ISPRA
Istituto Superiore per la Protezione
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Sistema Nazionale
per la Protezione
dell'Ambiente

Efficiency and decarbonization indicators in Italy and in the biggest European Countries

Edition 2025

RAPPORTI
418/2025

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ISPRA, Rapporti 418/2025
ISBN 978-88-448-1280-5

Graphic design
Grafica di copertina: Alessia Marinelli - ISPRA – Area Comunicazione Ufficio Grafica
Immagine di copertina: Elaborazione di Antonio Caputo da immagine generata con ChatGPT

Coordination of the online publication:
Alessia Marinelli
ISPRA – Communications Area

Settembre 2025

This report is fed by data produced by the colleagues involved in the greenhouse gas emissions Inventory, as well as colleagues involved in the GHGs projections. My gratitude goes to each one of them and in particular to Emanuele Peschi, always available to discuss any elaboration of data.
Any errors remain my responsibility.

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"Il problema che in primo luogo va risolto, e fallendo il quale qualsiasi altro progresso non è che apparenza, è la definitiva abolizione della divisione dell'Europa in stati nazionali sovrani."

"The most pressing problem, without whose solution progress is merely an illusion, is the definitive abolition of the division of Europe into national, sovereign states."

Altiero Spinelli, Ernesto Rossi, *Per un'Europa libera e unita / Towards a free and united Europe*, Ventotene, 1941.

"L'Italia è un paese di picchi e di abissi [...]. Il confronto con L'Europa, per molti versi anche traumatico, è destinato a rompere l'incantesimo dei nostri «cento anni di solitudine»".

Giovanni Perazzoli, *Contro la miseria. Viaggio nell'Europa del nuovo welfare*, 2014

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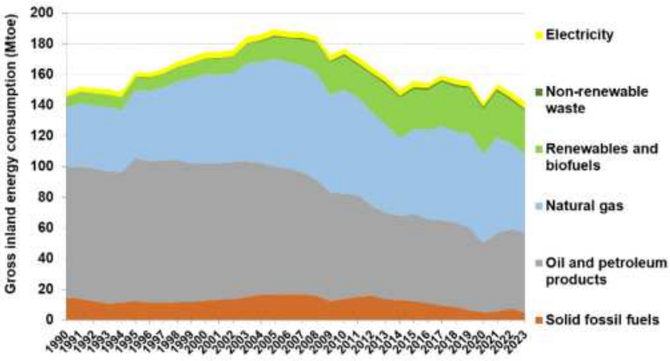
EXECUTIVE SUMMARY

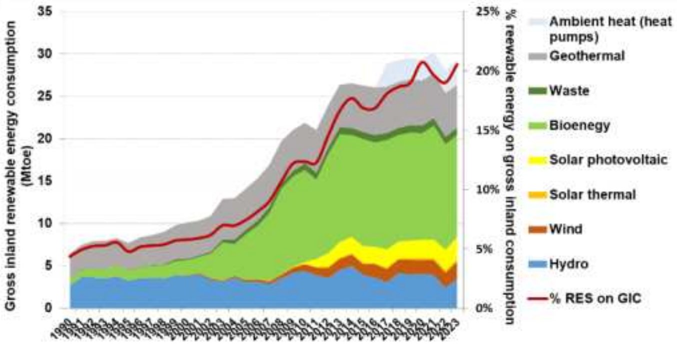
NATIONAL DATA

Italian energy consumption and GHGs

Gross inland energy consumption in Italy shows an increasing trend from 1990 until 2005, when it peaked at 189.4 Mtoe, then there was a reduction, accelerated by the economic crisis started in 2008, with the minimum value of 149.8 Mtoe reached in 2014 and a recovery in the following years. After the fall occurred in 2020 due to SARS-CoV-2 pandemic in 2021 a rebound of consumption has been recorded (+8.8% higher than 2020), with 154 ktoe, followed by further setback in 2022 and 2023, which is only 0.4% higher than 2020.



