will include, for the areas of smart specialization listed in Section 7.1.2.1, calls for demonstrative experimental projects, transfer to the economic operator projects, transfer of knowledge and expertise from universities to the business environment, innovation vouchers, grants for idea to market. These types of projects will develop cooperation between research organizations and the private sector and will perform technological and knowledge transfer. In parallel, innovative start-ups in the fields relevant for LTS implementation will benefit from project calls such as the Innovative Business Matching Fund and the Seed Capital Matching Fund, Grant Incubator and Grant Accelerator.

To increase the competitiveness of the national RDI system, **Program 8 (European and international cooperation) of PNCDI IV** includes elements supporting the participation of Romanian legal entities in European calls for RDI projects, such as Horizon Europe or Eureka.

Research organizations and companies in fields relevant to the implementation of LTS are also encouraged to directly submit project proposals in Horizon Europe calls. Of particular importance will be the participation of Romanian legal entities in European projects of the IPCEI type (Important Project of Common European Interest), participation supported, at the administrative and co-financing level, by the Romanian state authorities. In order to perform the decarbonization process, legal entities in Romania, especially companies interested in the implementation of innovative technologies for reducing emissions and increasing energy efficiency, are encouraged to participate in the annual calls organized by the Innovation Fund. In order to facilitate access to European funding sources for RDI activities such as Horizon Europe, Innovation Fund or IPCEI, responsible national institutions, such as the Ministry of Research, Innovation and Digitalization, the Ministry of Energy, the Ministry of the Economy, will publish announcements and organize meetings, dedicated to research organizations and companies.

Public funds to support RDI activities are also available within the 8 Regional Programs (PR) implemented by ADRs. Regarding RDI activities, the Regional Programs implement the Regional Smart Specialization Strategies (RIS3), within which lists of regional smart specialization areas, derived from the list of national smart specialization areas, are defined.

At the same time, the Smart Growth, Digitalization and Financial Instruments Program (PCIDIF) supports carrying out RDI activities from the level of concept (technological maturity level TRL 2) to the level of market introduction (TRL 9) by funding calls for complex projects, implemented in partnership by public and private partners, between research organizations and companies. Setting-up innovation hubs in areas of strategic interest and projects aimed at synergies with the actions of Horizon Europe actions and other European programs will also be funded. As in the case of PNCDI IV, for PCIDIF too it is necessary to focus some of these calls of projects on areas of smart specialization relevant to the implementation of LTS, such as the ones listed in Section 7.1.2.1.

For each call for projects launched within PNCDI IV, PR, PCIDIF or any other public funding programs and focused on the fields relevant for performing the national decarbonization process, it is highly relevant to coordinate the objectives of the call with the sectoral and national objectives of the LTS. Setting measurable and realistic targets for the calls of the RDI projects will drive the achievement of RDI results relevant for achieving the LTS targets.

The public financing of the RDI activities will be complemented by co-financing provided by the companies from the private sector. The co-funding will be performed in accordance with the state-aid rules. Public funding will be implemented both as grants and other financial instruments (guarantees, loans, etc.).

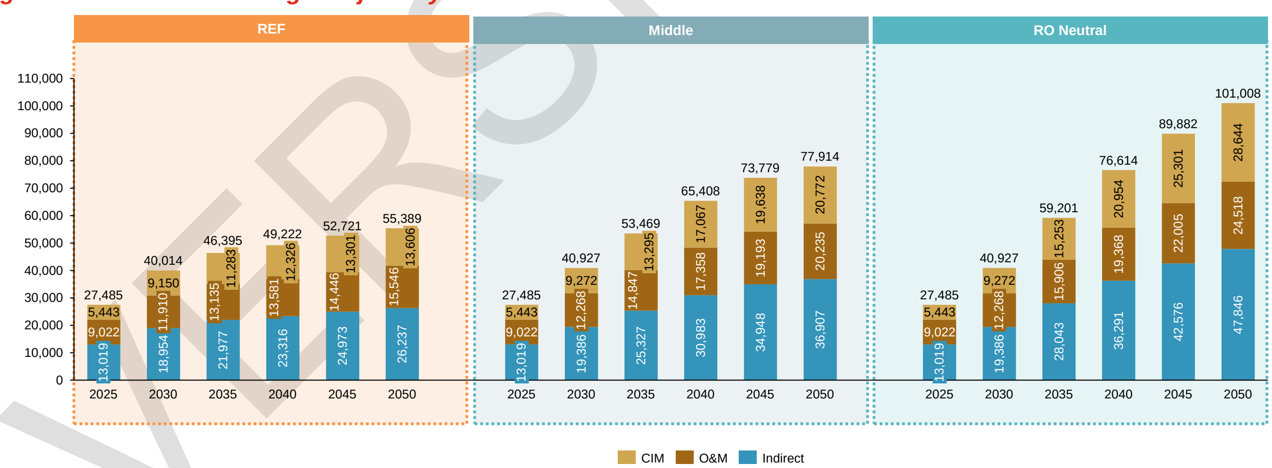
In parallel with the measures regarding the financing of RDI activities from public sources, it is necessary to popularize and widely apply the measures regarding the fiscal facilities granted by Romanian authorities for deploying RDI activities:

- According to article 20 of Law 227/2015 (Tax Code), with subsequent amendments, for the research and development activities (applied research and/or technological development) in each ongoing project, an additional deduction is granted when calculating the fiscal result, up to 50% of the eligible expenses for these activities. At the same time, the accelerated depreciation method can be applied the apparatus and equipment dedicated to research and development activities.
- According to article 60 of Law 227/2015 (Fiscal Code), with subsequent amendments, employees performing RDI activities, as part of an RDI project, are exempted from paying income tax.
- According to article 221 of Law 227/2015 (Fiscal Code), with subsequent amendments, companies carrying out only RDI activities, as well as related activities, are exempted from paying profit tax in the first 10 years of their activity

7.2 Green jobs and other benefits

One of the social benefits of the decarbonization process of the society is the creation of green jobs. In this Strategy, calculations on the number of green jobs which will be created as a result of its implementation are made according to the methodology presented in the paper "Jobs Impact of Green Energy", published by Jaden Kim and Adil Mohommad in May 2022 as International Monetary Fund working paper[16], which is based on scientific research from a number of authors. By applying the cited methodology in the currently developed LTS, more than 100,000 new green employment will be created by the year 2050 in the RO Neutral scenario (Figure 54). Most newly generated green jobs will be direct jobs and will be due to the manufacturing, construction, installation, operation and maintenance of the green technologies required for the deployment of the LTS. The greening of the economy will also be facilitated through indirect jobs that do not require specialized green knowledge or duties. For instance, new jobs will be created when materials employed for green technologies manufacturing are produced, when these products are handled, and when they are sold.

Figure 54. Total number of green jobs by scenario



The majority of direct jobs (about 35,000 by 2050, in RO Neutral) will be generated in the field of new PV and PV on rooftop & auto capacities, particularly for building and installing them (Figure 55). Additionally, green jobs will be created for operation and maintenance of solar, wind, hydro and nuclear capacities (Figure 56).

[16] https://www.imf.org/en/Publications/WP/Issues/2022/05/27/Jobs-Impact-of-Green-Energy-518411

Figure 55. Number of green jobs in CIM (Construction, Installation and Manufacturing) per scenario

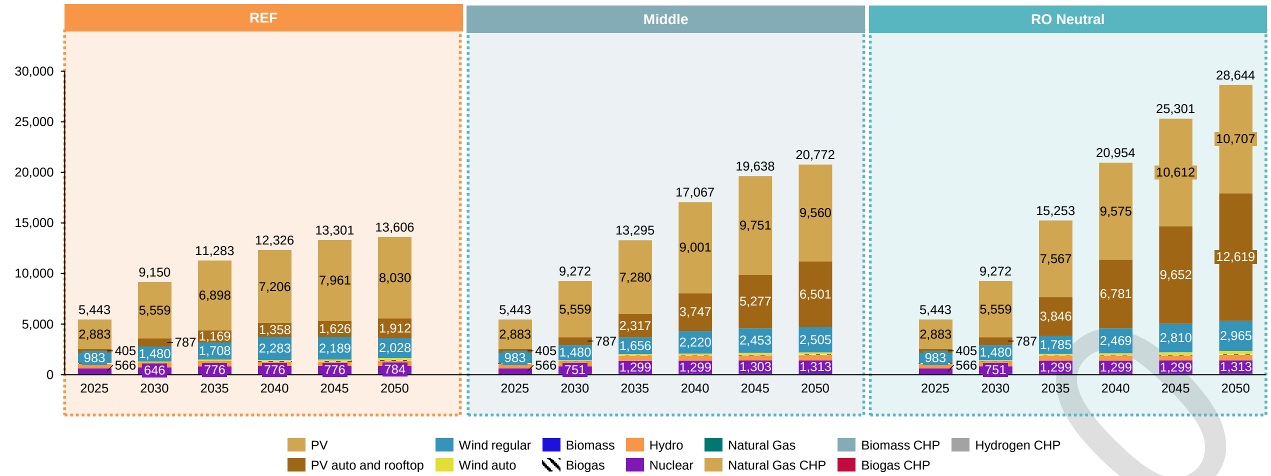
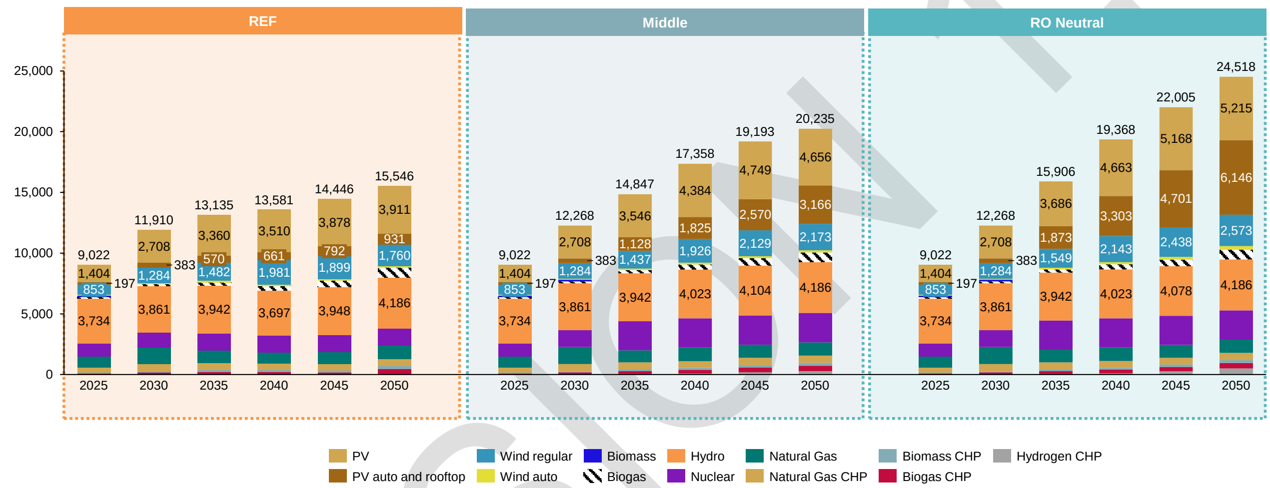
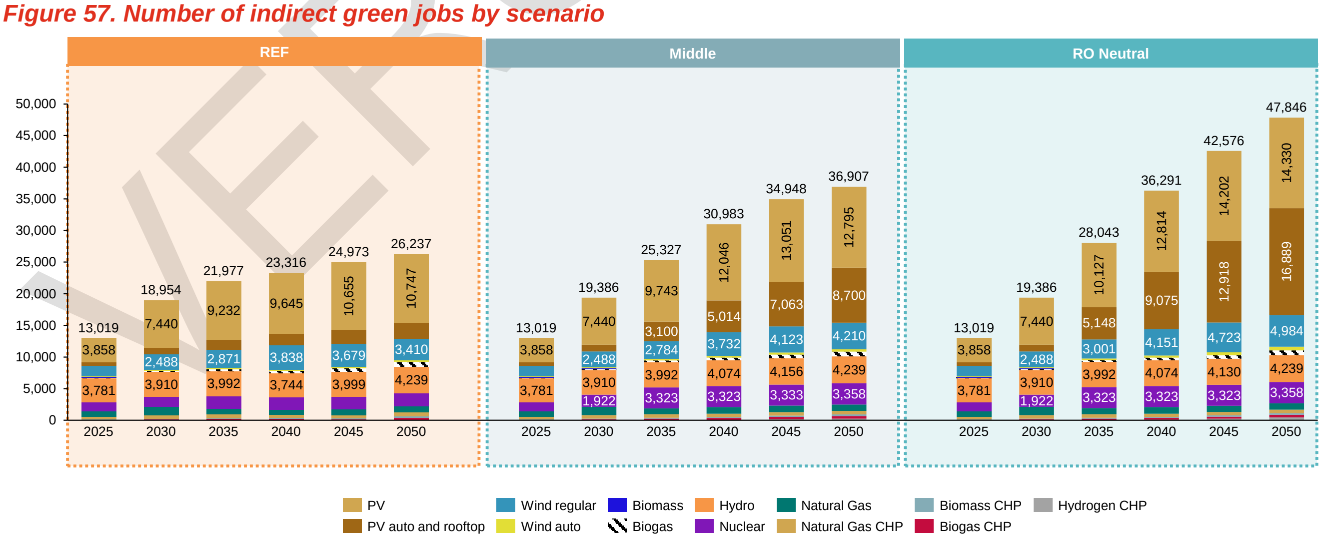


Figure 56. Number of green jobs in O&M (Operation and maintenance) per scenario



About 48,000 indirect green jobs will occur by 2050 in the RO Neutral scenario (Figure 57), the majority of them (approx. 65%) due to the new PV power plants which will be installed.

Figure 57. Number of indirect green jobs by scenario



8. INDICATORS FOR MONITORING LTS IMPLEMENTATION AND COORDINATION WITH SDG INDICATORS

A set of LTS indicators was created to monitor the progress of the target's accomplishment in each of the analysed scenarios and to perform comparison with other EU countries. When creating the LTS indicators, it was taken into account the list of national sustainable development indicators drafted within the project "Sustainable Romania" - Development of the strategic and institutional framework for the implementation of the national strategy for the sustainable development of Romania 2030 - (SIPOCA 613), published on the website of the Department for Sustainable Development (DDD)[17].

The first two LTS indicators are related to the energy intensity, i.e. primary and final energy consumption per GDP (Figure 58 and Figure 59). In 2050, the primary energy intensity will be in the range of 0.69 up to 0.71 kWh/EUR in RO Neutral, Middle and REF scenario. At the same time, the final energy intensity will be in the range 0.52 up to 0.61 kWh/GDP, again with the lowest value in the RO Neutral scenario. Both indicators show that the effect of the implementation of energy efficiency measures will be the generation of value added in the GDP with lower energy consumption. The value of these indicators will be nearly twice lower in 2050, compared to the 2019 level.

Figure 58. Primary energy intensity - Primary energy consumption per GDP

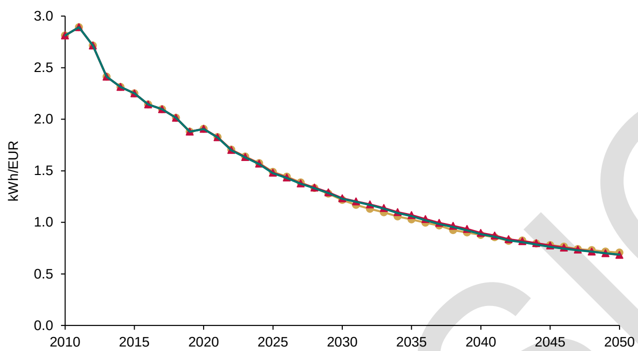
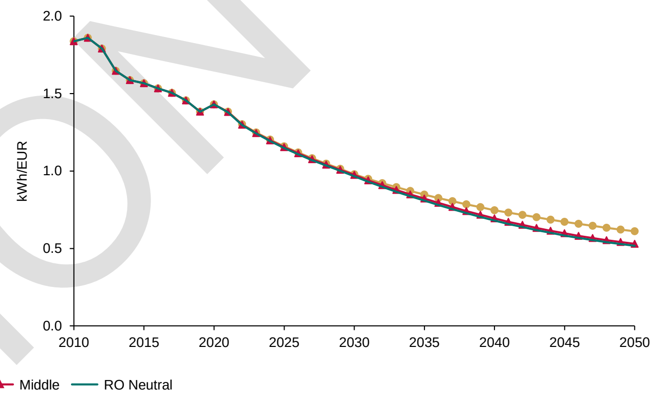


Figure 59. Final energy intensity - Final energy consumption per GDP



Two other indicators of the Romania LTS refer to the final energy consumption per capita and per dwelling. In 2019, Romania consumed 55% less final energy per capita, compared to the average of the EU countries. The currently increasing trend of these parameters is expected to continue. However, following the deployment of the Building renovation strategy, after 2030, these indicators will start to decrease (Figure 60).

In the residential sector, final energy consumption per dwelling indicator is considered. Since heating has the highest share in the final energy consumption in the residential sector, the implementation of the Building renovation strategy, as well as the large scale introduction of heat pump and other efficient technologies, will lead to decreasing the energy consumption per dwelling. In 2050, in the RO Neutral scenario, one dwelling will consume around 5,100 kWh (0.44 toe) annually (Figure 61).

[17] http://agregator.romania-durabila.gov.ro/indicatori.html

Figure 60. Energy intensity per capita - Final energy consumption per capita

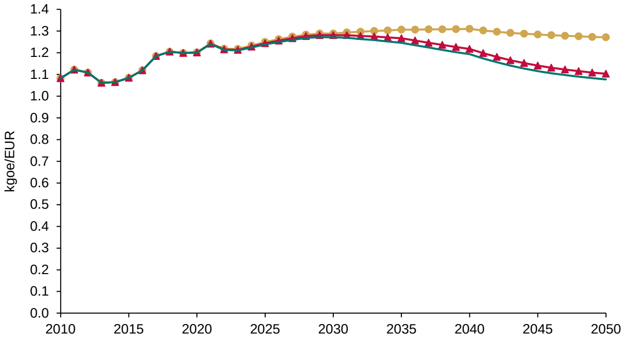
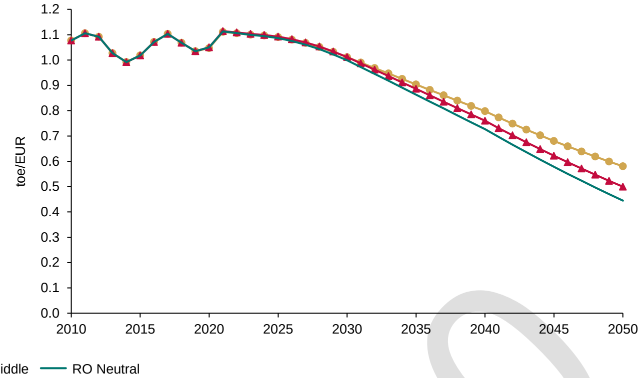
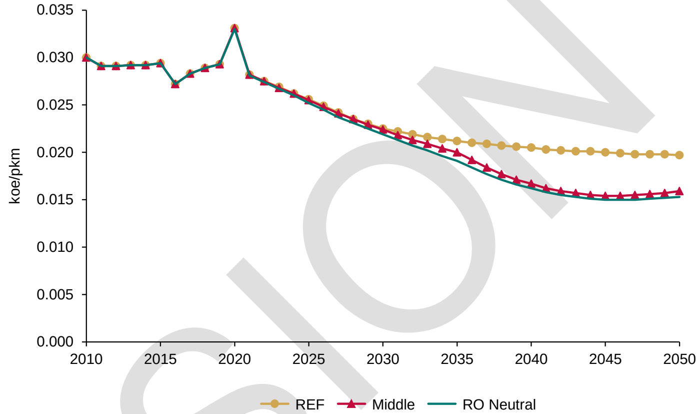


Figure 61. Final energy consumption per dwelling



For the transport sector, the indicator for specific consumption of passenger cars per passenger km (pkm) is analysed (Figure 62). The introduction of more efficient passenger cars, especially plug-in hybrid, electric and hydrogen cars, and the replacement of the diesel and gasoline cars will lower this indicator to 0.015 koe/pkm in 2050 in RO Neutral scenario. In 2019, the EU average value of this indicator was 0.03 koe/pkm.

Figure 62. Specific consumption of passenger cars per pkm



In addition to the above listed indicators, the LTS also considers a number of other national SDG indicators. Their predicted values by 2050, in the RO Neutral scenario, are presented in Table 7. Thus, the LTS approach allows a coordinated monitoring of the implementation progress of both the LTS and the SNDDR 2030.