Fossil fuels are the main energy carriers in the national energy system. From 1990 to 2007, the average ratio of fossil fuels over the gross domestic consumption was more than 90%, although with a slight decline. After 2007 the share of fossil energy has been severely reduced. From 1990 to 2023 the share of fossil energy decreased from 93.6% to 76.4%. The decline has become particularly steep since 2007. The national fuel mix has changed considerably since the 1990s. Oil products accounted for the predominant component with 57.3% of gross domestic consumption in 1990. The share of oil products has steadily decreased to 31.7% in 2020, with a rebound in the following years. The share of natural gas follows a specular trend with constant increase since 1990 up to 2020 (from 26.3% to 41.2%), followed by a decreasing trend (35.4% in 2023). The share of solid fuels, after a decreasing trend since 2012 up to 2021 (from 9.6% to 3.6%), recorded a rebound to 5% in 2022 and a downward trend up to 2024, around 1.5%.



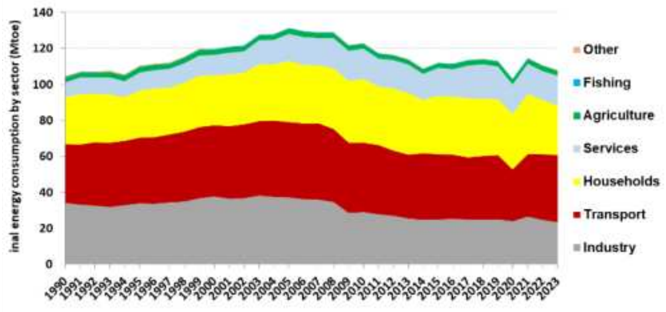
The share of energy from renewable sources is complementary to that observed for fossil fuels. From 1990 to 2007 there was a steady increase in the share of such sources from 4.4% to 9%. After 2007 the share accelerated to 20.7% of gross inland consumption in 2020, followed by a setback in the last years (19.6% in 2021 and 19% in 2022) and a rebound in 2023 (20.5%). According to the preliminary data for 2024, the renewable share on gross inland consumption should increase to around 21.7%.

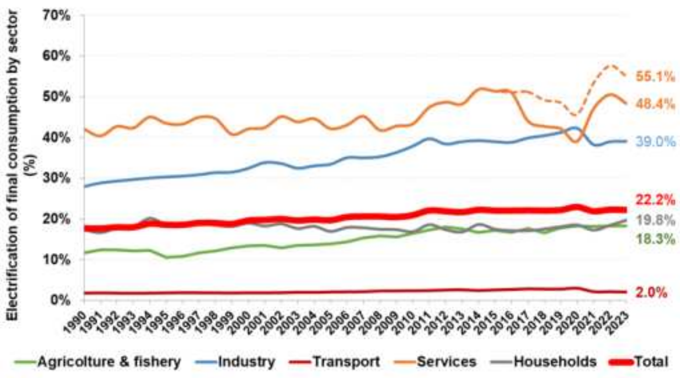
Up to 2000 the main sources of renewable energy have been geothermal and hydro, which accounted for more than 80% of gross inland consumption of renewable energy. The remaining share was mainly met by biomass and renewable wastes (bioenergy). Since 2000, the bioenergy has shown a considerable growth, reaching the peak of time series in 2008, with a share of 50.9%. After 2008 the share of bioenergy decreased (44.1% in 2023) in the aftermath of the increase of other sources, as solar (thermal and photovoltaic) and wind. Solar and wind sources have assumed significant role and together represent 16.9% of total renewable energy consumption in 2023. The energy by heat pumps has been recorded by Italy in the Eurostat budget since 2017. Such item in 2023 was 9.8% of renewable gross inland consumption.

The final energy consumption per sector shows structural peculiarities for each sector and different sensitivities to the contingency, such as economic crisis since 2008 or 2020 lockdown which have mainly affected the productive branches. The final energy consumption of industry decreased by 31.1% from

1990 to 2023, while the services increased by 103.1%. The trend of final consumption in the households is quite variable depending upon different climatic conditions that affect the consumption. The consumption of such sector in 2023 is 5.9% over the 1990 level. Transport increased by 13.4% compared to 1990, after the fall in 2020 due to the lockdown measures.

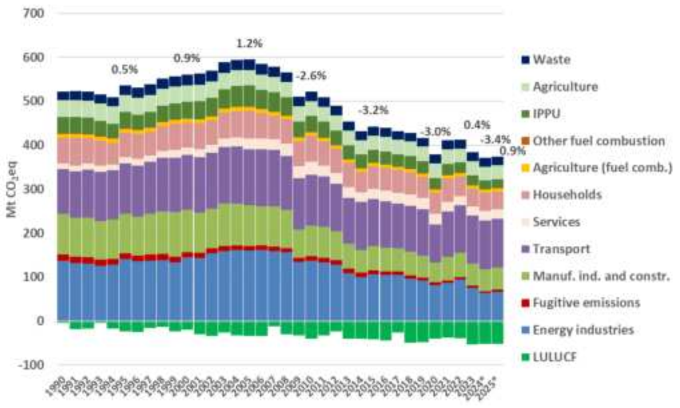
Since the 1990s, the structure of sectors in terms of energy consumption has changed considerably. Services account for an increasingly share of final consumption from 7.8% in 1990 to 15.4% in 2023, while industry reduces its share of energy consumption from 32.6% to 21.8% over the same period. Consumption in the households shows a growing trend until 2010 followed by slight decrease with large fluctuations mainly due to the average temperature. The average share of consumption in the other sectors, mainly agriculture and fisheries, is about 3%.





The electrification of final consumption is a key strategy to curb GHGs if pursued in parallel with the spread of renewable energy for electricity production. The share of electricity in final energy consumption increased since 1990 and in 2023 is 22.2%. The sectoral electrification level of final consumptions is quite different. Services show the highest share of electricity consumption, with more than 50% of the sector's final consumption. The rate of electrification of final consumption in industry has been steadily increasing since 1990, with 39% of electricity in the final consumption in 2023. The wide oscillations recorded in the last years for services and industry are also due to significant change in the countability methodology. The electrification of households and transport sectors shows no significant increase in the long run and in 2023 were 19.8% and 2% respectively. Agriculture and fisheries show an increase of electrification, similarly to industry, and in 2023 the level was 18.3%.

In this report the GHG emissions submitted by Italy and other EU countries to UNFCCC in April 2025 are considered, even though these data have recently undergone a comprehensive review by the European Commission. The outcome of this review, finalized at the end of August 2025, determined technical corrections which will be included in the next Inventory to be submitted in 2026.



GHGs show an increasing trend until 2005, followed by decrease also because of the economic crisis. In 2020 GHGs (380 Mt CO_{2eq}) were heavily affected by lockdown measure to contain SARS-CoV-2 pandemic. GHGs fell by 27.3% in 2020 compared to 1990 and by 36.3% compared to 2005. All sectors reduced the emissions, albeit at different rates. In 2021 and 2022 the GHGs rebounded, although to level below the 2019 level. In 2023 GHGs fell by 26.4% compared to 1990 and by 35.5% compared to 2005. Preliminary data for 2024 confirm the downward trend of total GHGs w/o LULUCF (about -3.4% year over year), while a new increase is expected in 2025 (around +1% year over year) based on data available for the first seven months.

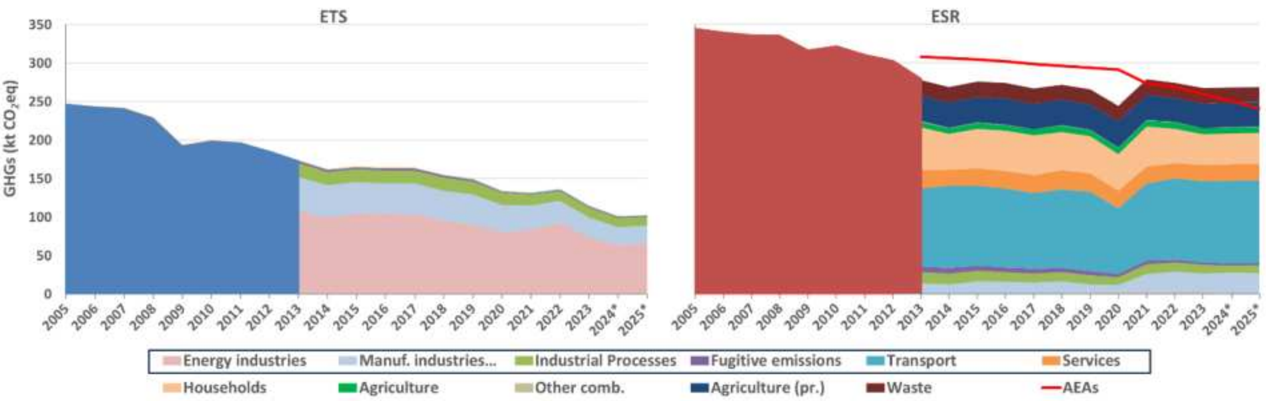
Emissions from manufacturing and construction decreased by 45.3% from 2005 to 2023. Transports increased steadily with a reversal of the trend only after 2007 and the sharp decrease in 2020; GHGs in 2023 are 15.1% lower than 2005, but still over 1990 level (+6.7%). Households reduced the emissions by 31% compared to 1990, while the sector of services increased of 78.1%.