Table 7. Values for some of the indicators defined in the SNDDR 2030, according to the LTS RO Neutral scenario

SDG	Indicator	Unit/year	History			Projected					
			2019	2020	2021	2025	2030	2035	2040	2045	2050
SDG 6	TGM0632 - Target 3 - Social - Population connected to sewerage systems and wastewater treatment plants on residential environments	Million inhabitants			11.01	11.1	11.15	11.42	11.91	12.63	13.52
	THC0662 - Target 6 - Social - Percentage of population connected to sewage system in total population	%			57.6%	68.9%	74.3%	79.9%	85.1%	90.5%	95.9%
SDG 7	THV0741 - Target 4 - Environment - Number of registered electric and hybrid vehicles	number			97,081	2,404,027	4,889,767	6,483,284	7,538,522	8,130,944	8,526,093
	THW0742 - Target 4 - Environment - Share of renewable energy in total energy consumption in transport	%			7.67%	24.6%	35.1%	79.2%	138.7%	195.5%	243.4%
	THX0743 - Target 4 - Environment - Biofuel consumption as a percentage of total fuel consumption used in transport	%			7.47%	7%	6.6%	5.40%	3.80%	2.10%	0.80%
	THZ0745 - Target 4 - Environment - Final energy consumption by type of energy carriers	ktoe		23,474	25,280	23,545	24,157	23,801	22,888	21,617	20,949
	TIB0751 - Target 5 - Environment - Number of residential buildings thermally rehabilitated	number		74.0	29.0	142.2	207.4	191.9	158.2	145.7	116.8
	TIH0762 - Target 6 - Environment - Share of total final energy consumption from renewable energy sources	%		24.61		32.4%	36.3%	40.9%	66.6%	78.4%	89.9%
SDG 8	TIL0811 - Target 1 - Economic - Gross national income per capita	EUR / capita			12,292	12,536.9	15,295.3	17,910.8	20,392.6	22,208.4	24,213.5
	TIN0813 - Target 1 - Economic - Annual growth rate of real GDP per capita	%			6.6%	5.1%	3.5%	2.9%	2.6%	1.8%	1.7%
SDG 9	TKB0932 - Target 3 - Environment - GHG intensity in industry	Kg CO2-eq / RON	0.03	0.04		0.02	0.01	0.01	0.01	0.01	0.01
	TKE0935 - Target 3 - Environment - Greenhouse gas emissions, by economic activities	ktCO2-eq				59781.1	49417.1	39642.1	20724.6	10695.4	2608.5
SDG 11	TLY1131 - Target 3 - Environment - Percentage of bus and train transport in total passenger transport	%		18.10%		25.0%	24.2%	23.7%	24.3%	25.2%	26.1%
SDG 12	TNO1211 - Target 1 - Environment - Energy productivity	EUR/kgoe		5.4		7.7	9.2	10.6	12.1	13.2	14.2
	TNX1252 - Target 5 - Environment - Quantity of household waste collected, by category	t		4,632,802		4,590,850	3,712,800	3,590,400	3,468,000	3,357,840	3,249,720

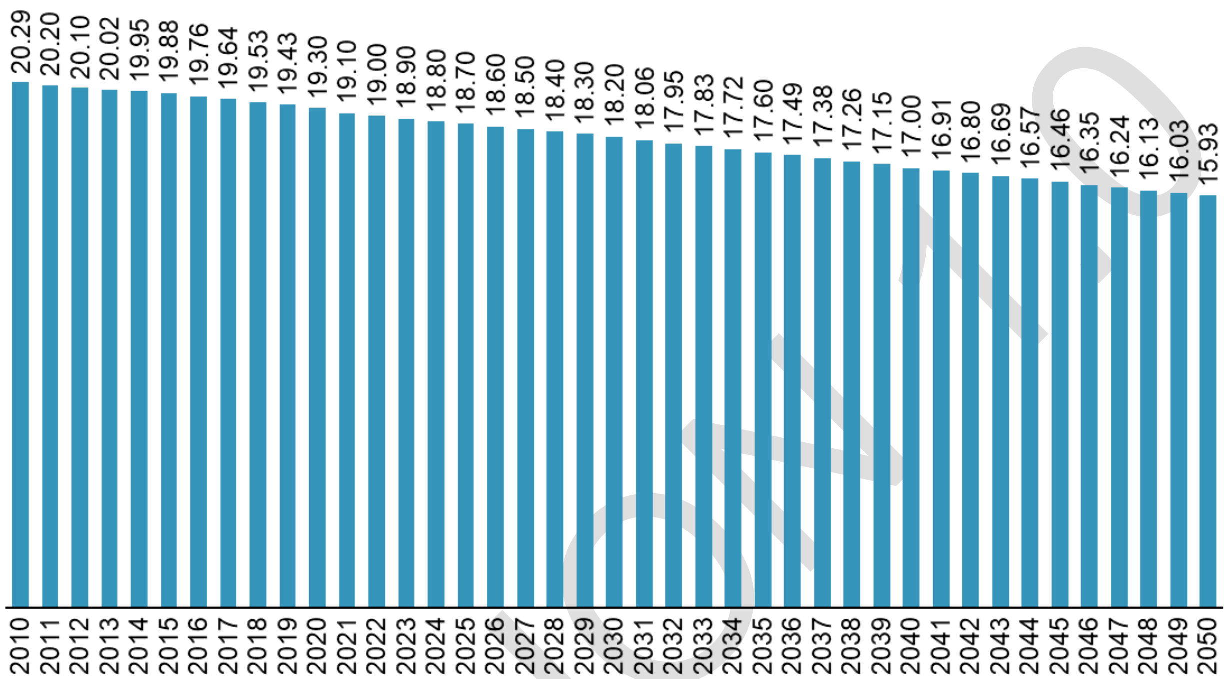
SDG 13	TPB1341 - Target 4 - Environment - Forest surface, of which forested annually	ha		6,449,417		Same as 2020					
	TPC1342 - Target 4 - Environment - CO_2 emission intensity	Kg CO_2-eq / RON	0.08			0.052	0.036	0.025	0.012	0.006	0.001
SDG 15	TQO1531 - Target 3 - Environment - Forest area as a percentage of the total area of the country	%		27.05%		Same as 2020					

9. ANNEXES

9.1 Macroeconomic assumption

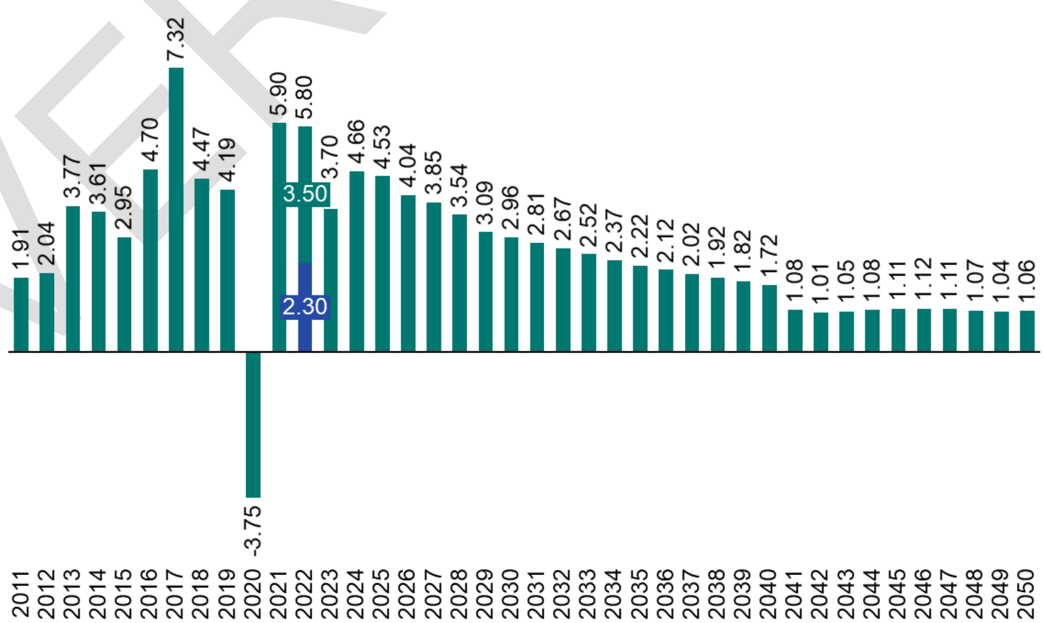
The population is one of the key assumptions when projecting the energy demand, and therefore the GHG emissions. Figure 63 shows the population evolution which was employed in all 3 scenarios, based on the data provided by the CNSP.

Figure 63. Population considered in all analysed scenarios



Another main assumption used in all scenarios is the GDP growth. For the projections of the GDP, the same information source (CNSP) was used. The average GDP growth in the period 2022-2050 is assumed to be 2.3%, with the dynamic presented in Figure 64.

Figure 64. Annual GDP growth considered in all analysed scenarios (%)



9.2 LEAP_RO calibration by means of 2010-2019 historical statistical data

As presented in the Executive Summary, the process of elaborating the national and sectoral targets of the LTS was based on the energy and climate model LEAP_RO, which takes into account the contributions of all economic fields with impact in the field of energy and climate change, developed specifically for the drafting the LTS. LEAP_RO was developed starting from historical statistical data for the period 2010-2019, taking 2010 as the base year and 2010-2019 as reference period. Following a complex calibration and optimization process and building upon statistical results reported for 2010, the LEAP_RO model predicted, with a maximum relative error of 3%, statistical data recorded for the period 2011-2019. The calibration and optimization process of the model and the comparison between the model predictions and statistical data from 2011-2019 are presented in the Chapters 9.2.1 – 9.2.6.

9.2.1 Energy system (Electricity and heat production)

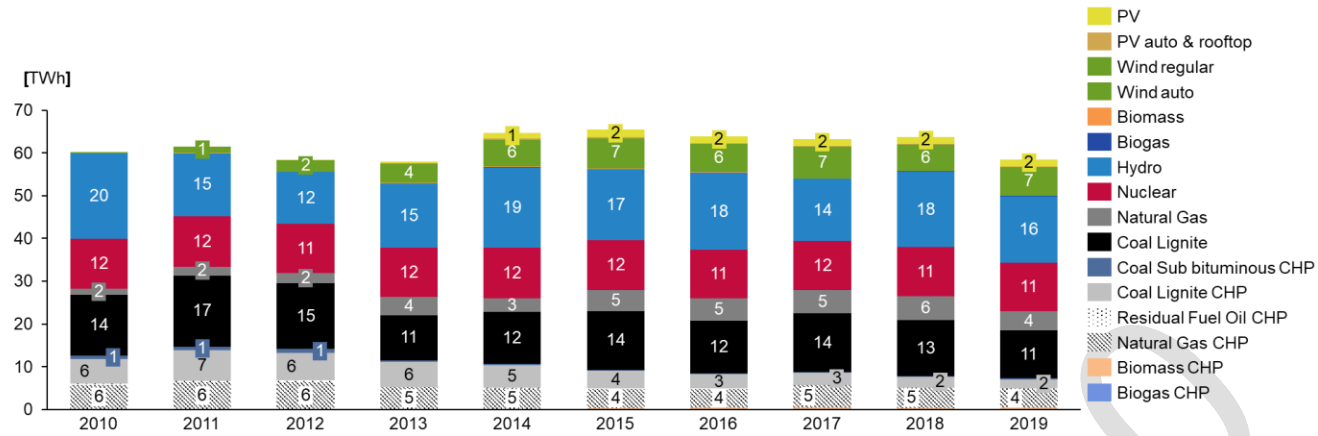
In the energy supply sector, the data for the electricity generation plays a central role in determining the system's ability to satisfy the demand and its security and stability in the process. In the development of the Romania's energy system model, the EUROSTAT/TEMPO energy balances were used and the relevant data was extracted and organized per type of power, thermal and CHIP plant and per fuel type. The resulting dataset is exhibited in Table 8. The period of time for which historical data was obtained and used to model the past in the LEAP_RO model was for 2010 – 2019. Figure 65 presents the total electricity generation from power plants and CHPs in 2010-2019, while Figure 72 depicts the production of electricity only from CHPs in the same period.

Data in Table 8 and Figure 65 show that, starting from 2013, the electricity generation due to RES - wind and solar – had a constant increase. The production from hydro power plants (PP) and nuclear PPs was relatively constant during the 2010-2019, whereas the coal fired power plants showed a decrease of their annual electricity production.

Table 8 - Electricity generation by power plants and CHP (2010 - 2019) in [TWh]

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Power plants	PV	-	-	0.002	0.305	1.243	1.735	1.626	1.676	1.644	1.614
	PV auto & rooftop	-	-	0.006	0.115	0.373	0.247	0.194	0.179	0.127	0.164
	Wind regular	0.3	1.363	2.46	4.28	5.843	6.696	6.292	7.114	6.092	6.516
	Wind auto	0.006	0.025	0.18	0.24	0.358	0.367	0.298	0.292	0.23	0.257
	Biomass	0.048	0.085	0.053	0.075	0.237	0.107	0.077	0.064	0.021	0.048
	Biogas	-	-	-	0.026	0.022	0.029	0.036	0.038	0.04	0.024
	Hydro	19.883	14.728	12.066	14.956	18.805	16.632	18.028	14.494	17.664	15.581
	Nuclear	11.623	11.747	11.466	11.618	11.676	11.64	11.286	11.509	11.377	11.28
	Natural Gas	1.57	2.069	2.415	4.178	3.327	4.9	5.286	5.323	5.719	4.487
	Coal Lignite	14.145	16.668	15.429	10.606	12.057	13.728	12.31	13.741	12.962	11.172
	Total from PP	47.576	46.684	44.077	46.399	53.94	56.081	55.433	54.432	55.877	51.142
CHP	Coal Sub bituminous	1.305	1.726	2.158	1.151	0.912	0.554	0.524	0.518	0.64	0.664
	Coal Lignite	12.197	13.187	12.326	12.714	11.487	10.659	8.309	6.981	5.92	4.723
	Residual Fuel Oil	1.424	1.078	0.801	0.216	0.164	0.253	0.349	0.107	0.19	0.056
	Natural Gas	18.827	20.287	17.511	15.594	14.672	14.455	15.291	15.617	14.063	13.07
	Biomass	0.116	0.15	0.316	0.313	0.613	0.759	0.877	0.941	0.839	0.899
	Biogas	0.002	0.023	0.047	0.064	0.073	0.075	0.071	0.068	0.052	0.05
	Total from CHP	33.872	36.45	33.16	30.052	27.923	26.755	25.422	24.231	21.704	19.461
Total electricity		81.448	83.134	77.237	76.451	81.863	82.836	80.855	78.663	77.581	70.603

Figure 65. Evolution of the electricity production of power plants and CHP during 2010 - 2019 (TWh)



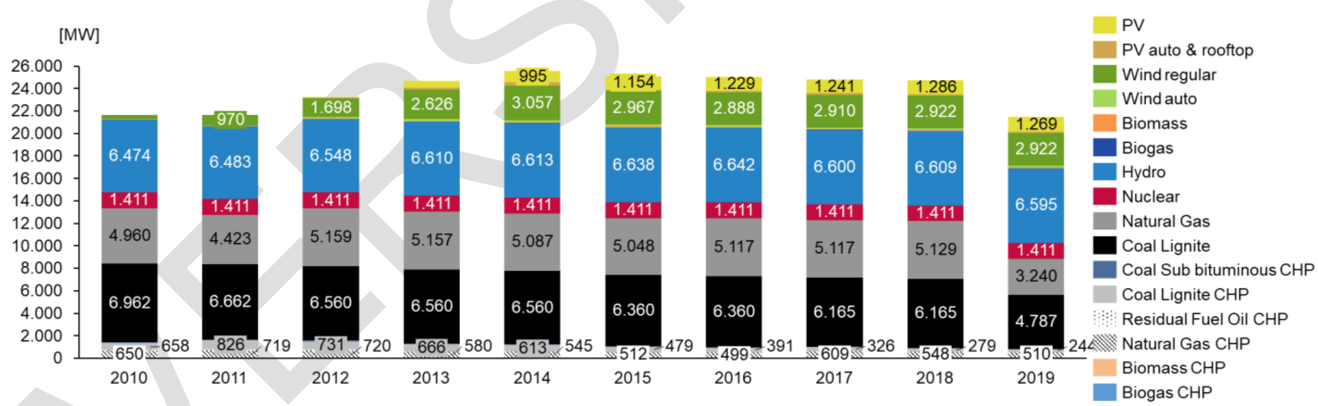
Source: LEAP_RO model, TEMPO/EUROSTAT energy balance

Another very important input into the energy model is the installed capacity of the power plants (Figure 66). The data from TEMPO, as well as the more detailed data from the yearly reports of the Romanian Energy Regulatory Authority (ANRE), were used. This data also confirms that the installed capacity of the RES power plants increased, while the installed capacity of the coal power plants decreased in the analysed period. Due to the price of the CO_2 certifications, to environmental permits, as well as to pollution standards, there was a dramatic decrease of the installed capacity of coal fired power plants, especially in the period after 2019.

Table 9 presents a list of coal power plants in 2019 (also used in the Romanian NECP). It can be noticed that around 3 GW of installed capacity have been decommissioned in the period 2019 – 2022.

Additionally, an analysis of the daily generation in 2021 for each of these power plants was made, according to the ENTSO-E database. Based on that, the availability of each capacity was calculated. For example, Figure 67 shows the profile of the daily electricity generation from the Rovinari power plant (which had the highest availability factor in 2021) and Figure 68 shows the pattern of electricity generation by the Paroseni power plant (which had one of the lowest availability factors in 2021).

Figure 66. Installed capacity by power plants (2010-2019)



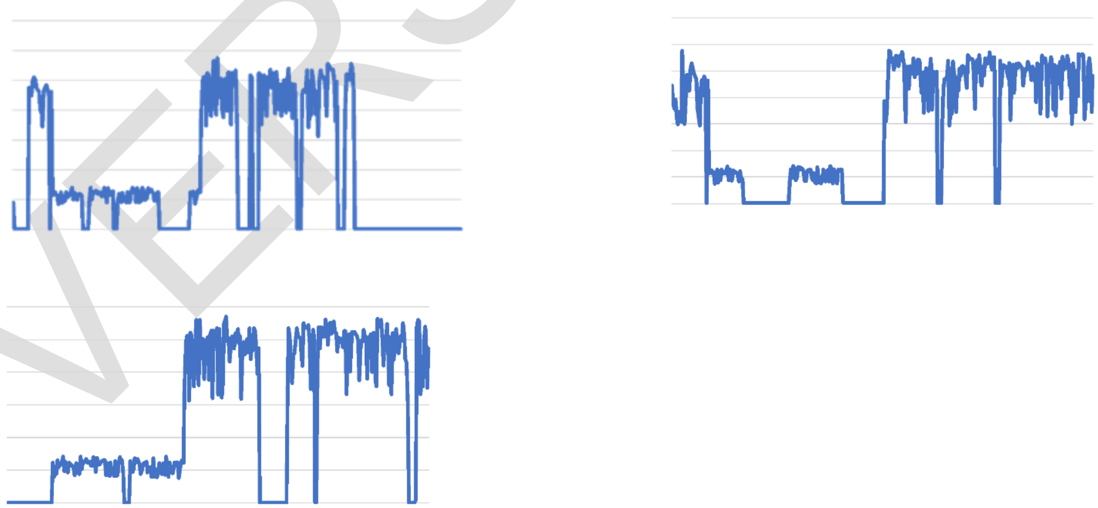
Source: LEAP model, ANRE, TEMPO

Table 9. Coal power plants and CHP data

Power plant	Block	Installed capacity	Electricity production in 2021 - ENTSO-E	Availability in 2021- ENTSO-E
		[MW]	[GWh]	[%]
Bacau		60	0	0
Rovinari	3	330	786	30
	4	330	1175	46
	6	330	1263	50

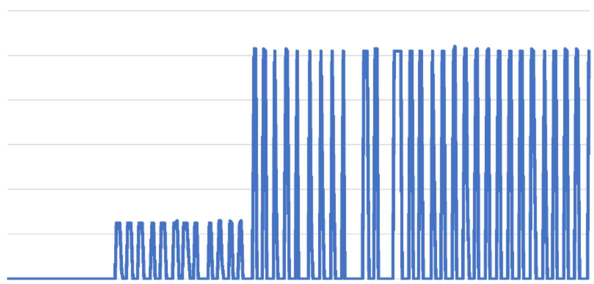
	5	330	0	0
Turceni	3	330	1	0
	4	330	946	37
	5	330	507	20
	7	330	536	21
	1	330	0	0
	6	330	0	0
Isalnita	7	315	763	30
	8	315	138	5
Mintia	2	210	2	0
	3	235	6	0
	4	210	0	0
	5	210	45	2
	6	210	0	0
Paroseni		150	155	12
Govora	3	50	NA	NA
	4	50	NA	NA
Iasi		60	NA	NA
Craiova	1	150	173	13
	2	150	260	20
Drobeta	1	60	NA	NA
	4	60	NA	NA
	5	60	NA	NA
	6	60	NA	NA

Figure 67. Daily generation from the block 3,4 and 6 of the Rovinari power plant in 2021



Source: ENTSO – E, team analysis

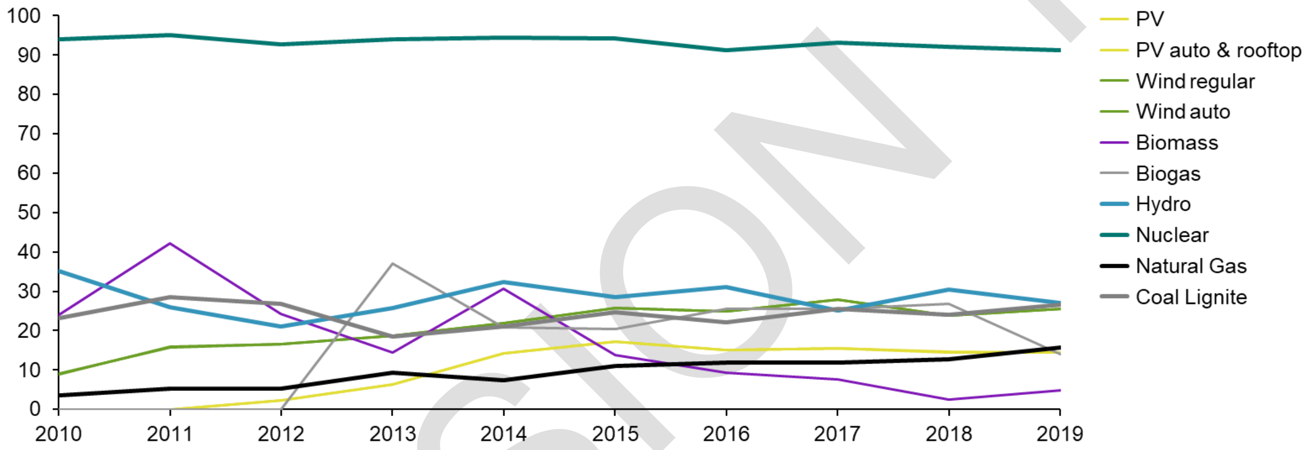
Figure 68. Daily generation from the Paroseni power plant in 2021



Source: ENTSO – E, team analysis

Based on the data for the annual electricity generation and the installed capacity, the model computed the availability of each type of power plant in the period 2010-2019 (Figure 69). The nuclear power plants had the highest availability rating.

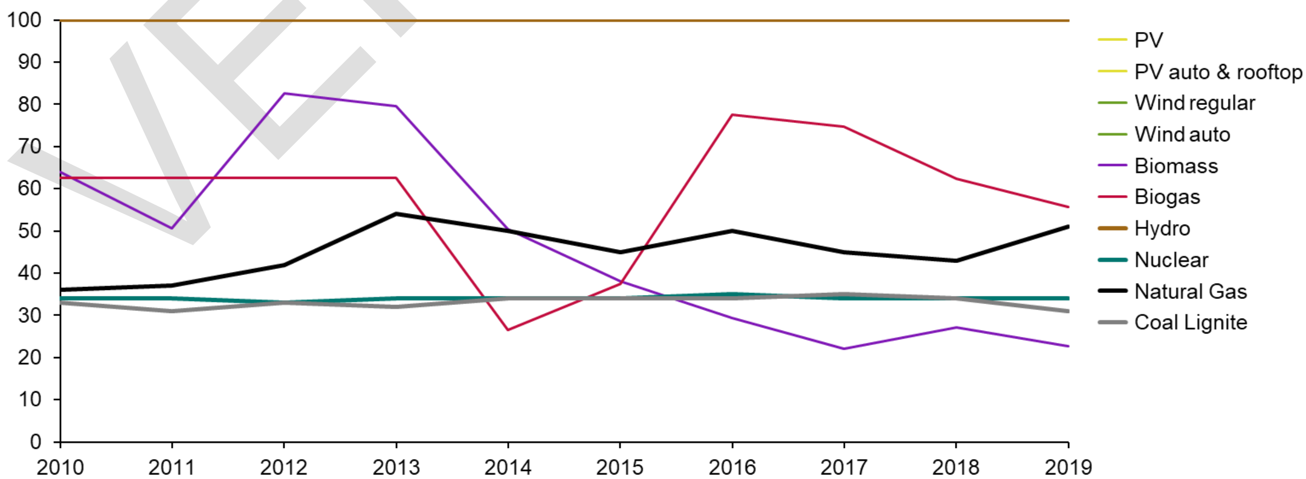
Figure 69. Availability of the power plants (2010-2019)



Source: Model LEAP_RO

Based on the TEMPO/EUROSTAT energy balances, the efficiency of each type of power plant was also calculated, as a ratio between the electricity generated and the quantity of fuel used (Figure 70). The most efficient technologies were the renewable once, i.e., solar, wind and hydro power plants.

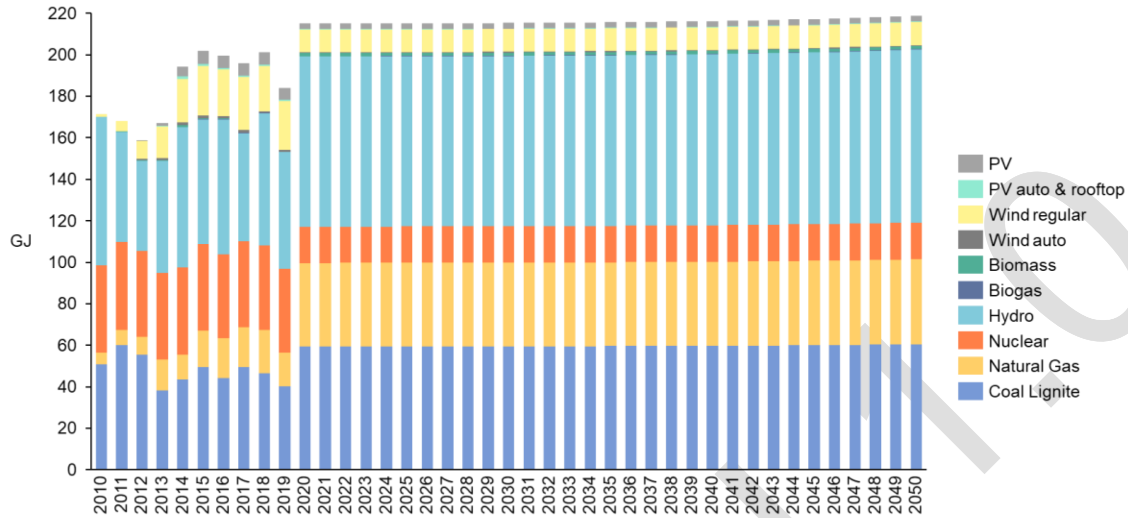
Figure 70. Efficiency of the power plants (2010-2019)



Source: Model LEAP_RO, TEMPO/EUROSTAT energy balance, team analysis

In order to test the capabilities of the model, a simulation of the electricity generation was made for the period 2019 - 2050 (Figure 71), where it can be noticed that the level of electricity generation is quasi-constant. On the other hand, by employing its optimization features, the LEAP_RO can generate distinct electricity production solutions for each year during 2019-2050 (Figure 71).

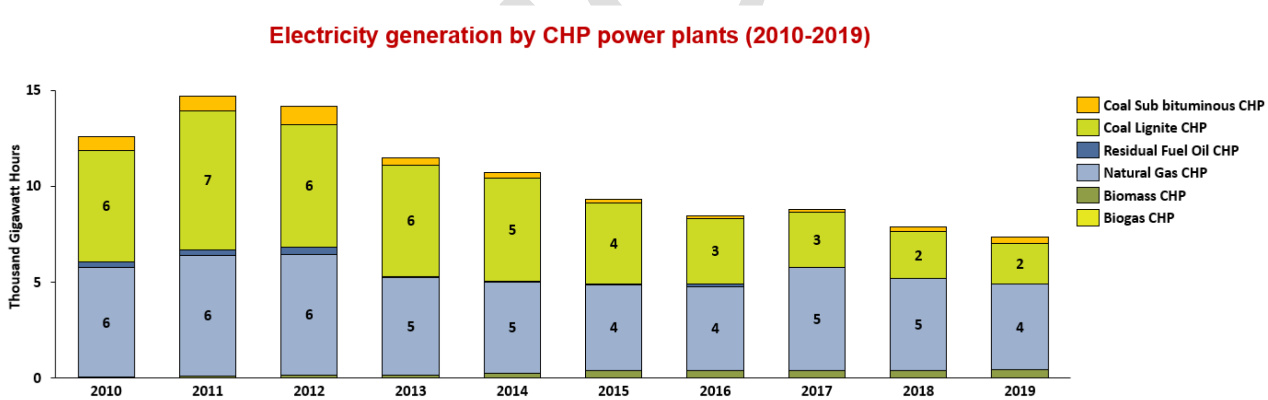
Figure 71. Simulation example of the electricity generation in the period after 2019



Source: Model LEAP_RO

The decrease of the electricity production from coal-based capacities is also noticeable in Figure 72, where the electricity generated by CHP capacity is shown. The main fuel used by these capacities was, in the analysed period, natural gas.

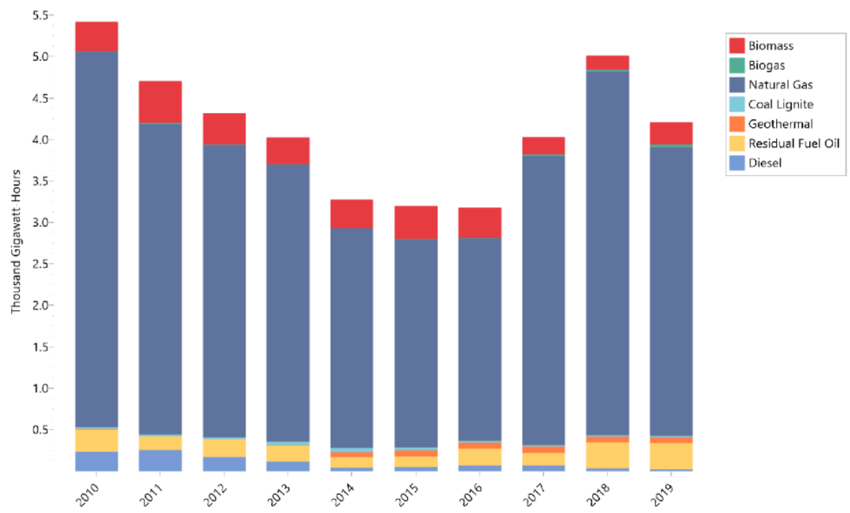
Figure 72. Electricity generation by CHP (2010-2019)



Source: Model LEAP_RO, TEMPO/EUROSTAT energy balance

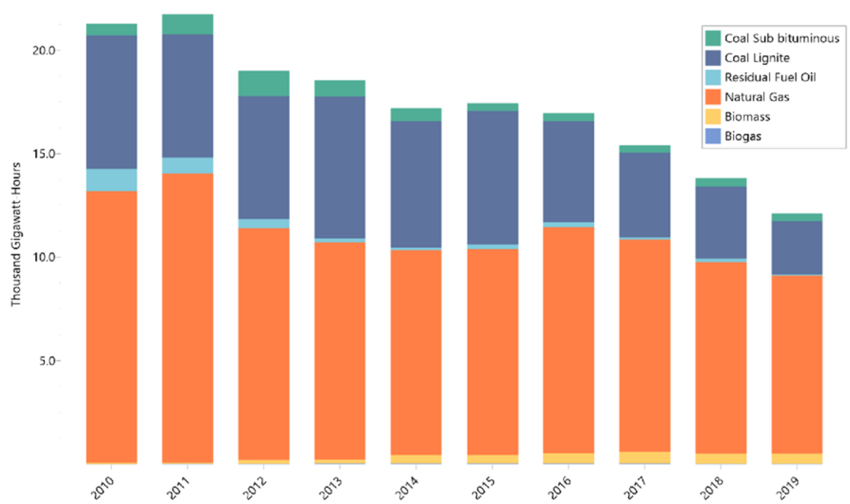
Using the data from the TEMPO/EUROSTAT energy balances, the heat production from the heat plants was used as an input into the LEAP_RO model (Figure 73), as well as the heat production from the CHPs (Figure 74). In the analysed period, natural gas was the main fuel for heat production.

Figure 73. Heat production by heat plants



Source: Model LEAP_RO, TEMPO/EUROSTAT energy balance

Figure 74. Heat production by CHP



Source: Model LEAP_RO, TEMPO/EUROSTAT energy balance

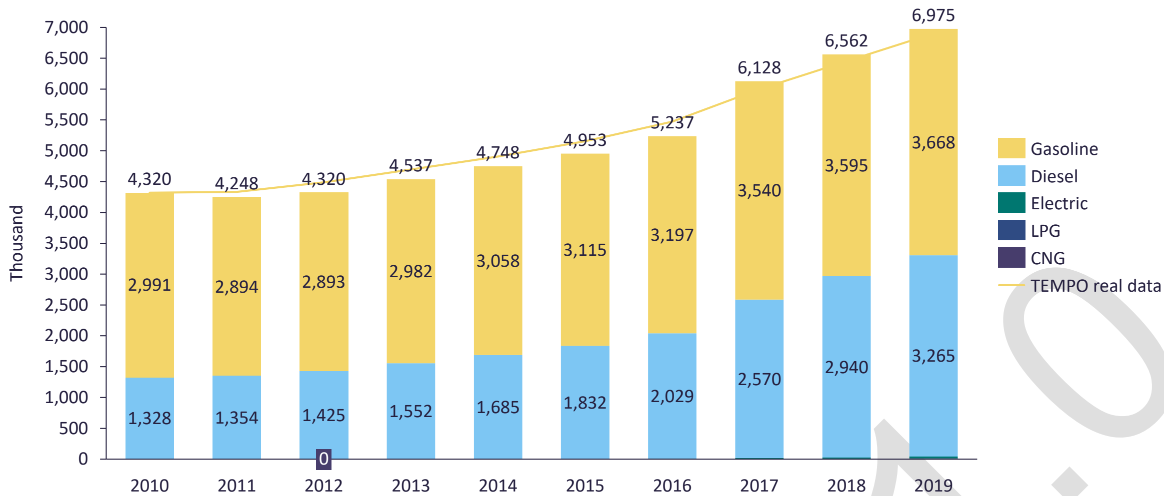
9.2.2 Transport sector

For the road transport sector, the main parameters through which the energy demand can be determined are the passenger per km and the tonnes of freight per km. These parameters were calculated based on the number of vehicles, number of kilometres per vehicle [km per vehicle] and number of passengers or goods per vehicle. The fuel economy of the vehicles taken into consideration was also factored when determining the energy demand for road transport sector.

The evolution of the number of registered cars during 2010-2019 is presented in Figure 75. In Figure 76, the INS data on annual registrations of new cars in the analysed period and the estimation of the same data made by the LEAP_RO model following the calibration based on macroeconomic data, historical data on road transport and the average duration of use of passenger cars in Romania are presented.

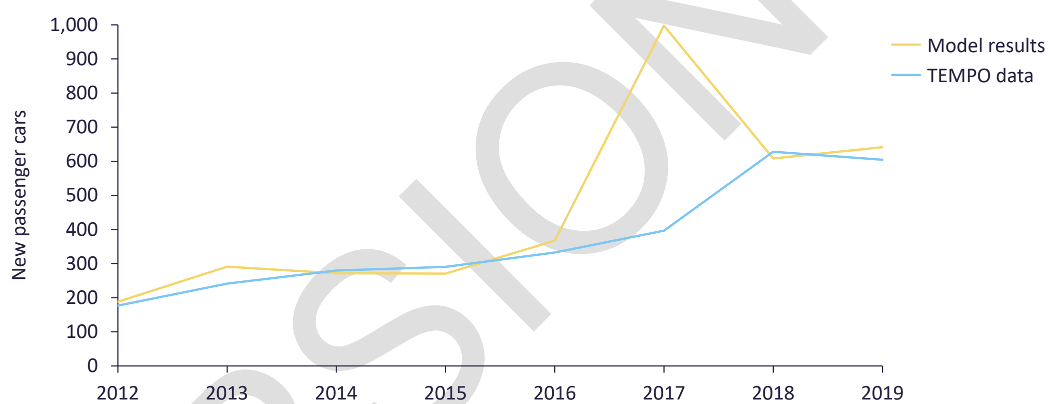
An increasing trend of the number of passenger cars can be observed. In 2019, there were 60% more cars accounted for, compared to 2010. Regarding the number of cars per capita, when compared to the other EU countries, Romania has the lowest value, but also one of the highest increases throughout the period 2005-2018 (Figure 77).

Figure 75. Number of passenger cars projected from the model and real data from TEMPO



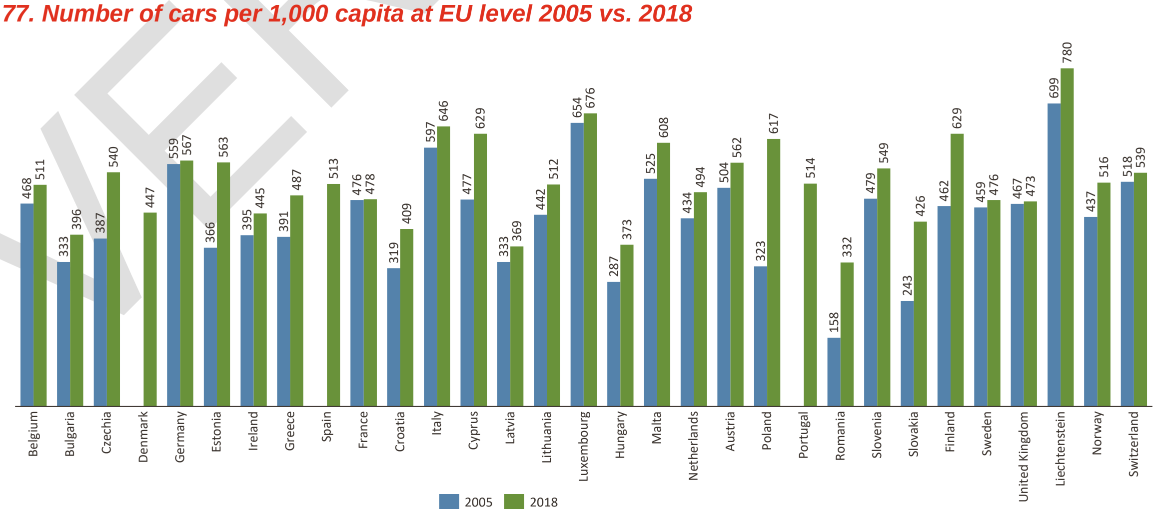
Source: LEAP model, National Institute of Statistics, team analysis

Figure 76. New passenger cars registered projected from the model and real data from TEMPO



Source: LEAP model, National Institute of Statistics, team analysis

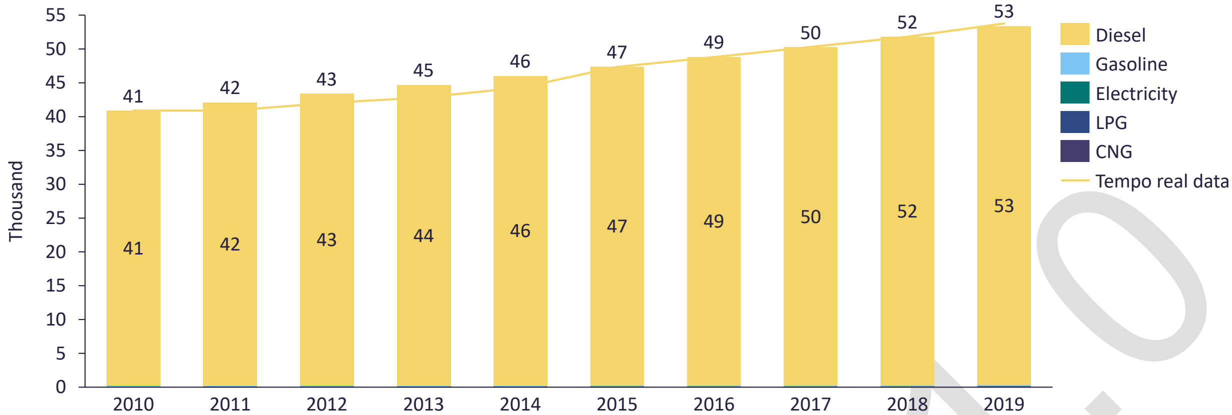
Figure 77. Number of cars per 1,000 capita at EU level 2005 vs. 2018



Source: EUROSTAT, Passenger cars per 1 000 inhabitants, Team analysis

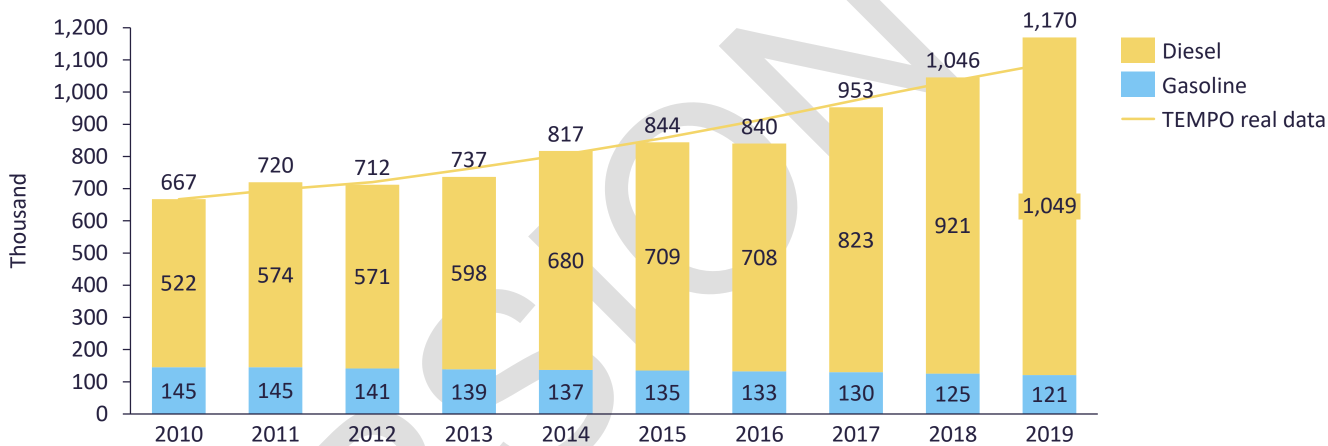
Additionally, for the road transport, the number of buses & mini-buses (passenger road transport vehicles) and the number of HGV & LCV (freight road transport vehicles) were also used in the model. Figure 78 and Figure 79 show the modelling output per fuel type and the real data provided by INS. The number of both types of vehicles increased during 2010-2019, with the number of HGV increasing more significantly (more doubling in the analysed period).

Figure 78. Number of passenger road transport vehicles projected from the model and real data from TEMPO



Source: LEAP model, National Institute of Statistics, team analysis

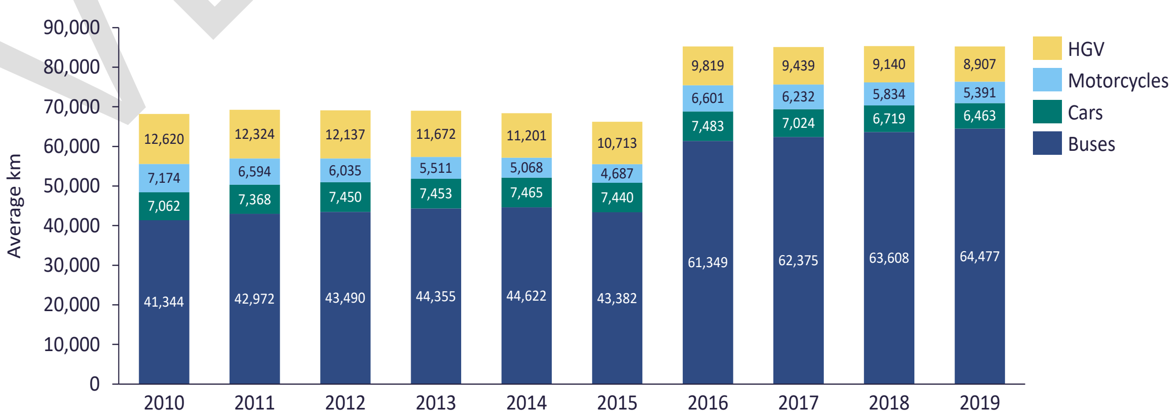
Figure 79. Number of Heavy Goods Vehicles (HGV) projected from the model and real data from TEMPO



Source: LEAP model, National Institute of Statistics, team analysis

The second parameter which is very important for calculating the passenger kilometres is the average km per vehicle. For this purpose, data from EUROSTAT/TEMPO were used, as presented in Figure 80. It can be noticed that the average passenger kilometres of the buses were very high (and higher when compared to all other types of vehicles), a major increase occurring in 2016 compared to 2015.