GHGs per capita increased from 9.2 t CO_{2eq} in 1990 to 10.3 t CO_{2eq} in 2004, in the following years there was a rapid decline up to 6.4 t CO_{2eq} in 2020, followed by a rebound in the next years. In 2023 the GHGs per capita came back to 6.5 t CO_{2eq}. The GHGs per capita decreased from 2005 to 2023 with an average annual rate of -2.5% (-1% since 1990).

GHGs from ETS and ESR

To monitor the achievement of emissions reduction targets the GHGs must be allocated in the two compartments: ETS (EU Emissions Trading System, EU ETS) and ESR (Effort Sharing Regulation), defined according to the European legislation.

ETS covers 29.8% of national GHGs in 2023. The share of such emissions steeply decreased from 2005, when it was 41.5%. The ESR scope from 2021 to 2030 remains substantially unchanged compared to the previous period up to 2020, but since 2021 only CO_2 from domestic aviation is not included in the ESR sector, no longer NF3, as until 2020. ESR accounts for 69.6% of total GHGs in 2023 with an increasing share since 2005, when it was almost 58%. GHGs decreased both in ETS and in ESR from 2005 to 2023, even though in ETS with a rate more than 2 times the rate in ESR, -53.6% and -22.6% respectively. Moreover, the ESR target requires compliance with annual thresholds and data since 2021 show that such thresholds have been exceeded: 5.5 $MtCO_2eq$ in 2021, 5.4 $MtCO_2eq$ in 2022, 8.2 $MtCO_2eq$ in 2023. The mentioned technical corrections carried out by the EC determine an increase of such figures of about 1.8 $MtCO_2eq$ per year.



In 2024 preliminary data show a gap of about 19 $MtCO_2eq$, with some uncertainty. Such uncertainty is even wider for 2025 whose early extrapolation shows a gap of about 30 $MtCO_2eq$. According to the policy scenario in the National Energy and Climate Plan (MASE, 2024) the ESR emissions should decrease by 40.6% in 2030, not achieving the mandatory target for any year up to 2030, while the ETS emissions should decrease by 66%.

On the ETS side the dominant role is played by energy industries (64.1% of ETS GHGs in 2023) whose emissions are almost totally included in ETS, only a marginal share is in ESR. In the latter compartment the dominant role is played by transport with 39.5% of GHGs in 2023, the tiny share in ETS for such sector is utterly due to pipeline transport. GHGs from manufacturing industries and construction, together with industrial procesess, account for 33.3% in ETS and 13.4% in ESR. The fugitive emissions in ETS concern only CO_2 from flaring in refineries, while all other sources and GHGs are in ESR. GHGs from services are almost totally in ESR and represent 7.8% of compartment's GHGs. GHGs from households (14.9% of ESR), agriculture (both combustion and processes; 14.9% of ESR), and waste (7.6% of ESR) are totally in ESR.

Sectors with higher share of GHGs should be the priority targets of policies and measures directed to achieve the GHGs reduction goal set for ESR emissions.

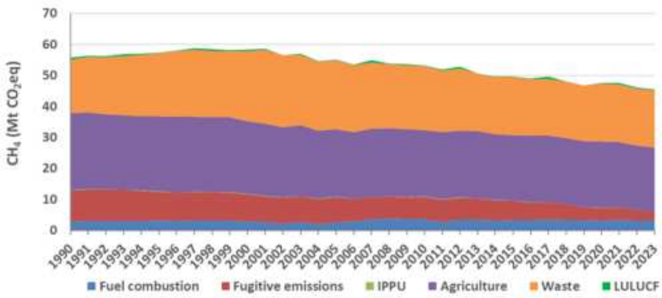
Methane emissions

Methane is a powerful greenhouse gas, second only to carbon dioxide in terms of its contribution to global warming (IPCC, 2021). It is accounted in the GHGs inventory considering Global Warming Potential (GWP) 28 times that of CO_2 over a period of 100 years, according to the UNFCCC's rules. Methane has a GWP about 85 times that of CO_2 over a period of 20 years, although CO_2 has an atmospheric lifetime of thousands of years, while methane disappears in about 10-15 years. The rapid decay of methane and its high impact on atmospheric temperature make it a primary target to curb in a timely and effective manner the climate change.