Figure 80. Average km per vehicle type



Source: EUROSTAT (Motor vehicle movements on national and foreign territory), National Institute of Statistics, team analysis

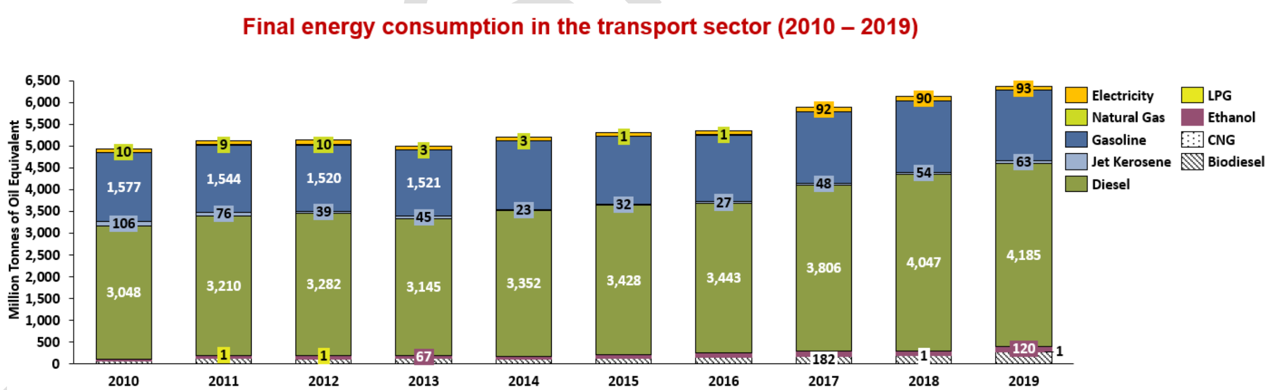
Table 10 presents the average number of passengers for the passenger road transport vehicles, motorcycles, cars and the average tonnes of goods per HGV & LCV. The data for the buses and HGV are derived from the National statistics Institute's data for passenger/tonne kilometres and total number of kilometres. For cars and motorcycles, the data from the JRS TIMES EU model - data for Romania were used. The fuel consumption of each type of vehicle was derived from the calibration of the model.

Table 10. Occupancy and fuel consumption by vehicle type

Vehicle	Fuel	Occupancy/goods Passenger/t	Fuel consumption l/100 km
Passenger road transport vehicles	CNG/Biogas		
	Diesel	9.36	33
	Gasoline	9.36	34
	LPG	9.36	37
Motorcycles	Gasoline	1.10	4
Cars	CNG	1.98	8.4
	Diesel	1.98	6.9
	Gasoline	1.98	7.6
	LPG	1.98	8.4
HGV & LCV	Diesel	3.10	33
	Gasoline	3.10	25

Based on all these data sets, the LEAP_RO model computed the final energy consumption of the transport sector (Figure 81). In the analysed period 2010-2019, regarding the fuels used on the road transport, the diesel had highest share, followed by the gasoline.

Figure 81. Final energy consumption in the transport sector (2010 – 2019)



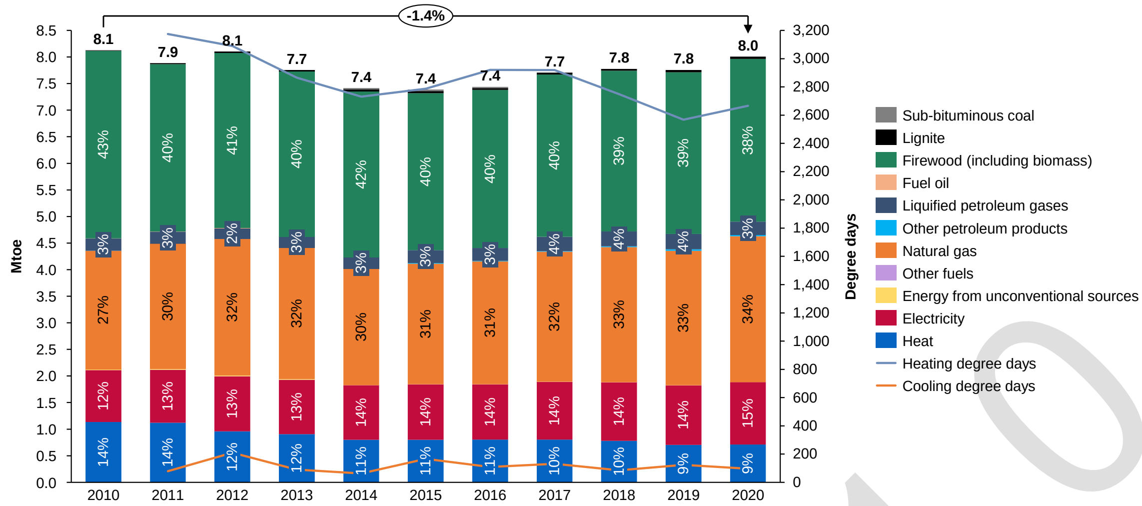
Source: LEAP model

9.2.3 Buildings (Residential and Commercial and Services) sector

9.2.3.1 Residential sector

Final energy consumption in the Residential sector slightly decreased (by 1.4%) in the period 2010-2020 (Figure 82). Even though the firewood (including biomass) consumption have decreased by 13% over the period, it continued to have the highest share in the residential final consumption. A significant reduction of around 30% in the district heat consumption is noticeable during the period. At the same time, the consumption of natural gas and electricity increased by 23% and 20%, respectively. A correlation between the energy consumption in the household sector and heating and cooling degree days is evident for most of the period.

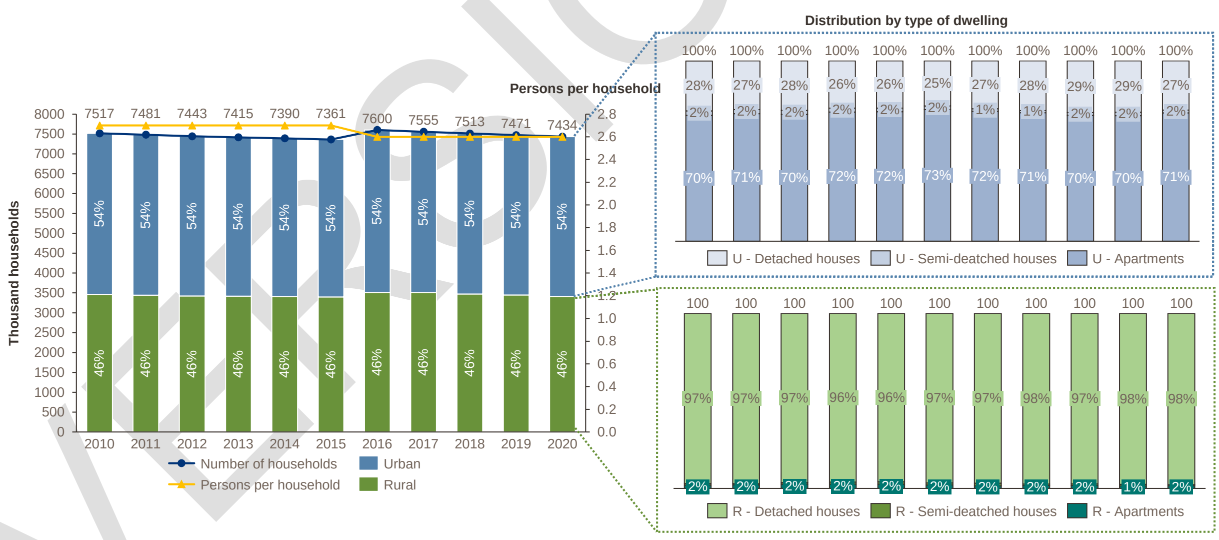
Figure 82. Final energy consumption by fuels – households



Source: INS - Energy Balances, Eurostat – Heating and cooling degree days for Romania

A key input parameter relevant for estimation of the useful demand in the residential sector is the number of persons per household, which in the model for Romania is also used to estimate the number of households. According to the Eurostat data, the average number of persons per household in Romania has reduced from 2.7 in the period 2010-2015 to 2.6 for the period 2016-2020 (Figure 83). Based on the national statistical data, 54% of the population lives in urban area and 46% in rural area. Most of the urban population lives in apartments (around 71%), and on average 27% in detached houses, while the remaining 2% in semi-detached houses. Around 97% of the households in rural areas are detached houses, and the rest 3% are semi-detached houses and apartments (Figure 83).

Figure 83. Number of households, person per households and distribution of households by type

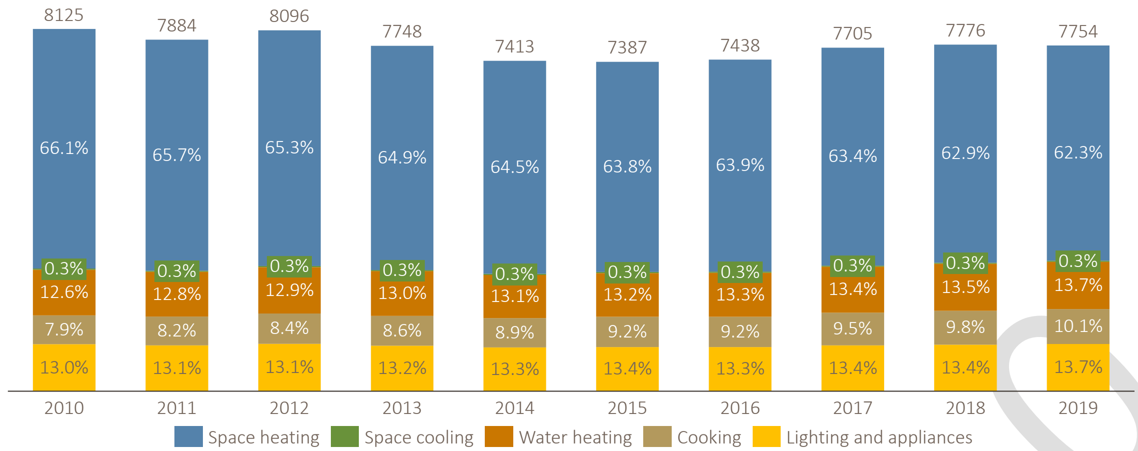


Source: Eurostat – Average number of persons per household, INS – The structure of households by the dwelling's tenure status

Note: Number of households is calculated using the data on usually resident population from INS and average number of persons per household form Eurostat

Based on the Eurostat data on the quantities of final energy consumption in households by end use, the shares for the end-uses were evaluated and used as input parameter in the model. The disaggregation of total households' energy consumption by end-use shows that, on average, over 60% of the energy is used for space heating, water heating and the energy used for lighting and other appliances accounts for around 13% each, while about 8% of the energy is used for cooking (Figure 84).

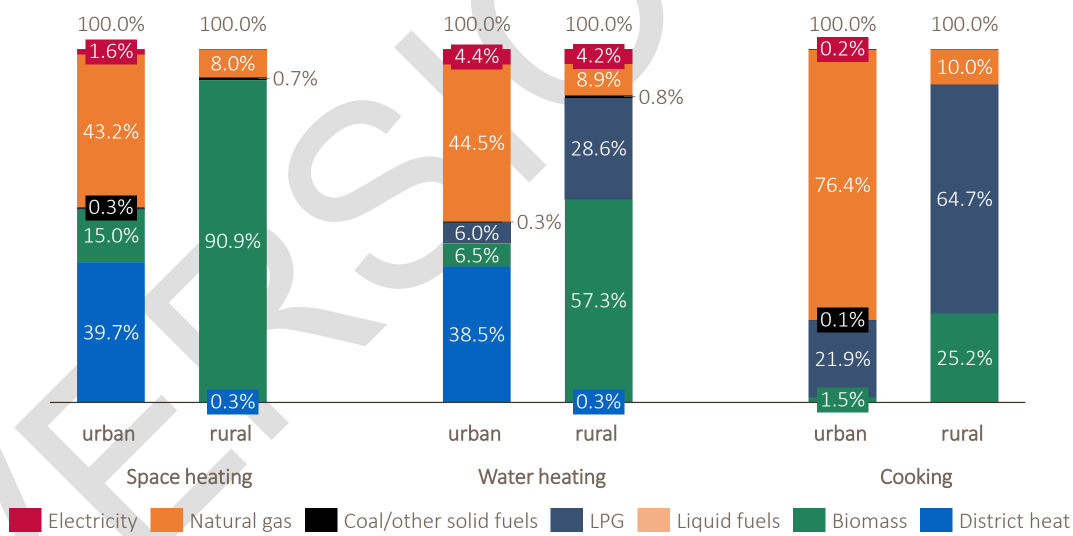
Figure 84. Disaggregated final energy consumption in households by end-use (in %)



Source: Eurostat – Disaggregated final energy consumption in households – quantities; Project team analysis.

Besides the distribution by end-use, another key input parameter is the fuel share for each end-use type. The fuel shares used in the model for Romania are based on the survey on the household energy consumption made in 2009. The survey results show that the urban households mainly use natural gas (~44%) and heat from the district systems (~39%) to satisfy their space and water heating demands. Most rural households use biomass for space heating (around 91%) and water heating (57%). A significant share of water heating demand in the rural area is also met with LPG (~29%). For cooking, the urban households mostly use natural gas (76%) as well as LPG (22%), while the rural households use LPG (~65%) and biomass (25%). A small share of natural gas is also used in rural homes for all end-uses.

Figure 85. Fuel share by end-use and by type of dwelling

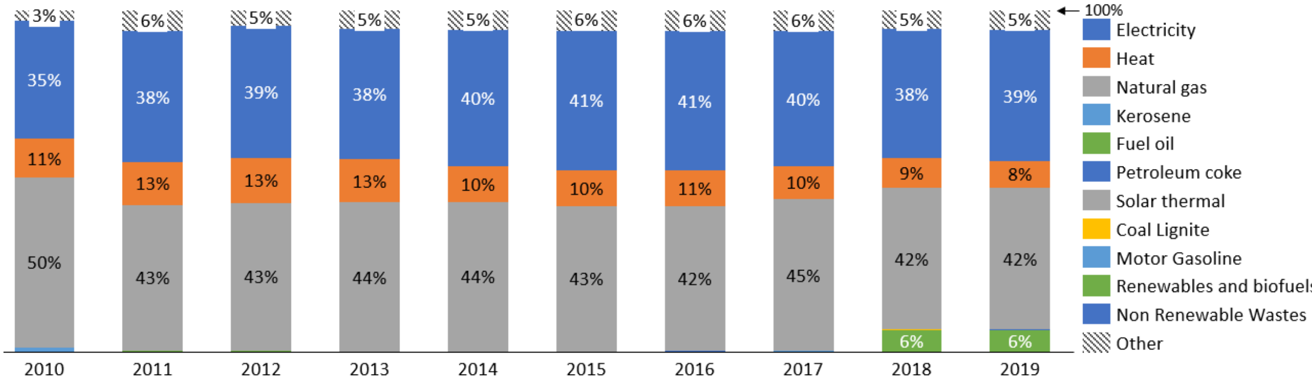


Source: National Institute of Statistics (INS), Report "Development of detailed statistics on energy consumption in households" (SECH Project), 2009, (Annex 4)

9.2.3.2 Commercial and Services sector

The Commercial and Services sector is defined in LEAP_RO to cover energy consumption from various types of fuel. The data set used in LEAP_RO is based on data from the Energy Balance of Romania for the period 2010-2019 (Figure 86). Figure 86 provides an overview of the fuels' mix in the Commercial and Services sector.

Figure 86. Fuels mix and energy demand in the COMSEC sector



Source: LEAP_RO model, EUROSTAT, INS

From Figure 86, one can notice that within this sector the demand for natural gas is the largest and that there was little decrease in the dependency on natural gas within 20102-2019. The demand for electricity was the second highest demand within this sector, with a slight increase of this type of demand within the Commercial and Services sector in the analysed period. In 2018-2019, the emergence of energy consumption from RES and biofuels can be observed.

9.2.4 Industry sector

The share of the industry sector in the overall energy consumption remained nearly constant throughout the whole period analysed period, starting from 29.4 % in 2010 and decreasing to 27.4% in 2020.

Table 11. Share of industry in total energy consumption

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Share of industry in total energy consumption	29.4%	31.3%	29.8%	29.0%	29.9%	29.7%	28.6%	28.0%	28.2%	28.1%	27.4%

Table 12. Share of main fuel categories in the industry sector

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Fossil fuels	81.7%	85.2%	84.3%	81.4%	79.9%	80.1%	78.0%	79.0%	79.2%	79.0%	79.1%
Bioenergy	4.0%	3.2%	4.1%	4.6%	4.4%	4.2%	5.1%	4.9%	4.0%	4.0%	3.5%

The industry sector is predominantly fossil-fuel based. Over the period 2010-2020, the fossil fuel share slightly decreased, from 81.7% in 2010 to 79.1% in 2020. The share of biomass used in the industry varied within the period, remaining as low as 3.5% in 2020.

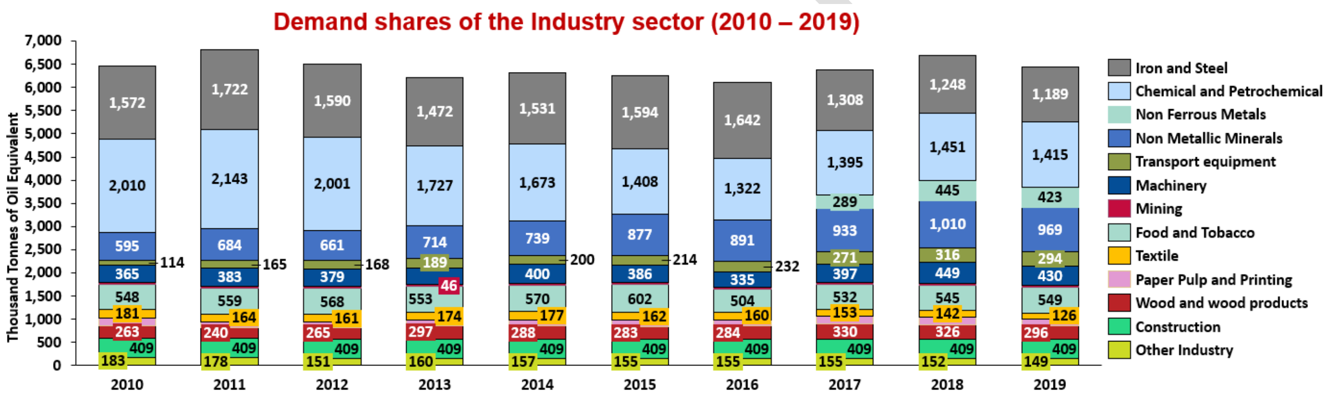
The category that has the largest share in final energy consumption in the overall Industry sector in the represented period was Chemical & petrochemical, with a 24.8% average energy consumption share and a decreasing trend (31.3% in 2010, 22.2% in 2020). The second category with the highest energy consumption level in the overall Industry sector was Iron & steel with an average final energy consumption share of 23.1% and a decreasing trend (24.3% in 2010 and 16.5% in 2020). Non-metallic minerals category had an average share of 14.2%, showing a notably increasing trend (9.2% in 2010 up to 18.7% in 2020). The next category is Food, beverages & tobacco with an average share of 8.6%. The Construction and Machinery categories hovered around average shares of 6% and 5.8%, respectively. The other categories had average shares below 5%: Wood and wood products (4.4%), Transport equipment (3.4%), Textiles and leather (2.5%), Industry not elsewhere specified (2, 4%), Non-ferrous metals (2.2%), Paper, pulp and printing (1.9%) and Mines and quarries (0.6%).

Table 13. Final energy consumption in the Industry sector in the period 2010-2020 per industrial field

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Iron & steel	1574.8	1879.3	1647.3	1636.2	1648.8	1774.7	1689.9	1363.1	1169.5	1158.9	1059.0
Chemical & petrochemical	2028.5	2231.1	1958.3	1644.7	1649.7	1416.3	1249.4	1341.8	1428.2	1477.2	1437.1
Non-ferrous metals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	288.7	469.5	423.5	404.9

Non-metallic minerals	595.4	686.8	886.6	789.6	846.9	940.0	998.9	1020.9	1129.5	1092.4	1202.3
Transport equipment	114.2	164.8	166.2	205.3	207.1	226.1	211.9	231.7	297.5	291.2	313.7
Machinery	364.9	362.3	359.8	360.2	401.4	351.5	361.4	395.9	427.4	429.5	342.1
Mining & quarrying	47.6	51.5	49.2	43.2	40.1	34.9	37.9	41.3	38.9	37.5	37.2
Food, beverages & tobacco	557.3	564.6	581.9	528.8	556.7	559.3	570.6	585.3	537.0	575.4	553.1
Paper, pulp & printing	165.3	67.9	79.7	80.2	102.5	123.3	136.7	172.4	140.7	160.3	134.9
Wood & wood products	263.4	225.4	254.2	259.3	274.4	289.7	332.0	329.6	344.1	322.3	282.5
Construction	409.4	476.2	448.9	392.9	369.6	389.8	351.7	351.0	334.0	378.9	417.1
Textile & leather	180.8	176.7	162.8	171.4	178.3	171.3	149.6	164.7	148.0	170.4	132.6
Not elsewhere specified (industry)	182.8	172.9	153.2	161.0	152.0	142.0	173.8	151.4	148.0	143.6	120.6
Total Industry sector [ktoe]	6484.2	7059.7	6748.3	6272.8	6427.4	6418.9	6263.8	6437.7	6612.4	6661.1	6437.0

Figure 87. Share of categories in the industry sector

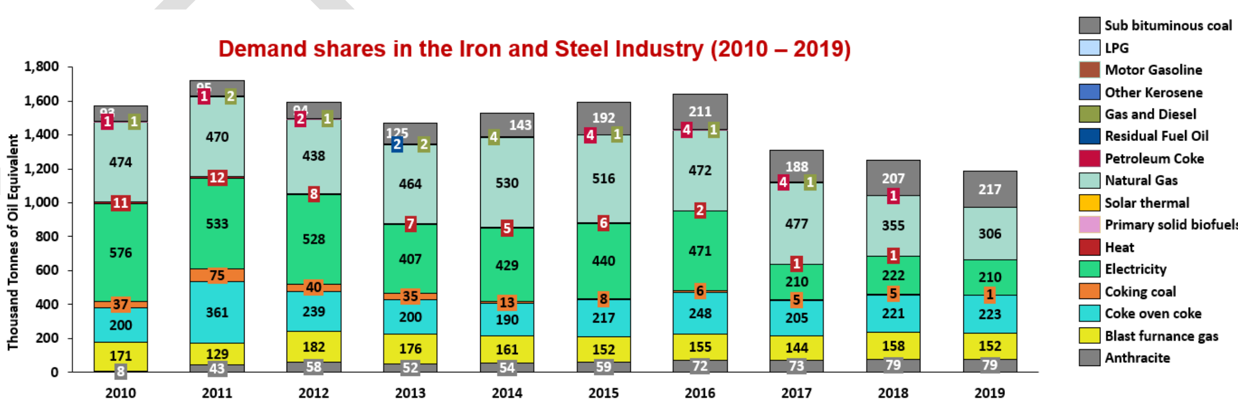


Source: LEAP_RO model, EUROSTAT, INS

9.2.5.1 Iron and steel industry

The fuel mix in Iron and Steel industry is shown in Figure 88.