According to the recent report of the International Energy Agency (IEA, 2025) and IPCC (2022) reducing anthropogenic methane emissions is one of the most effective strategies, including in economic terms, to rapidly reduce the rate of warming and contribute significantly to efforts to limit the increasing global temperature.

National methane emissions, without the contribution of natural sources, represent on average 10.6%±0.8% of total emissions from 1990 to 2023. Methane emissions without LULUCF decreased from 55 to 45.2 Mt CO_2eq from 1990 to 2023 (-17.9%). The reduction of methane emissions is lower than the reduction of total GHGs (-26.4%). Moreover, GHGs other than methane reduced by 27.4% from 1990. These rates show the need to achieve methane emissions reduction from the main sources.

Among the main sources, methane emissions from wastes in 2023 were higher than 1990 levels (+6.8%), although the trend is descending from 2005 (-17.1%). Since 1990 agriculture decreased by 15.6% and fugitive emissions by 72.6%. Considering only methane emissions, agriculture contributes with 46.1% in 2023, while the waste sector accounts for 40.9%. Fugitive emissions make up 6.2%, and unburned methane in the energy sector accounts for 6.8%.

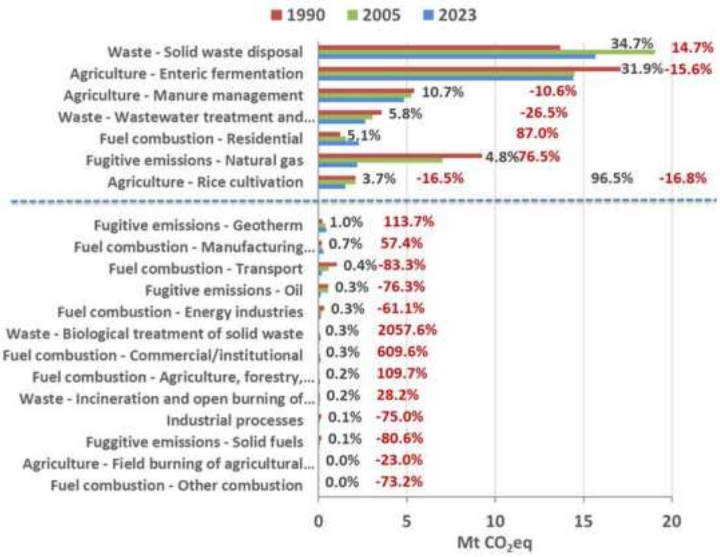


By far the most important source of the agricultural sector is represented by enteric fermentation, or the digestive processes of farm animals. This source represents 69.3% of methane emissions from the agriculture in 2023, followed by manure management with 23.3% and rice cultivation with 7.3%. Emissions due to the combustion of agricultural residues in the open field represent 0.06%.

In the waste sector, the dominant source of methane emissions is represented by the disposal of solid waste, responsible for 84.8% of sector's methane emissions, the next source is represented by wastewater treatment, with 14.2%. The remaining two sources, biological treatment of solid waste and incineration and open field burning, account for a share lower than 1%.

Most of the fugitive methane emissions are due to the natural gas supply chain (production, transport, and distribution) which in 2023 accounts for 78% of total fugitive methane emissions with a share that has decreased significantly since 1990, when it was 91.2%. Oil and natural gas supply chains have recorded reductions in methane emissions of more than 76.5% since 1990.