Figure 88. Final energy consumption - Iron and Steel Industry



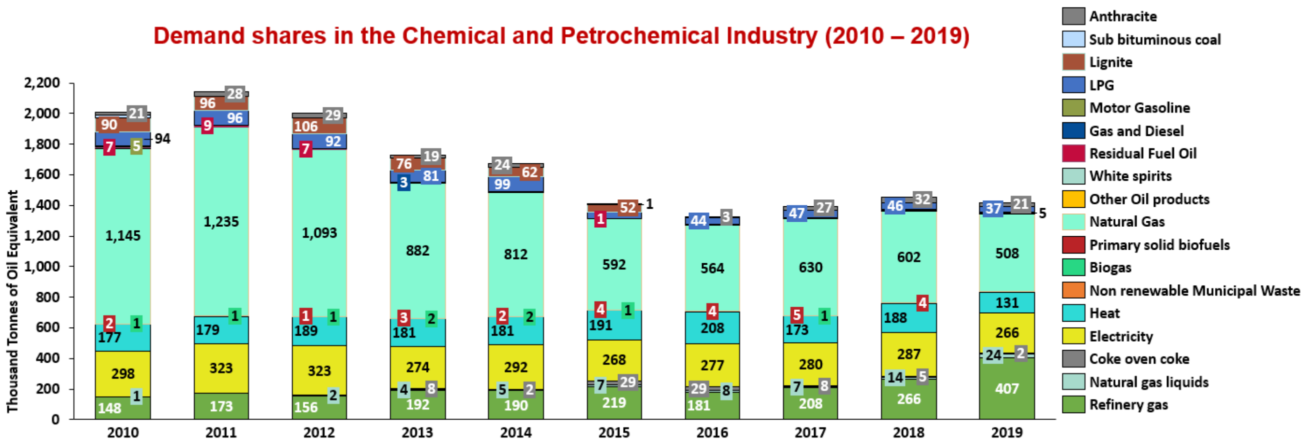
Source: LEAP_RO model, EUROSTAT, INS

Electricity, natural gas, blast furnace gases, coke oven coke and sub-bituminous coal had the highest share in final energy consumption in the iron & steel industry in the period 2010-2019. The electricity showed a decreasing trend, from 37% in 2010 to 18% in 2019. Similarly, the natural gas decreased from 30% in 2010 to 26% in 2019. An increasing trend could be noted for the sub-bituminous coal, from 6% in 2010 to 18% in 2019. The blast furnace gases and coke oven coke had smaller variations, with an average final energy consumption share of 11% and 16%, respectively, for the entire period.

9.2.5.2 Chemical and petrochemical industry

The fuel mix in Chemical and Petrochemical is shown in Figure 89.

Figure 89. Final energy consumption - Chemical and Petrochemical



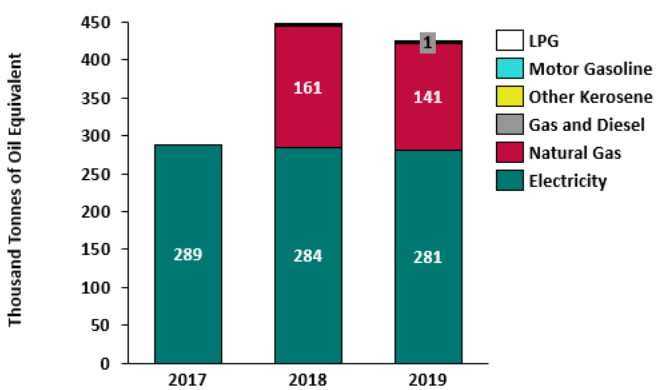
Source: LEAP_RO model, EUROSTAT, INS

The natural gas, electricity, heat and refinery gas had the highest final energy consumption share in the Chemical and Petrochemical industry in the period 2010-2019. The natural gas share had a decreasing trend from 57% in 2010 to 36% in 2019. The share of electricity slightly increased from 15% in 2010 to 19% in 2019. An increasing trend could be noted for the refinery gas share, from 7% in 2010 to 29% in 2019. The heat had average share of 11% for the entire period.

9.2.5.3 Non – ferrous metals industry

The fuel mix in Non-Ferrous Metals is shown in Figure 90.

Figure 90. Final energy consumption - Non - Ferrous Metals



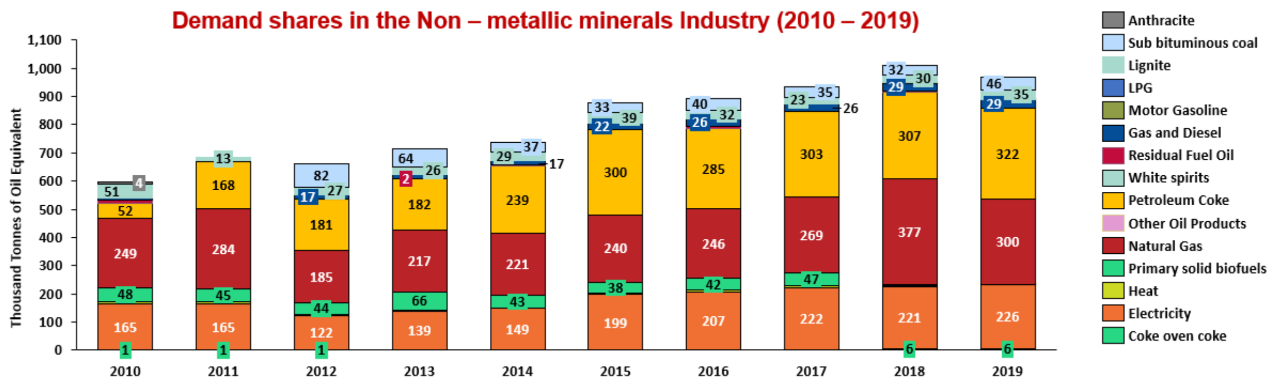
Source: LEAP_RO model, EUROSTAT, INS

Electricity and natural gas had the highest final energy consumption share. Electricity had an average share of 65%, while the natural gas had 34%.

9.2.5.4 Non – metallic minerals industry

The fuel mix in Non-Metallic Minerals is shown in Figure 91.

Figure 91. Final energy consumption - Non-Metallic Minerals



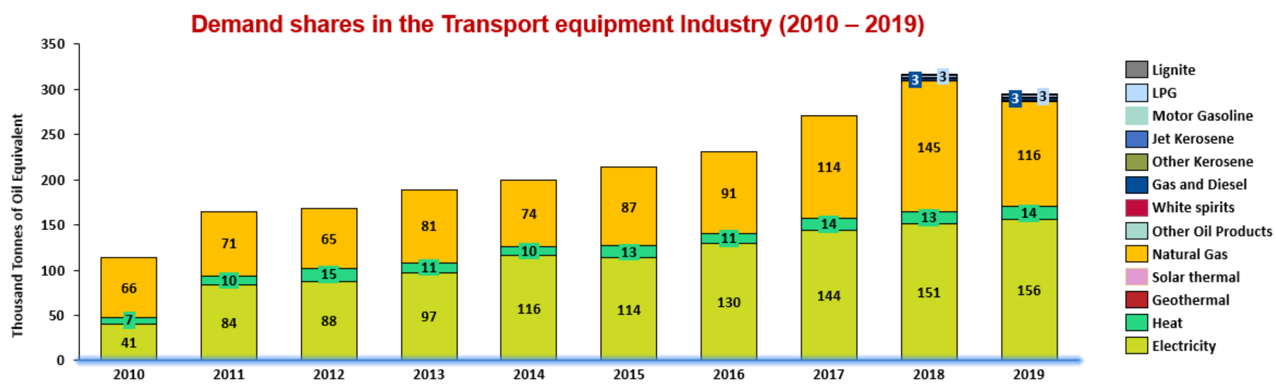
Source: LEAP_RO model, EUROSTAT, INS

Natural gas, electricity and petroleum coke had the highest final energy consumption share in this category. The natural gas share declined from 42% in 2010 to 31% in 2019, while petroleum coke share increased from 9% in 2010 to 33% in 2019. The electricity had an average share of 22%, while the other fuels had an average share of 5% for the period 2010-2019.

9.2.5.5 Transport equipment

The Transport equipment category has the following fuels mix, shown in Figure 92.

Figure 92. Final energy consumption - Transport equipment



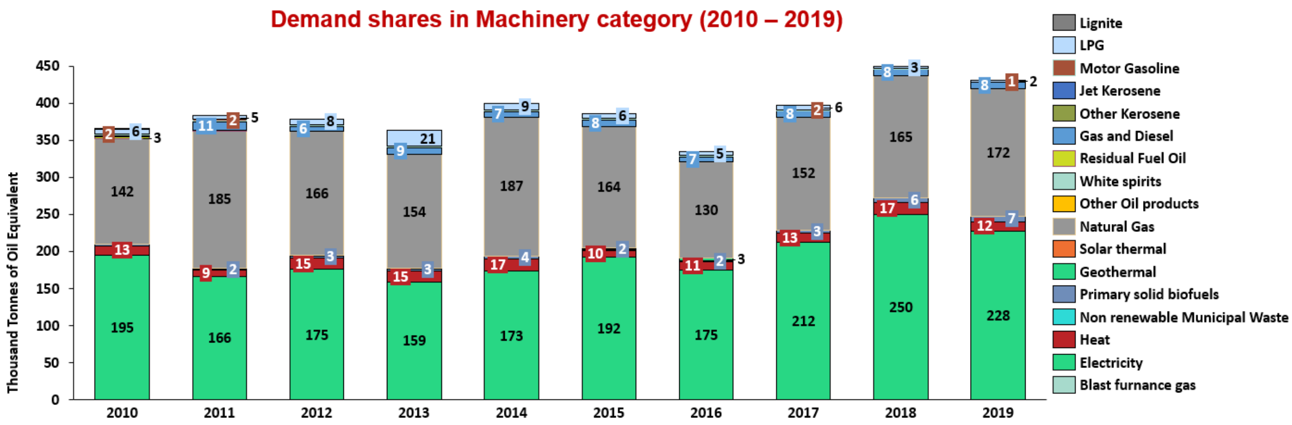
Source: LEAP_RO model, EUROSTAT, INS

Natural gas and electricity had the highest final energy consumption shares, with almost 45% each for the period 2010-2019.

9.2.5.6 Machinery category

The fuels used in the Machinery category are shown in Figure 93.

Figure 93. Final energy consumption – Machinery



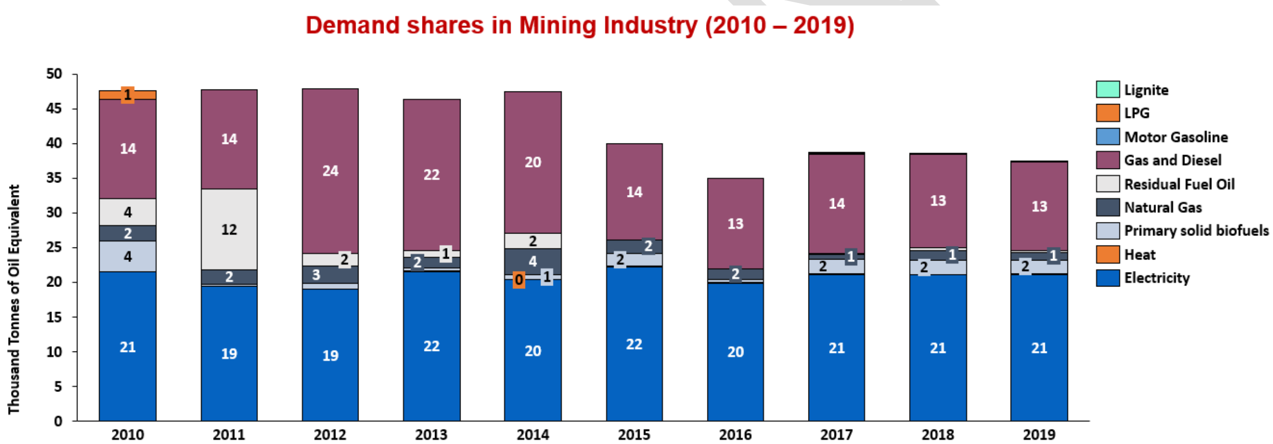
Source: LEAP_RO model, EUROSTAT, INS

As shown on the figure, the electricity had the highest final energy consumption share, 53%, for the period 2010-2019, followed by natural gas, with a share of approximately 40%.

9.2.5.7 Mining industry

In the category Mining, the fuel mix is shown in Figure 94.

Figure 94. Final energy consumption - Mining



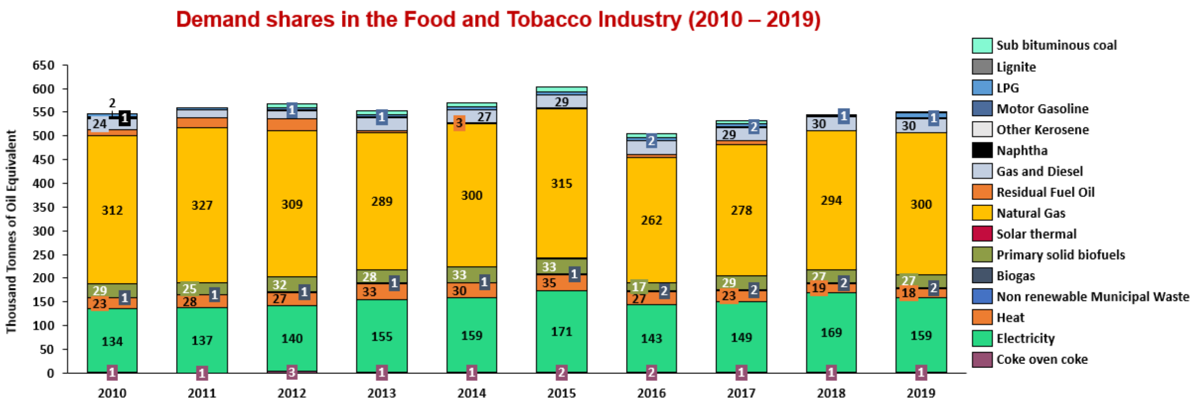
Source: LEAP_RO model, EUROSTAT, INS

For the period 2010-2019, the electricity had a final energy consumption average share of 50%, followed gas and diesel.

9.2.5.8 Food and tobacco industry

The energy sources used in Food and Tobacco category are shown in Figure 95.

Figure 95. Final energy consumption - Food and Tobacco industry



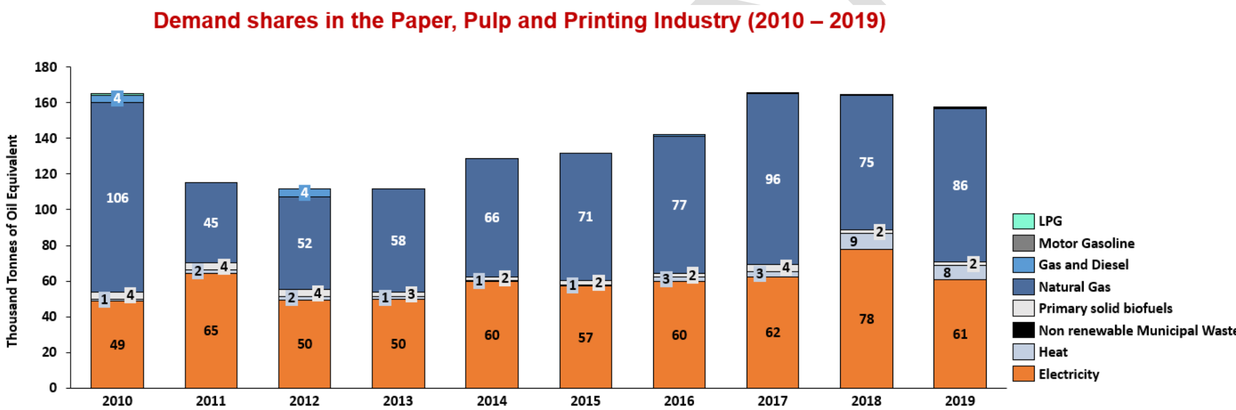
Source: LEAP_RO model, EUROSTAT, INS

Amongst all the fuels in this category, the natural gas had a final energy consumption average share of 54%, followed by electricity with 27%

9.2.5.9 Paper, pulp and printing industry

The structure of energy use in Paper, Pulp and Printing category is shown in Figure 96.

Figure 96. Final energy consumption - Paper, Pulp and Printing industry



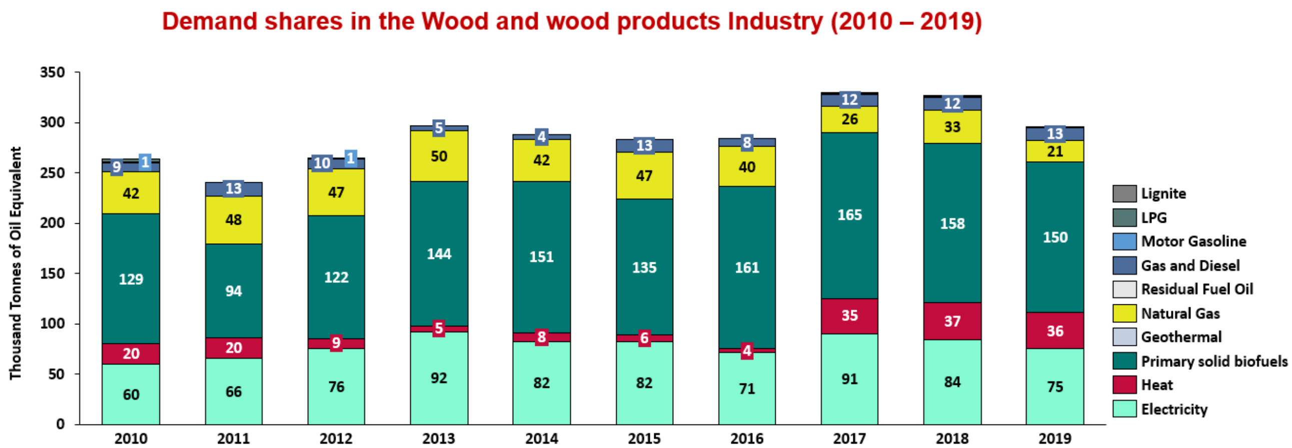
Source: LEAP_RO model, EUROSTAT, INS

The natural gas and electricity had the highest 27% share in this category. The natural gas had a declining trend, from 64% in 2010 to 54% in 2019. On the other hand, the electricity share varied during the analysed decade, never decreasing below 30%.

9.2.5.10 Wood and wood products industries

The fuels that contributed to the Wood and wood products are shown on Figure 97.

Figure 97. Final energy consumption - Wood and wood products industry



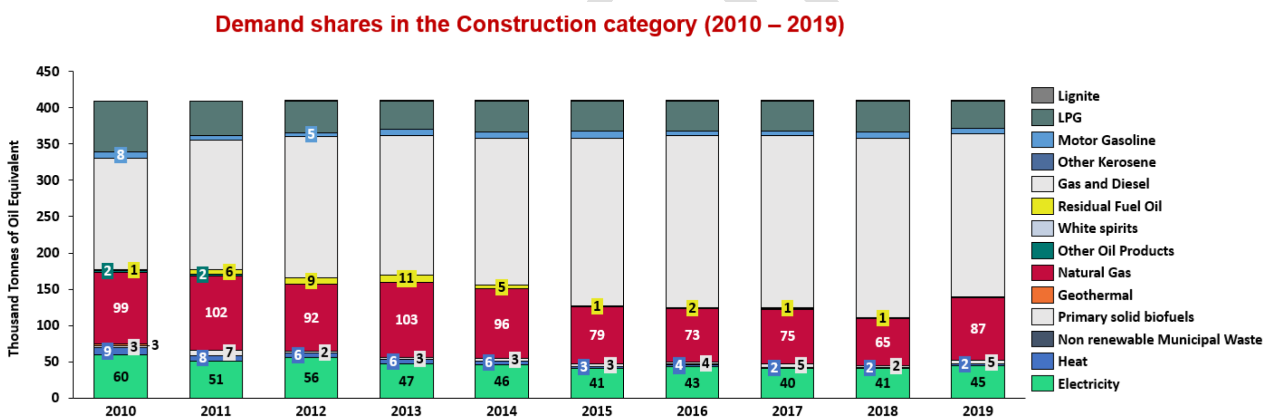
Source: LEAP_RO model, EUROSTAT, INS

Natural Gas, primary solid biofuels, heat and electricity had the highest final energy consumption shares. Primary solid biofuels were responsible for almost 50% average final energy consumption. The electricity had an average share of 25%, natural gas showed a decreasing trend, from 16% in 2010 to 7% in 2019, while heat varied through the years, starting from 8% in 2010 and reaching 12% in 2019.

9.2.5.11 Construction

The fuel mix in Construction is shown on Figure 98.