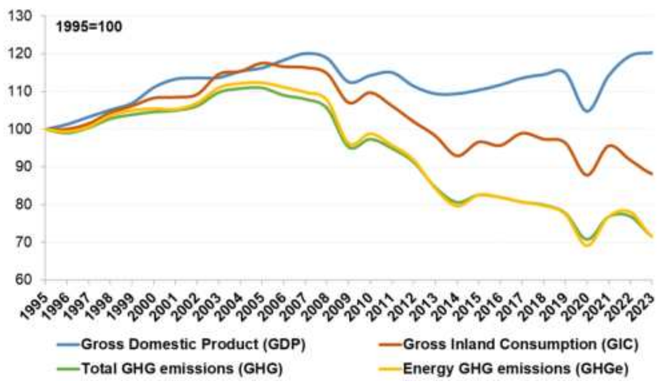
Unburned methane emissions in the energy sector are mainly due to the dominant source of the civil sector (mainly residential) with 81% of methane emissions in the energy sector, followed by manufacturing and construction industries with 9.6%, transport with 5.5% and energy industries with 3.8%.



Arranging in descending order the methane emissions from each source recorded in 2023 it can be noted that 96.5% of methane emissions come from seven key sources that emit 43.6 Mt CO_2eq. Emissions from key sources decreased by 16.8% since 1990. Minor sources, which are cumulatively responsible for 3.5% of emissions, are 39.9% lower than 1990 level. The disposal of municipal solid waste is the first key source with 34.4% of total methane emissions, followed by enteric fermentation with 31.9%. The first two sources are responsible for two-thirds of methane emissions.

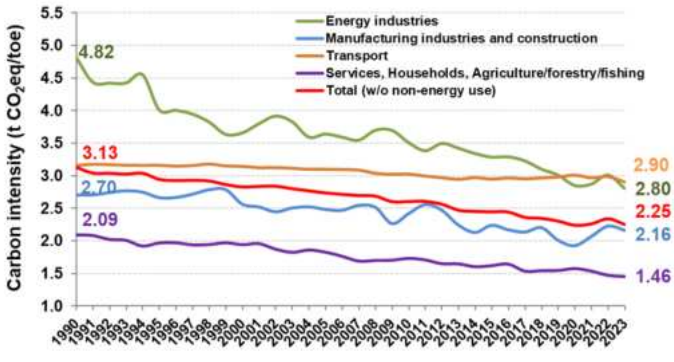
Energy intensity and decarbonization indicators

To assess the relationship between energy, economy and GHGs the trends of gross inland energy consumption (GIC), gross domestic product (GDP at chain linked volumes, reference year 2020) and GHG emissions are analysed. GDP and GIC had parallel trends up to 2005. Then the two parameters begun to diverge showing an increasingly decoupling. GHGs grew slower than GDP until 2005, highlighting a relative decoupling. After 2005, the divergence between the two parameters became wider showing even absolute decoupling when the GDP increased and GHGs decreased (2015-2019).



Decoupling is also evident from the decreasing trend in the ratio of GIC to GDP since 2005. The decreasing trend in energy GHGs per primary energy consumption is mainly due to the replacement of higher carbon fuels with natural gas, mostly in power sector and industry, and to the increase of renewable share. The same decreasing trends are confirmed for final energy consumption (net of non-energy uses) per GDP and for GHGs per final energy consumed.

In the period 1995-2023 the GIC per GDP decreased from 101.1 toe/M€ to 74 toe/M€ (-26.8%). Over the same period, GHGs per GDP fell by 40.5%, from 336.7 t CO_2eq / M€ to 200.3 t CO_2eq/M€, while energy emissions per primary energy goes from 2.81 t CO_2eq/toe to 2.21 t CO_2eq/toe, with a reduction of 21.3%. Since 2005 there has been an acceleration in the decrease of energy intensity (on the economy side) and decarbonization of the national economy up to 2019/2020, once again highlighting the growing decoupling of economic activity, energy consumption and emissions. The causes of such decoupling are manifold and among the main ones there is the contraction of industrial activities, which are more energetic intensive as compared to services characterized by lower energy intensity and higher value added. GHGs per energy consumed (primary and final) decreased rapidly since 2005 mainly because of the increasing share of renewable energy since 2007. After 2020 the indicators show an upward trend due to the increasing share of oil fuels (2021 and 2022) and solid fuels (2022), while in 2023 the indicators get back the downward trend.