Figure 98. Final energy consumption – Construction



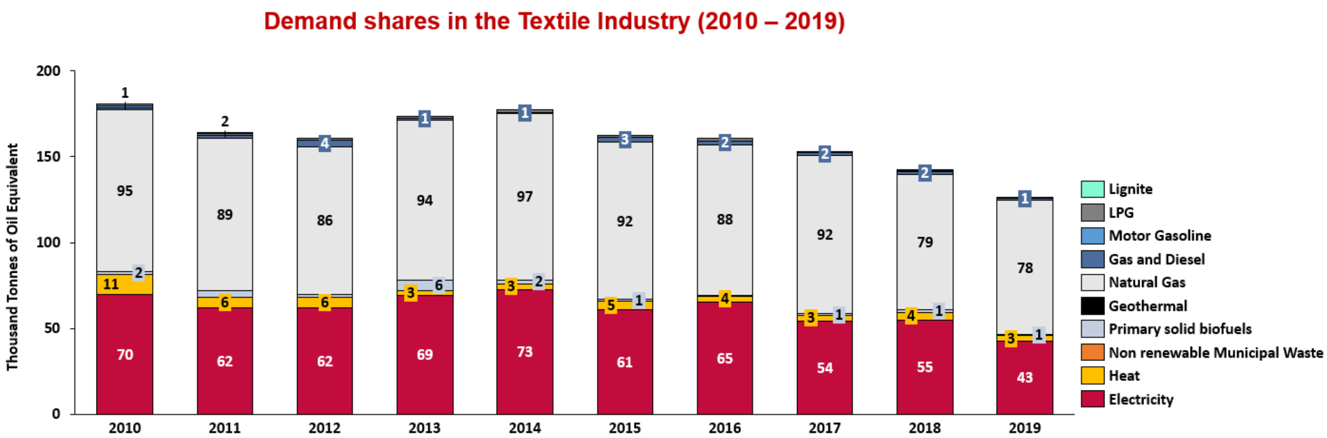
Source: LEAP_RO model, EUROSTAT, INS

The LPG, Gas and Diesel, Natural Gas and Electricity accounted the most for the Construction category. Gas and Diesel had the highest share in this category, with an increasing trend, from 38% in 2010 to 55% in 2019. The natural gas and electricity had average shares of 21% and 11%, respectively.

9.2.5.12 Textile industry

The fuels that contributed the in Textile sector final energy consumption are shown on Figure 99.

Figure 99. Final energy consumption - Textile



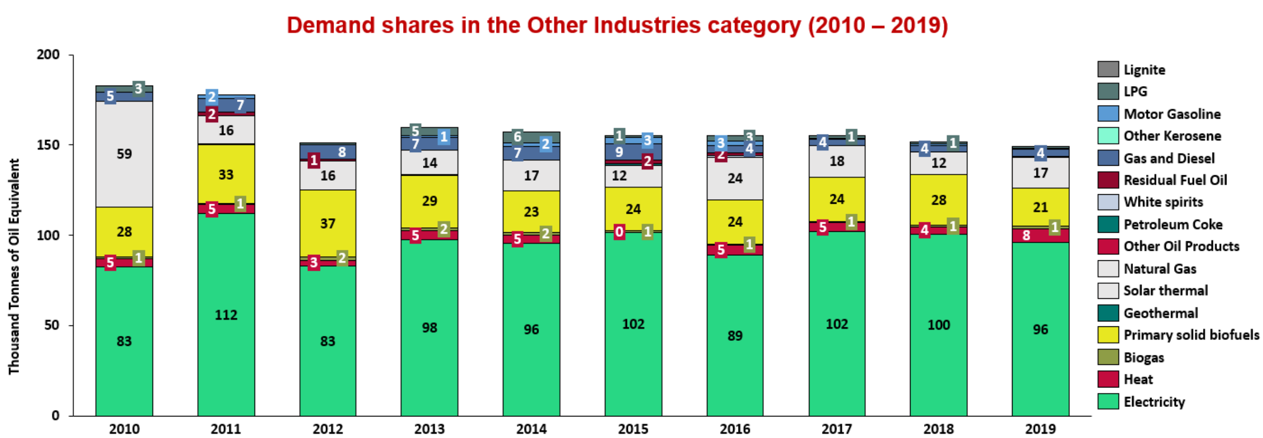
Source: LEAP_RO model, EUROSTAT, INS

Natural gas and Electricity had the most significant sector final energy consumption share in this category, with an average of 56% and 38% respectively, for the period 2010-2019.

9.2.5.13 Other industries

The structure of sector final energy consumption in the Other industries category is shown on Figure 100.

Figure 100. Final energy consumption - Other Industry



Source: LEAP_RO model, EUROSTAT, INS

The electricity, primary solid biofuels and natural gas had the highest final energy consumption share in the entire period. The electricity share increased from 45% in 2010 to 64% in 2019. On the other hand, the natural gas share declined from 32% in 2010 to 12% in 2019. The primary solid biofuels remained almost constant through the decade, with an average final energy consumption share of 17%.

9.2.5 Agriculture and LULUCF sector

9.2.5.1 Land Use, Land Use Change and Forestry (LULUCF) (or Forestry and Other Land Use)

The land use categories used in the LEAP_RO follow the IPCC methodology for the development of National GHG Inventories (2006 IPCC Guidelines), i.e., the country territory is divided into the following land categories: forest land, cropland, grassland, wetland, settlements, and other land. To estimate the GHG emissions/removals, one of the key parameters is the land area for each category and the land conversion area between categories (i.e., the area of land converted into the other types of land).

The implied carbon-stock-change factors are the other essential parameters relevant for emissions/removals estimation. These factors include carbon gains and losses (i.e., net carbon stock change) in living biomass per area, net carbon stock change in dead wood per area, net carbon stock change in mineral soils per area, and net carbon stock change in organic soils per area.

The land area by category and the carbon stock change indicators are used to define the following new variables in the model: Net carbon-stock change in living biomass, Net carbon-stock change in dead wood, Net carbon-stock change in mineral soil, and Net carbon-stock change in organic soil. The sum of these variables represents the Net carbon emissions/removals from land (expressed as million tons of C), which are then converted to units of CO2 emissions by multiplying the carbon stock change by (-44/12).

The key assumptions for the land area (by category) and the carbon-stock-change indicators used in the LEAP_RO model were based on the historic data (for the period 2010 – 2020) reported in the CRF (Common Reporting Format) tables as part of the National GHG Inventory Report of Romania submitted to the UNFCCC (the resubmissions from September 2022).

The following subsections give an overview of the assumptions used in the LEAP_RO model by land category.

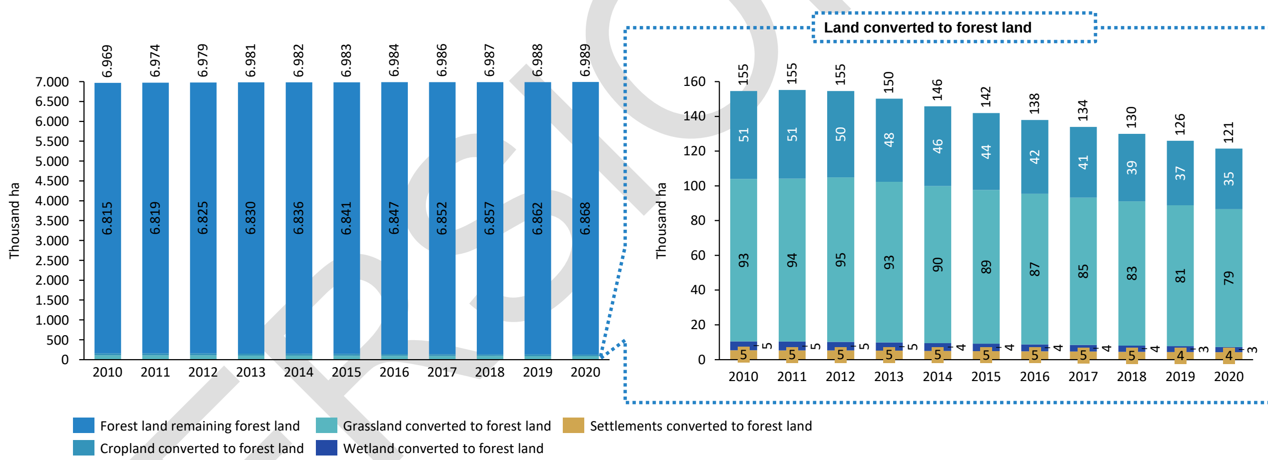
Forest Land

- **Land Area**

The country's forest land area accounted for around seven million ha (Figure 101), and about 98% of it did not change (i.e., category forest land remaining forest land) during 2010-2020. Most of the forest land that remained in this category was on mineral soil, while only a small share of about 0.034% (or 2.5 thousand ha) was on organic soil.

With less than 2% of the total forest land, the land area converted from the other categories (mainly grassland and cropland) to forest land has gradually decreased from nearly 150 thousand ha in 2010 to around 121 thousand ha in 2020.

Figure 101. Forest land area (in thousand ha)



Source: LEAP model

- **Net – carbon stock change indicators**

Table 14 presents the implied carbon-stock-change factors for forest land used in the model, based on the CRF Table 4A.

Table 14. Implied net-carbon stock change indicators for forest land (in kg C/ha)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Carbon gains in living biomass per area											
FL to FL	1699	1702	1704	1702	1699	1697	1695	1692	1690	1688	1685
CL to FL	1412	1474	1769	1971	2095	2208	2318	2430	2529	2607	2695
GL to FL	899	912	909	1011	1029	1037	1054	1074	1100	1124	1143
WL to FL	951	951	970	970	970	970	970	970	970	970	970

SL to FL	3265	3285	3210	3246	3257	3250	3236	3219	3198	3177	3156
Carbon losses in living biomass per area											
FL to FL	-670	-740	-771	-776	-720	-732	-694	-741	-788	-764	-781
Net carbon stock change in dead wood per area											
CL to FL	89	89	89	91	91	88	83	76	68	59	52
GL to FL	84	84	85	87	89	89	88	86	82	78	74
WL to FL	94	91	91	90	88	83	76	66	54	43	35
SL to FL	85	81	75	71	70	69	70	71	72	73	73
Net carbon stock change in mineral soils per area											
CL to FL	1840										
GL to FL	1840										
WL to FL	2200										
SL to FL	2599										
Net carbon stock change in organic soil per area											
FL to FL	-2600										

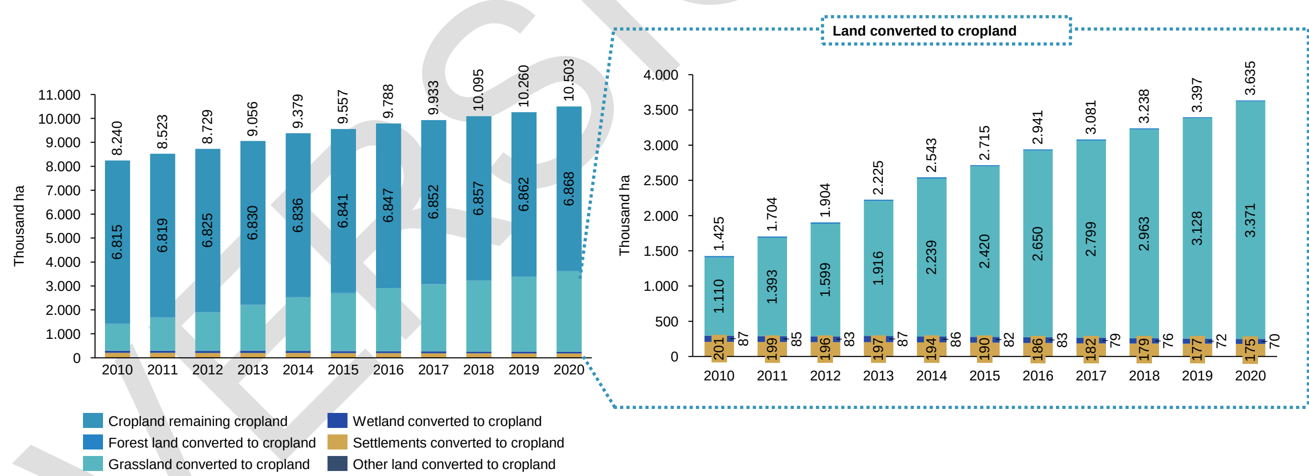
Note: FL= Forest land, CL=Cropland, GL=Grassland, WL=Wetland, SL=Settlements

Crop land

- **Land Area**

The total cropland area in the country increased from 8.2 million ha in 2010 to 10.5 million ha in 2020 (Figure 102). Approximately 6.8 million ha of the cropland remained unchanged. The 27.5% increase in the total cropland area was due to the land conversions mainly originating from grassland, increasing the converted land area from 1.4 million ha in 2010 to 3.6 million ha in 2020.

Figure 102. Cropland area (in thousand ha)



Source: LEAP model

- **Net – carbon stock change indicators**

Table 15 presents the implied carbon-stock-change factors for cropland used in the model, based on the CRF Table 4B.

Table 15. Implied net-carbon stock change indicators for cropland (in kg C/ha)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Carbon gains in living biomass per area											
CL to CL	60	59	75	85	77	92	82	126	98	88	86
GL to CL	932	1134	791	942	814	480	542	365	355	357	436
WL to CL	705	162	187	554	207	84	331	98	106	126	172

SL to CL	329	334	329	335	328	306	313	300	351	369	360
OL to CL	1406	81	73	125	70	60	67	56	54	51	48
Carbon losses in living biomass per area											
CL to CL	-125	-107	-72	-80	-69	-78	-58	-110	-79	-55	-47
FL to CL	-4746	-4701	-633	-651	-675	-854	-886	-974	-1008	-1046	-1099
GL to CL	-570	-666	-440	-535	-466	-263	-294	-195	-199	-190	-242
WL to CL	-453	-47	-62	-241	-70	-11	-138	-14	-21	-30	-28
Net carbon stock change in dead wood per area											
FL to CL	-465	-456	-61	-63	-65	-81	-84	-87	-90	-93	-100
Net carbon stock change in mineral soils per area											
CL to CL	57	63	62	61	133	130	127	119	115	110	261
FL to CL	-1839	-1839	-1840	-1840	-1841	-1841	-1841	-1840	-1840	-1840	-1837
GL to CL	-100										
WL to CL	-100										
SL to CL	800										
OL to CL	340										
Net carbon stock change in organic soil per area											
CL to CL	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000

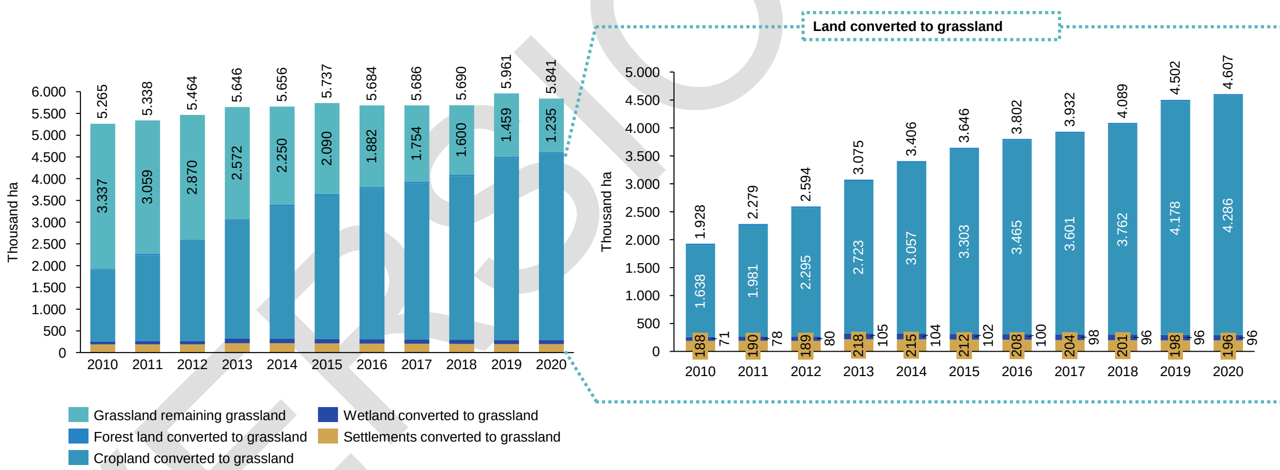
Note: FL= Forest land, CL=Cropland, GL=Grassland, WL=Wetland, SL=Settlements, OL=Other land

Grassland

- **Land Area**

Even though the changes in total grassland area during 2010-2020 were minor, from 5.3 million ha in 2010 to 5.8 million ha in 2020 (Figure 103), what is noticeable is the conversion occurring between the grassland and the cropland. The land area converted from cropland to grassland increased from 1.9 million ha in 2010 to 3.6 million ha in 2020, being slightly larger than the land conversion from grassland to cropland.

Figure 103. Grassland area (in thousand ha)



Source: LEAP model

- **Net – carbon stock change indicators**

Table 16 presents the implied carbon-stock-change factors for grassland used in the model, based on the CRF Table 4C.

Table 16. Implied net - carbon stock change indicators for grassland in [kg C/ha]

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Carbon gains in living biomass per area											
GL to GL	12	13	13	14	14	15	15	15	15	15	15
FL to GL	0	0	0	0	0	0	0	0	0	0	0
CL to GL	656	603	485	528	382	276	190	165	176	333	119
WL to GL	120	53	46	146	23	20	19	15	20	18	27

SL to GL	19	18	17	14	13	12	11	10	9	8	7
OL to GL	110	107	106	93	90	88	85	82	78	73	69
Carbon losses in living biomass per area											
GL to GL	0	-1	-1	-1	-2	-2	-3	-3	-3	-3	-3
FL to GL	-4833	-4814	-3236	-3244	-3277	-4006	-4011	-4253	-4241	-4235	-4185
CL to GL	-1140	-1041	-836	-923	-660	-475	-330	-281	-302	-576	-203
Net carbon stock change in dead wood per area											
FL to GL	-191	-189	-126	-127	-127	-154	-154	-153	-153	-153	-154
Net carbon stock change in mineral soils per area											
GL to GL	207										
FL to GL	-1840										
CL to GL	100										
SL to GL	900										
OL to GL	440										
Net carbon stock change in organic soil per area											
GL to GL	2500										

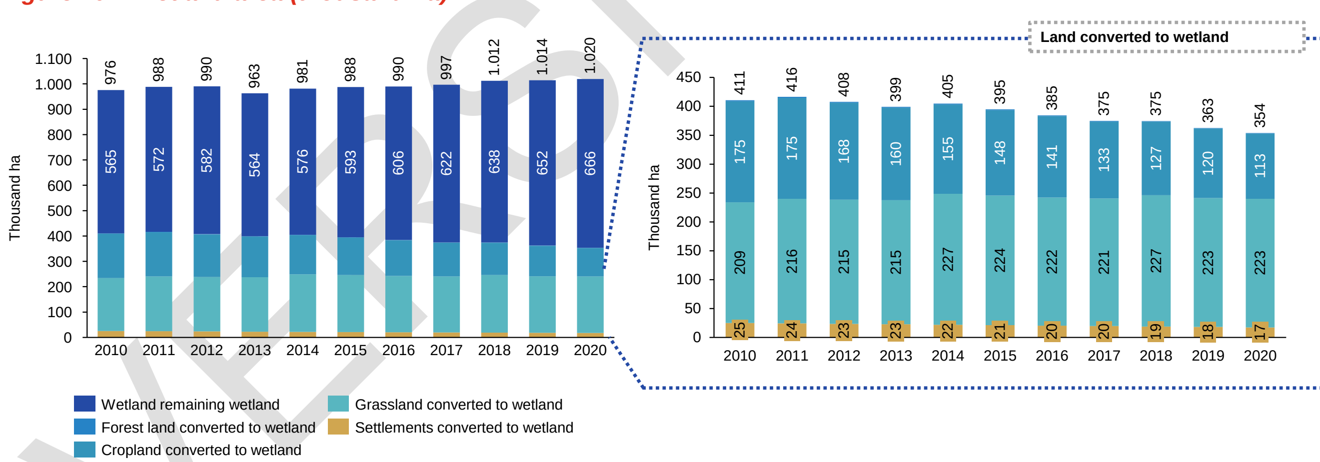
Note: FL= Forest land, CL=Cropland, GL=Grassland, WL=Wetland, SL=Settlements, OL=Other land

Wetland

- **Land Area**

The total wetland area varied during 2010-2020 between 0.96 million ha to about 1 million ha (Figure 104), out of which around 60% remained unchanged. The conversion of other land types (primarily grassland and cropland) to wetlands slightly declined from 0.42 million ha in 2010 to 0.35 million ha in 2020.

Figure 104. Wetland area (thousand ha)



Source: LEAP model

- **Net – carbon stock change indicators**

Table 17 presents the implied carbon-stock-change factors for wetland used in the model, based on the CRF Table 4D.

Table 17. Implied net-carbon stock change indicators for wetland (in kg C/ha)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Carbon gains in living biomass per area											
WL to WL	32	0	0	0	0	0	1	0	0	0	0
CL to WL	219	125	26	14	51	33	31	20	58	33	21

GL to WL	409	174	82	95	229	53	60	80	169	42	90
SL to WL	110	0	0	0	0	0	10	0	0	0	0
OL to WL	121	0	0	0	0	0	16	0	0	0	0
Carbon losses in living biomass per area											
WL to WL	-36	0	0	0	0	0	-2	0	0	0	0
FL to WL	-4356	-4408	0	0	0	0	0	0	0	0	0
CL to WL	-565	-244	-57	-38	-112	-72	-65	-43	-125	-72	-51
GL to WL	0	0	0	0	0	0	0	0	0	0	-1
Net carbon stock change in dead wood per area											
FL to WL	-399	-400	0	0	0	0	0	0	0	0	0
GL to WL	0	0	0	0	0	0	0	0	0	0	-2
Net carbon stock change in mineral soils per area											
FL to WL	-2200										
CL to WL	100										
GL to WL	-23	-21	-19	-18	-16	-14	-13	-12	-10	-9	-8
SL to WL	900										
OL to WL	440										

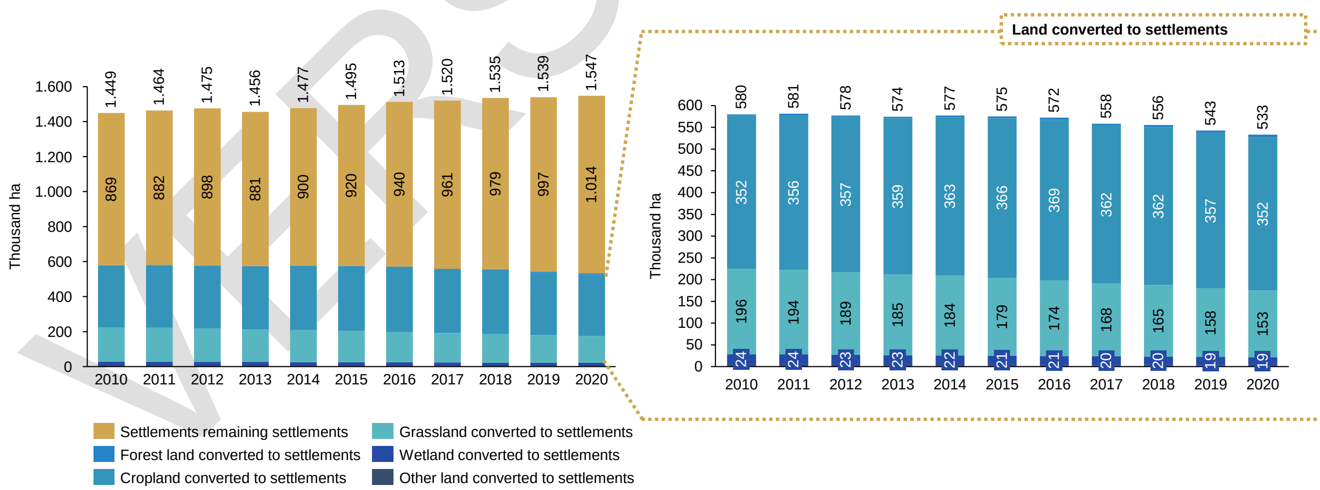
Note: FL= Forest land, CL=Cropland, GL=Grassland, WL=Wetland, SL=Settlements, OL=Other land

Settlements

- **Land Area**

The increase in total settlement area was negligible during 2010-2020, from 1.45 million ha in 2010 to 1.55 million ha in 2020 (Figure 105). Around 60% - 65% of the total settlement area remained unchanged over the period, while the rest resulted from the conversion of cropland and grassland (mainly).

Figure 105. Settlements area (in thousand ha)



Source: LEAP model

- **Net – carbon stock change indicators**

Table 18 presents the implied carbon-stock-change factors for settlements used in the model, based on the CRF Table 4E.

Table 18. Implied net-carbon stock change indicators for settlements (in kg C/ha)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020

Carbon losses in living biomass per area											
FL to SL	-3227	-3402	-14169	-13079	-12231	-13649	-12577	-12319	-11447	-10702	-9562
CL to SL	-808	-266	-232	-231	-266	-249	-237	-108	-215	-131	-141
GL to SL	-195	-119	-70	-82	-134	-72	-71	-53	-112	-47	-97
WL to SL	-85	0	0	0	0	0	-25	0	0	0	0
Net carbon stock change in dead wood per area											
FL to SL	-294	-307	-1269	-1176	-1096	-1210	-1112	-1029	-957	-895	-813
Net carbon stock change in mineral soils per area											
FL to SL	-2600										
CL to SL	-800										
GL to SL	-907	-906	-906	-906	-905	-905	-905	-904	-904	-904	-903
WL to SL	-900										
OL to SL	-440										

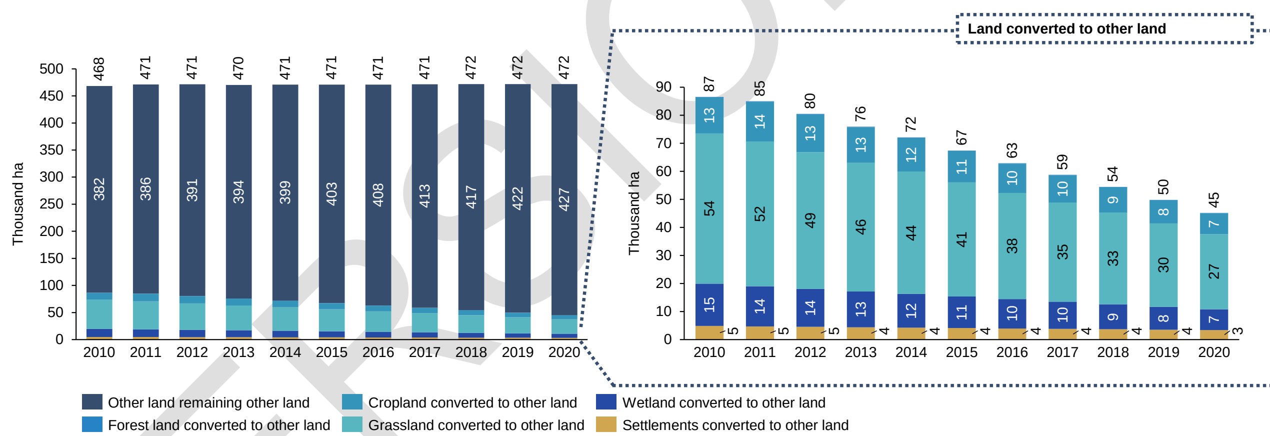
Note: FL= Forest land, CL=Cropland, GL=Grassland, WL=Wetland, SL=Settlements, OL=Other land

Other land

- **Land Area**

The remaining land area was categorized as other land, and, in the case of Romania, accounted for about 0.47 million ha. In 2010, less than 20% of the total other land area was converted from other categories, (mainly grassland), but in the recent years this share decreased to about 10%.

Figure 106. Other land area (in thousand ha)



Source: LEAP model

- **Net – carbon stock change indicators**

Table 19 presents the implied carbon-stock-change factors for settlements used in the model, based on the CRF Table 4F.

Table 19. Implied net-carbon stock change indicators for other land (in kg C/ha)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Carbon losses in living biomass per area											
CL to OL	-127	-759	-4	-16	-13	-4	0	-5	-33	-6	-7
GL to OL	-186	-56	-13	-9	-57	-4	-14	-48	-31	-12	-12
WL to OL	-388	0	0	0	0	0	0	0	0	0	0
Net carbon stock change in mineral soils per area											
FL to OL	-2150	-2150	-2150	-2150	-2150	-2150	-2150	-2150	-2150	-2150	-2150

CL to OL	-340	-340	-340	-340	-340	-340	-340	-340	-340	-340	-340
GL to OL	-453	-452	-452	-452	-452	-451	-451	-451	-450	-450	-449
WL to OL	-440	-440	-440	-440	-440	-440	-440	-440	-440	-440	-440
SL to OL	-440	-440	-440	-440	-440	-440	-440	-440	-440	-440	-440

Note: FL= Forest land, CL=Cropland, GL=Grassland, WL=Wetland, SL=Settlements, OL=Other land

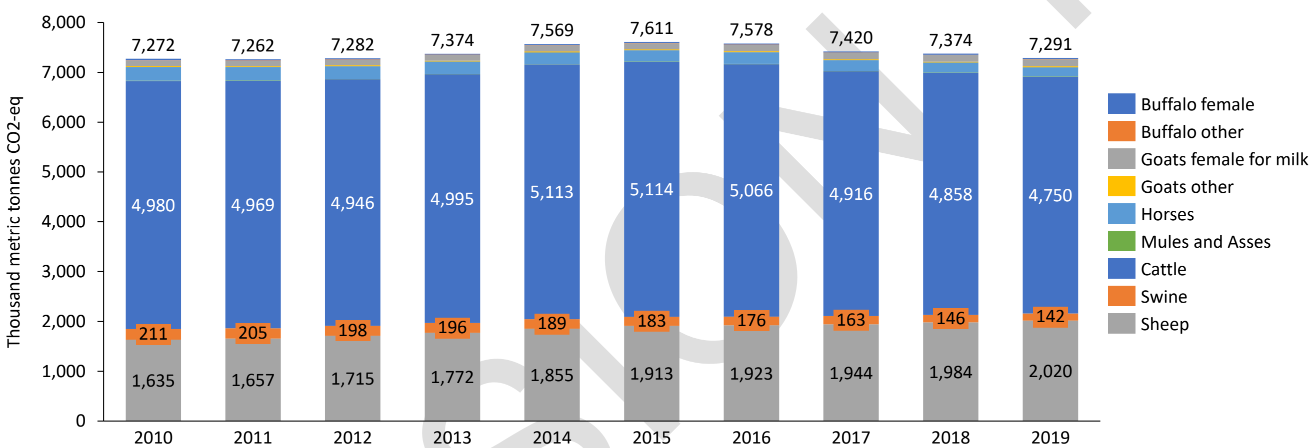
9.2.5.2 Agriculture sector

The agriculture sector is also included in the LEAP_RO model by employing the IPCC methodology. To this purpose, the activity data and the corresponding emission factors (together with some additional parameters) were used as input parameters to the model, while the GHG emissions were computed as an output parameter.

Enteric fermentation

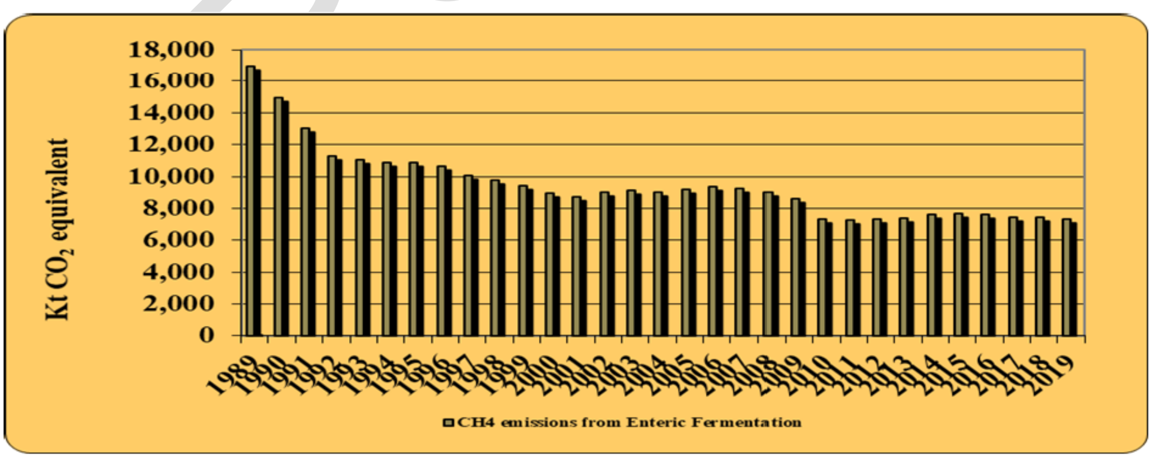
The emissions from the enteric fermentation which were computed by LEAP_RO are presented in Figure 107. Their value was then compared to the data from INEGS, as presented in Figure 108. It can be noticed that, during 2010-2019, most of the emissions were due the cattle and sheep and that their total level was nearly constant throughout the period.

Figure 107. GHG emissions – Enteric fermentation emissions during 2010-2019 according to LEAP_RO model



Source: LEAP_RO model, team analysis

Figure 108. Methane emission trend due to the Enteric Fermentation

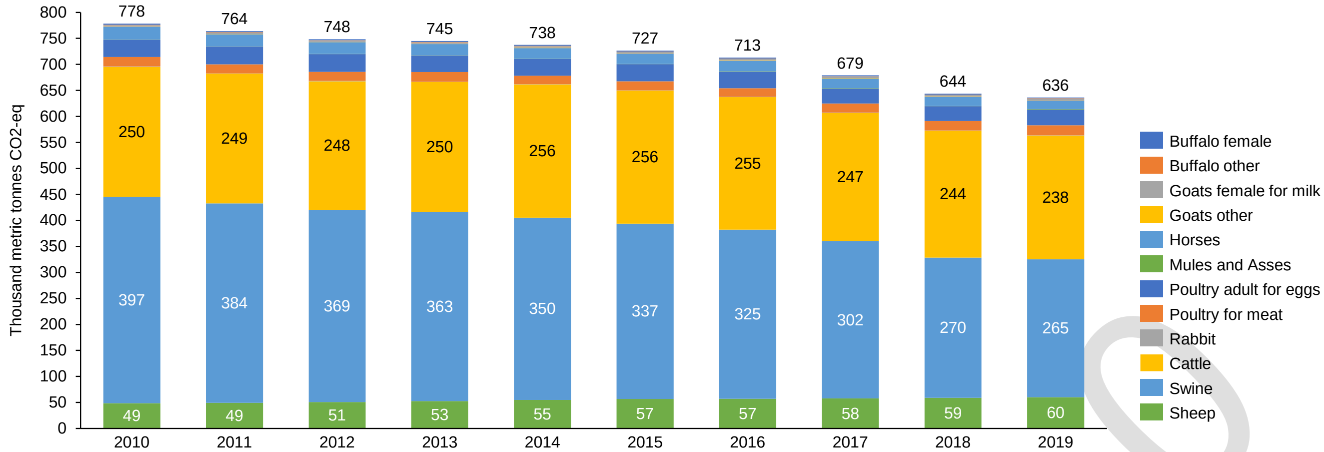


Source: INEGES

Manure management

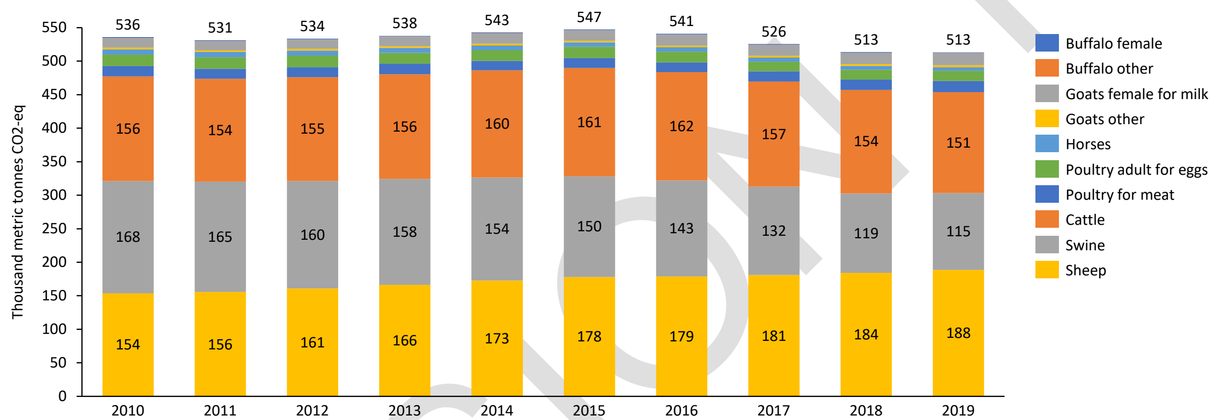
Figure 109 and Figure 110 indicate that cattle, swine and sheep were the major source of methane and nitrogen emissions during 2010-2019.

Figure 109. GHG emissions – Manure management (Methane)



Source: LEAP model, team analysis

Figure 110. GHG emissions – Manure management (Nitrogen)



Source: LEAP model, team analysis

9.2.6 Waste sector

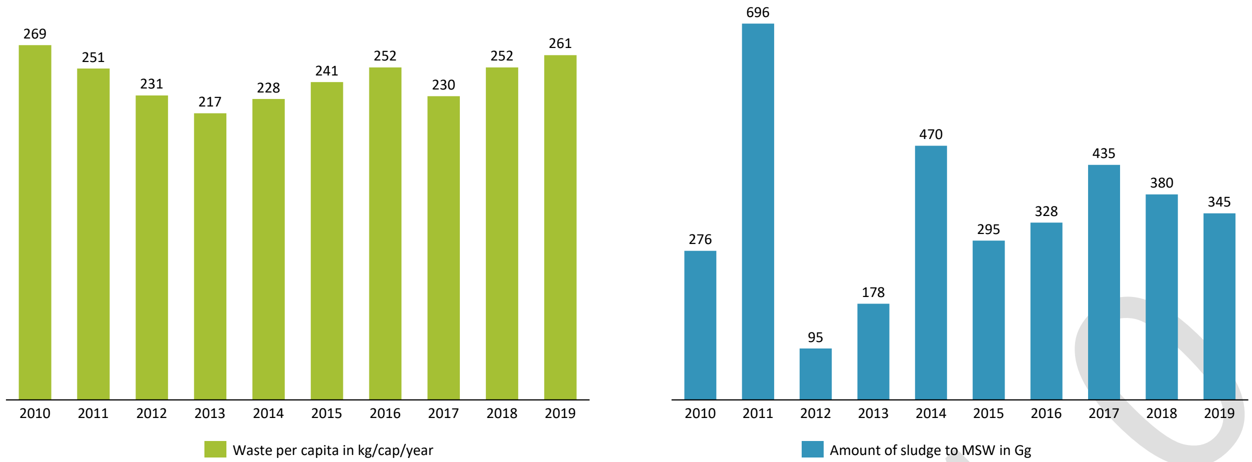
The waste sector can be divided in 4 sub-sectors: Solid Waste Disposal, Biological Treatment of Solid Waste, Incineration and open burning of waste and Domestic wastewater treatment and disposal. Some of the key macroeconomic parameters (demographic, etc.) used for modelling Solid Waste Disposal in LEAP_RO were constant for the entire 2010-2019 period, whereas others varied throughout the decade (Figure 111 and Figure 112).

Figure 111. Key macroeconomic, demographic and other type of parameters used for modelling solid waste disposal, defined within the LEAP_RO model

Branch	Expression	Scale	Units
DOCf	0.5		fraction
Delay Time	13		months
Fraction of methane in developed gas	0.5		fraction
Oxidation Factor_OX_unmanaged	0		factor
Oxidation Factor_OX_managed	0.1		factor
Conversion factor C to CH4	16/12		factor
Waste per capita	Interp(1989, 205.8, 1990, 208.1, 1991, 221.7, 1992, 235.4, 1993, 249, 1994, 262.7, 1995, 283.7, 1996, 292.1, 1997, 300.5, 1998, 30...		kg/cap/year
Percentage to SWDS for MSW	100	Percent	%
Waste generation rate	0.139		Gg/USDm GDP/year)
Percentage to SWDS for industry	90	Percent	%
Amount of sludge to MSW	Interp(2010, 275.5, 2011, 696.1, 2012, 95, 2013, 177.7, 2014, 469.9, 2015, 294.5, 2016, 327.7, 2017, 434.7, 2018, 380, 2019, 345)		Gg

Source: Model LEAP_RO

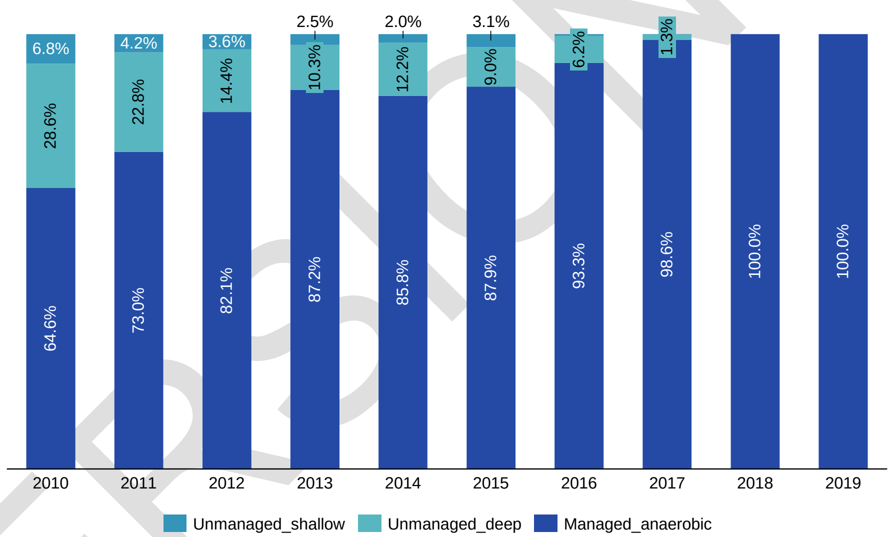
Figure 112. The evolution of waste parameters per capita (kg/cap/year]) and the amount of sludge from municipal solid waste (Gg) in the period 2010-2019



Source: Model LEAP_RO

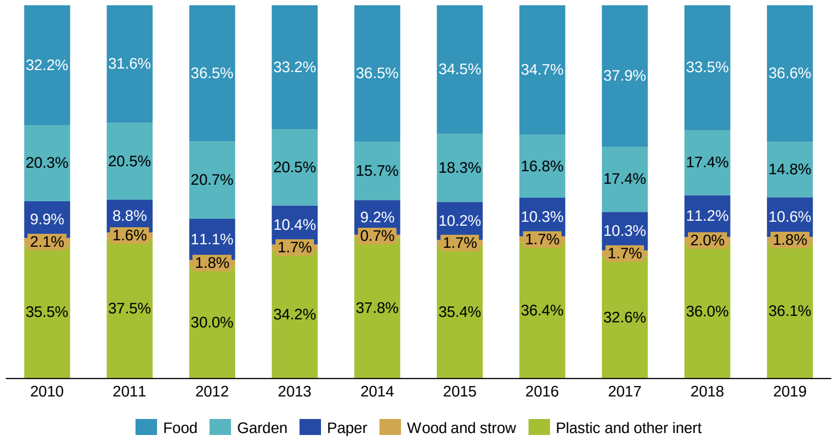
Additionally, the LEAP_RO model considered other parameters, such as the Distribution of waste in Municipal Solid Waste (MSW), Composition of waste, Dissolved organic carbon (DOC), Methane generation constant, Methane correction factor-industry, Distribution of waste-industry, Distribution of sludge – MSW.

Figure 113. Distribution of Waste in MSW



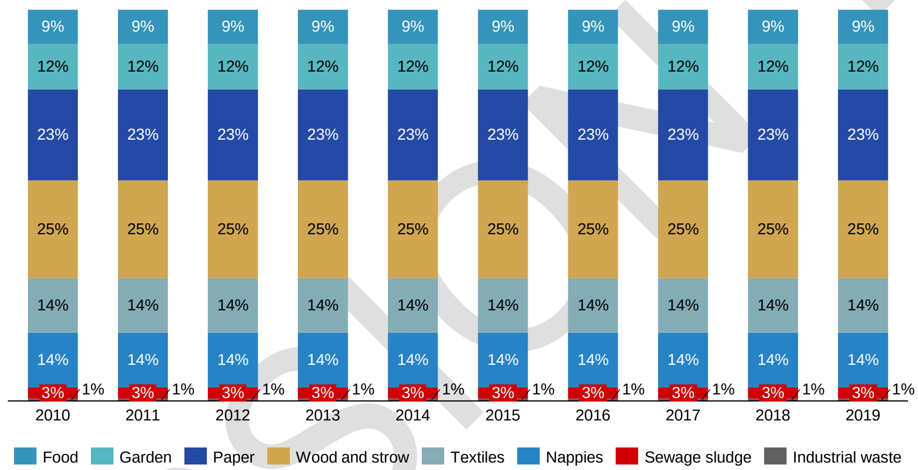
Source: Model LEAP_RO

Figure 114. Composition of waste



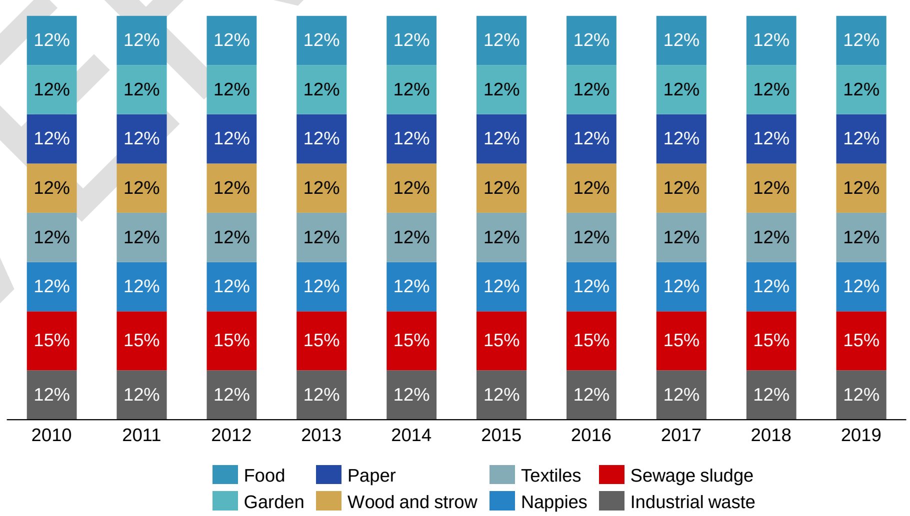
Source: Model LEAP_RO

Figure 115. DOC in weight fraction



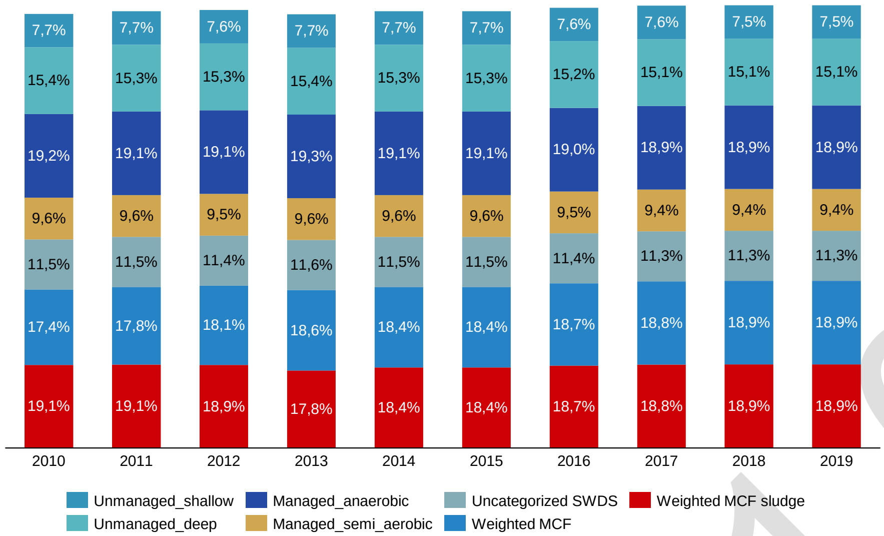
Source: Model LEAP_RO

Figure 116. Methane generation constant



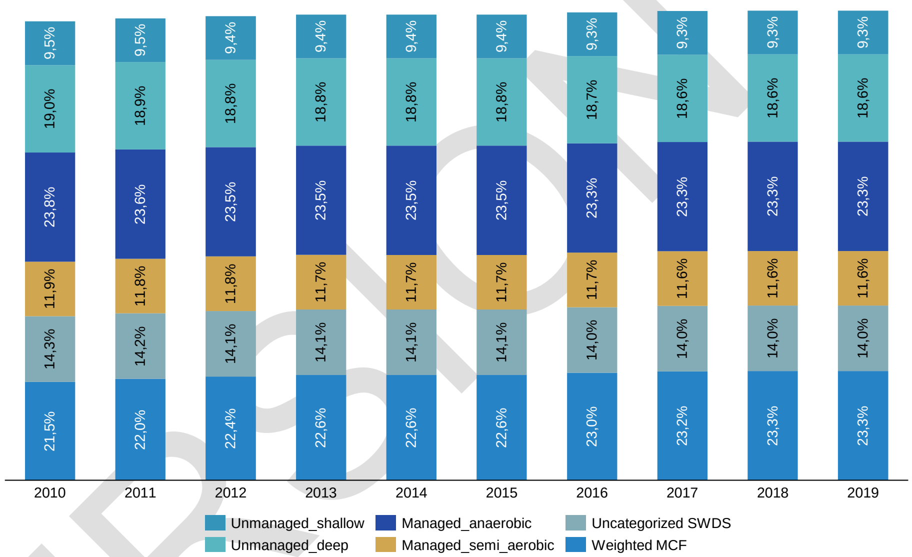
Source: Model LEAP_RO

Figure 117. Methane correction factor in MSW



Source: Model LEAP_RO

Figure 118. Methane correction factor in industry



Source: Model LEAP_RO

Figure 119.Distribution of waste industry and distributions of sludge in MSW

Source: Model LEAP_RO

The main parameters employed for modelling Biological Treatment of Solid Waste are listed in the Figure 120. They were constant during the entire period of the analysis 2010-2019.

Figure 120. Main parameters used for modelling Biological Treatment of Solid Waste

Branch	Expression	Scale	Units
CH4 emission factor	10		g CH4/kg waste treated
N2O emission factor	0.6		g N2O/kg waste treated
Biogas TJ converted to mass of CH4	50.4		TJ/Gg
Leakage at biogas facility	5		fraction

Source: Model LEAP_RO

Incineration and burning of waste sector is divided into 3 subcategories: clinical, hazardous and biogenic waste. The modelling parameters employed for the first and second subcategories are presented in Figure 121.

Figure 121. Input parameters for the sub - categories of the Incineration and open burning of waste category

Branch	Expression	Scale	Units	Branch	Expression	Scale	Units
C content of waste	60	Percent	%	C content of waste	50	Percent	%
Fossil Carbon as percentage of total_carbon	40	Percent	%	Fossil Carbon as percentage of total_carbon	90	Percent	%
Efficiency_of comustion	100	Percent	%	Efficiency_of comustion	100	Percent	%
N2O emission factor	100		kg N2O/Gg wet waste	N2O emission factor	100		kg N2O/Gg wet waste
CH4 emission factor	6		kg CH4/Gg wet waste	CH4 emission factor	6		kg CH4/Gg wet waste

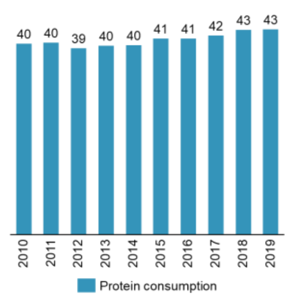
Source: Model LEAP_RO

For Biogenic waste, an emission factor for N_2O of 226 kg N_2O/Gg wet waste and for CH_4 of 60 kg CH_4/Gg wet waste were considered. All of the above listed factors cover the 2010-2019 period.

The last category of Waste considered, Domestic wastewater treatment (WWT) and discharge, consists of two sub-categories: Domestic and Industrial WWT. The DWWT main parameters were nearly constant in the period 2010-2019, as shown Figure 122.

Figure 122. The main parameters used for modelling the treatment and disposal of domestic wastewater

Branch	Expression	Scale	Units
Degradable organicv component BOD	21.9		kg BOD/cap/year
Fraction of waste removed as sludge	0.63		fraction
Protein consumption	Interp(2010, 39.9300, 20...		kg/person/year
Fraction of nitrogen in protein	0.16		kg N/kg protein
Fraction of non_consumption protein	1.1		factor
Fraction of industrial and commercial co_discharge	1.25		factor
Nitrogen removed with sludge	0		kg
Emission factor	0.005		kg N2O-N/kg N

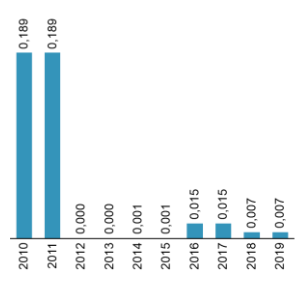


Source: Model LEAP_RO

The sub-categories Unconnected to sewerage; Connected to sewerage which are not connected to wastewater treatment plants and Centralized aerobic treatment plant are modelled by several paraments. However, the only factor that varied during 2010-2019, as shown on the Figure 123.

Figure 123. The main parameters used for modelling the subcategories Not connected to sewage systems; Connected to sewage systems which are not connected to wastewater treatment plants and Centralized aerobic treatment plant

Branch	Expression	Scale	Units
Max_CH4 production capacity B0	0.6		kg CH4/kg BOD
CH4 correction factor MCF	0.5		factor
Correction factor for industrial BOD discharged in	1.25		factor



***Source**: Model LEAP_RO*

Industrial WWT includes, among others, the waste the beer industry, pulp & paper and petroleum products refinery. The main factors used for modelling industrial WWT and their 2010-2019 values are presented in Figure 124.

Figure 124. The main parameters used for modelling the industrial WWT - beer industry, paper & pulp industry and refining petroleum products

Branch	Expression	Scale	Units
Methane conversion factor_MCF	0.7		factor
Maximum methane producing capacity BOI	0.25		kg CH4/kg COD
EF for industrial wastewater	0.18		kg CH4/kg COD
Wastewater generated	6.3		m3/t
Degradable organic compoment COD	2.9		kg/m3

Branch	Expression	Scale	Units
Methane conversion factor_MCF	0.03		factor
Maximum methane producing capacity BOI	0.25		kg CH4/kg COD
EF for industrial wastewater	0.01		kg CH4/kg COD
Wastewater generated pulp_paper	162		m3/t
Wastewater generated petroleum	0.6		m3/t
Degradable organic compoment COD pulp_paper	9		kg/m3
Degradable organic compoment COD petroleum	1		kg/m3

Source: Model LEAP_RO

9.3 List of abbreviations

ANRE	**National Regulatory Authority in the field of Energy**
BR 4	**Romania's Fourth Biennial Report under the UNFCCC**
BR 5	**Romania's Fifth Biennial Report under the UNFCCC**
CAP SP	**Strategic Plan of Common Agricultural Policy 2023-2027**
CCGT	**Combined Cycle Gas Turbine**
CCUS	**Carbon Capture Use and Storage**
CEO	**Energy Complex Oltenia**
CISC	**Interministerial Committee on Climate Change**
CHP	**Combined Heat and Power**
CNG	**Compressed Natural Gas**
CNSP	**National Commission for Strategy and Prognosis**
CRF	**Common Reporting Format**
CTE	**Thermoelectric Plant**
DDD	**Department for Sustainable Development**
DG ENER	**Directorate-General for Energy**
DF REFORM	**Directorate-General for Structural Reform Support**
DOC	**Dissolved Organic Carbon**
EC	**European Commission**
EIB	**European Investment Bank**
EEA	**European Environmental Agency**
ENTSO-E	**European Network of Transmission System Operators for Electricity**
EU	**European Union**
EU ETS	**European Union Emissions Trading System**
FEC	**Final Energy Consumption**
GD	**Government Decision**
GEO	**Government Emergency Ordinance**
GHG	**Greenhouse Gas**
HGV	**Heavy Goods Vehicle**
INEGES	**National Inventory of GHG**
INS	**National Institute of Statistics**
IPCC	**Intergovernmental Panel on Climate Change**
IPPU	**Industrial Processes and Product Use**
LCV	**Light Commercial Vehicle**
LEAP	**Low Emission Analysis Platform**
LEAP_RO	**The energy and climate predictions model specifically elaborated for the Romanian LTS**

LPG	**Liquefied Petroleum Gas**
LTS	**Long Term Strategy**
LULUCF	**Land Use, Land-Use Change and Forestry**
MADR	**Ministry of Agriculture and Rural Development**
MCID	**Ministry of Research, Innovation and Digitalization**
MDLPA	**Ministry of Development, Public Works and Administration**
ME	**Ministry of Energy**
MEc	**Ministry of Economy**
MIPE	**Ministry of European Investments and Projects**
MMAP	**Ministry of Environment, Waters and Forests**
MMSS	**Ministry of Labour and Social Protection**
MS	**EU Member State**
MSW	**Municipal Solid Waste**
MTI	**Ministry of Transport and Infrastructure**
NC 8	**Romania's Eight National Communication under the UNFCCC**
NECP	**National Energy and Climate Plan – In Romania, this is called the Integrated National Plan for Energy and Climate Changes 2021-2030 (PNIESC)**
NEEAP IV	**National Energy Efficiency Action Plan (2017)**
NIR	**National Inventory Report**
OECD	**Organisation for Economic Co-operation and Development**
PEC	**Primary Energy Consumption**
PM	**Prime Minister**
PNASC	**National Action Plan for the implementation of the SNASC in the period 2023-2030**
PNDR	**2014-2020 National Programme for Rural Development**
PNRR	**National Recovery and Resilience Plan**
PP	**Power Plant**
RDI	**Research, Development and Innovation**
RES	**Renewable Energy Source**
SRE-E	**Renewable Energy Source in Electricity**
SRE-H&C	**Renewable Energy Source in Heating & Cooling**
RES-T	**Renewable Energy Source in Transport**
SDG	**Sustainable Development Goal**
SNASC	**National Strategy on Adaptation to Climate Change for 2022-2030**

SNDDR 2030	**National Strategy for the Sustainable Development of Romania 2030**
SNRTL	**National Long-Term Renovation Strategy to support the renovation of the national stock of residential and non-residential buildings, both public and private, and its gradual transformation into a real estate stock with a high level of energy efficiency and decarbonization by 2050**
UNFCCC	**United Nations Framework Convention on Climate Change**
UN	**United Nations**
WWT	**Wastewater Treatment**

9.4 List of documents and data info sources (Selection)

For calibrating the LEAP_RO model and elaborating hypotheses and targets of the LTS, the following list of documents and data sources were employed (selection):

1. Energy balances 2010-2021 (EUROSTAT, TEMPO)
2. National Energy and Climate Plan for 2021 - 2030 (NECP)
3. The National Energy Strategy of Romania 2022-2030, with the perspective of 2050
4. Romania’s Fourth and Fifth Biennial Report under the United Nations Framework Convention on Climate Change (UNFCCC) (BR 4 and BR 5)
5. Romania’s Eighth National Communication under UNFCC
6. National Inventory Report (NIR), 2022
7. Common Reporting Format (CRF) Tables, 2010-2020
8. Romania - Progress in the net zero transition, OECD, 2021
9. JRC Model - EU_TIMES_2019_11 (technology efficiency)
10. Opportunities for Hydrogen Energy Technologies Considering the National Energy & Climate Plans, Trinomics, 2020
11. Romania's National Recovery and Resilience Plan (PNRR) adopted by the EU Council on 28.10.2021
12. National Strategy for the Sustainable Development of Romania 2030
13. The macroeconomic data of the National Commission for Strategy and Prognosis (CNSP)
14. National Strategy on Adaptation to Climate Change for 2022-2030 (SNASC 2022-2030) and National Action Plan for the implementation of the SNASC in the period 2023-2030 (PNASC 2022-2030)
15. National Strategy for Research, Innovation and Smart Specialization, 2022-2027
16. The Paris Agreement on Climate Change, adopted in December 2015 and entered into force in November 2016
17. National Strategy for the Sustainable Development of Romania 2030 (SNDDR 2030)
18. National Action Plan for implementing the SNDDR 2030
19. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions “Next steps for a sustainable European future - European action for sustainability”, COM(2016) 739 final, 22.11.2016
20. Regulation (EU) 2018/841 of the European Parliament and of the Council of 30 May 2018 on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework and amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU, with its latest amendments and completions.
21. Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 Governance of the Energy Union and Climate Action
22. Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC
23. Commission Regulation (EU) No 601/2012 of 21 June 2012 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council
24. Regulation (EU) 2018/842 of the European Parliament and of the Council of 30 May 2018 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement and amending Regulation (EU) No 525/2013

25. Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014 amending Directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large undertakings and groups
26. Commission Delegated Regulation (EU) 2021/2139 of 4 June 2021 supplementing Regulation (EU) 2020/852 of the European Parliament and of the Council by establishing the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to climate change mitigation or climate change adaptation and for determining whether that economic activity causes no significant harm to any of the other environmental objectives
27. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions “A hydrogen strategy for a climate-neutral Europe” - COM(2020) 301 final, 08.07.2020
28. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and The Committee Of The Regions “A Green Deal Industrial Plan for the Net-Zero Age” - COM(2023) 62 final, 01.02.2023
29. Proposal for a regulation of the European Parliament and of the Council on establishing a framework of measures for strengthening Europe’s net-zero technology products manufacturing ecosystem (Net Zero Industry Act) - COM(2023) 161, 16.03.2023
30. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions “Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe’s recovery” - COM(2021) 350 final, 05.05.2021
31. Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC
32. Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources
33. Fit for 55 package

Energy production

34. ANRE National Reports, 2015-2021
35. INS (TEMPO):
    a. Electric energy production by type of energy plant
    b. Structure of thermoelectric energy by type of consumed fuel
    c. Installed capacity of electric generating sets (end of year)
36. Monthly consumption reports, Transelectrica, 2019
37. Actual generation per Generation Unit, ENTSOE-E
38. GEO 108/2022 of June 30, 2022 on the decarbonization of the energy sector, with its latest amendments and completions
39. GEO 175/2022 of December 14, 2022 for setting-up measures regarding the investment objectives for the realization of hydropower plants in progress, as well as other projects of major public interest that use renewable energy, as well as for the modification and completion of some legislation, with its latest amendments and completions
40. The 2021-2025 Restructuring Plan of the Oltenia Energy Complex with a 2030 perspective
41. GEO 21/2022 of March 10, 2022 regarding setting-up the legal framework for granting restructuring state-aid to Oltenia Energy Complex S.A. company

Transport

42. Romania's General Transport Master Plan (MPGT) and the Investment program for the development of transport infrastructure for the period 2021-2030
43. Emission reduction strategy for the transport sector in Romania – A report produced under the framework of the EUKI Project, 2018
44. Inland Waterways' Importance for the European Economy. Case Study: Romanian Inland Waterways Transport, scientific paper by V.R. Ionescu, published in Journal of Danubian Studies and Research, Vol. 6, Pag. 180, 2016
45. Transport and environment report 2020: Train or plane?, EEA
46. Registered road vehicles, TEMPO
47. Motor vehicle movements on national and foreign territory (registered in the reporting country), EUROSTAT
48. Passengers transport in domestic and international transport, by type of transport, TEMPO
49. Freight transport by type of vehicles, transport capacity and type of road transport, TEMPO
50. New registrations of road vehicles for passenger transport, by macroregions, development regions and counties, TEMPO
51. New registrations of vehicles for freight transport, by macroregions, development regions and counties, TEMPO

Buildings

52. 01_JRC-EU-TIMES Full Moldel, Nijs, Wouter, Ruiz, Pablo, European Commission, 2019, http://data.europa.eu/89h/8141a398-41a8-42fa-81a4-5b825a51761b
53. Renovating Romania - A strategy for the sustainable renovation of Romania's building stock, Buildings Performance Institute Europe, 2014
54. National Long-Term Renovation Strategy to support the renovation of the national stock of residential and non-residential buildings, both public and private, and its gradual transformation into a real estate stock with a high level of energy efficiency and decarbonization by 2050 (SNRTL)
55. The potential for investment in energy efficiency through financial instruments in the European Union - Romania in-depth analysis, EC & EIB, 2020
56. Report on the state of the public heat energy supply service in the centralized system for 2019, ANRE
57. INS:
    a. Resident population by age, sex, urban/ rural area, macroregions, development regions and counties, TEMPO
    b. The structure of households by the dwelling's tenure status, urban/ rural area, TEMP
    c. Development of detailed statistics on energy consumption in households, SECH Project, Final Report - Annex 4.
58. EUROSTAT
    a. Average number of persons per household, by household composition, number of children and working status of the persons in the household
    b. Final energy consumption in households by end-use (Disaggregated final energy consumption in households – quantities)
    c. Final energy consumption - other sectors - households - energy use
        i. Final energy consumption - other sectors - households - energy use - space heating
        ii. Final energy consumption - other sectors - households - energy use - space cooling
        iii. Final energy consumption - other sectors - households - energy use - water heating
        iv. Final energy consumption - other sectors - households - energy use – cooking
59. Energy efficiency trends in buildings in the EU, Odyssee-Mure, 2021

Agriculture & LULUCF

60. Structural Survey in Agriculture, INS, 2016
61. Agricultural Census (2020 - provisional data)
62. National Forest Accounting Plan for Romania for the First Commitment Period (2021-2025)
63. Strategic Plan of Common Agricultural Policy 2023-2027 (2023-2027 CAP SP)
64. 2014-2020 National Programme for Rural Development (PNDR)
65. National Strategy for Forests 2030

Waste

66. https://www.eea.europa.eu/themes/waste/waste-prevention/countries/romania-waste-prevention-country-profile-2021/view
67. https://zerowasteeurope.eu/wp-content/uploads/2020/07/zero_waste_europe_policy-briefing_achieving-the-eu%E2%80%99s-waste-targets.pdf
68. https://www.esauk.org/application/files/9616/4268/9204/Appendix_2_ESA_EF_Review_Final.pdf
69. National Strategy for the Circular Economy in Romania, 2022