Decarbonization at sectoral level can be assessed by energy emissions and energy consumption by sector. The carbon intensity by energy is the ratio between GHGs and energy consumption. The average carbon intensity by sector is very different among sectors, depending upon the different deployment of renewable sources and electrification of final energy consumption. The carbon intensity of energy industries decreases by 41.8% in 2023 compared to 1990, from 4.82 t CO_2eq/toe to 2.8 t CO_2eq/toe. The carbon intensity of manufacturing industry in 2023 is 2.16 t CO_2eq/toe, decreasing by 20.2% compared to 1990 level. The carbon intensity for transport is 2.9 t CO_2eq/toe (-8.2% compared to 1990) and shows the highest value in the last years with the slowest decreasing slope since 1990 among sectors. The carbon intensity in the civil sector is 1.47 t CO_2eq/toe, 29.5% down compared to 1990 value. All declining trends of these indicators are statistically significant to Mann-Kendall test ($p<0.001$). Overall, the carbon intensity for the energy consumption considered, accounting by 93.6%±1.2% of gross energy inland consumption from 1990 to 2023, is 2.25 tCO_2eq/toe in 2023 (-28.1% compared to 1990 level).

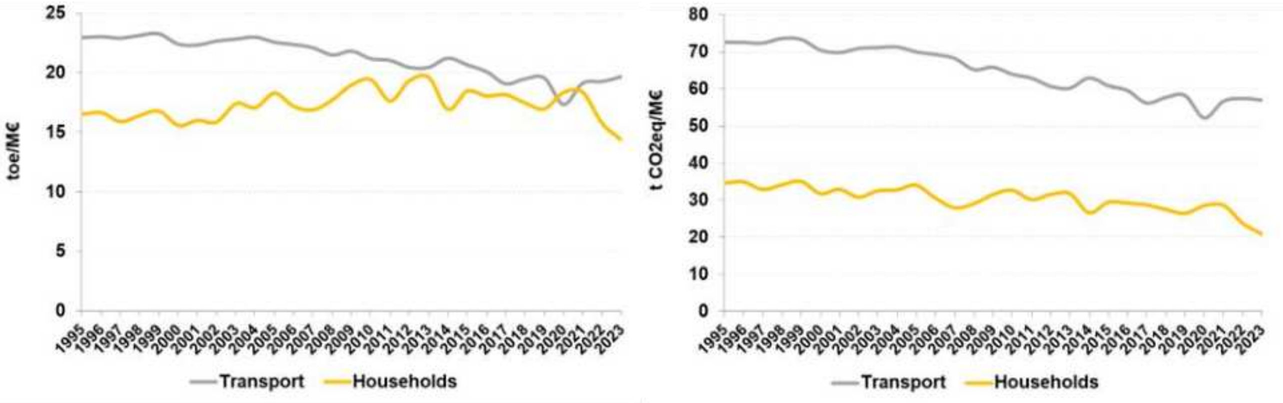
Energy and carbon intensities by economy

The carbon and energy intensity indicators by sector are calculated matching the GHGs by sector with respective energy consumption and value added or GDP for households and transports. Emissions by sector include only direct emissions and emissions from electricity self-production in industry. Indirect emissions, due to electricity consumption from the grid, are not considered, since they are allocated in the energy industries. GHGs from the three sectors (agriculture, industry, services) represent on average 34.5±0.8% of total GHGs. Services metrics suffer some bias due to the inclusion in this sector of emissions from fossil waste burnt in incinerators with energy recovery, while on the energy side the waste incineration is included in the transformation sector.

Overall, emissions from the three sectors fell by 28.9% in 2023 compared to 1995. Combustion and process emissions decreased by 30.2% and 26.8%, respectively. In 2023 the energy intensity (toe/M€) of industry is well below the 1995 level (-34.9%), while services are higher (+26.3%), although in the last years the sector intensity decreased significantly. As for agriculture, after a downward trend from 2003 to 2015 the intensity increased but 2023 level is -8.2% compared to 1995. Aggregate energy intensity for the three sectors decreased by 26.7% over the period 1995-2023.

Carbon intensity, the ratio between GHGs and value added, decreased because of the increasing share of renewable energy and fuels with lower carbon content, such as natural gas. The carbon intensities per value added are very different among sectors. Agriculture has the highest values, while services recorded the lowest ones. In 2023 the agriculture intensity is 16.8% below the 1995 level, while services are 12.3% over. Industry shows a robust downward trend (-45.8% in 2023 compared to 1995) which heavily determine the aggregate trend (-43.3% in 2023).

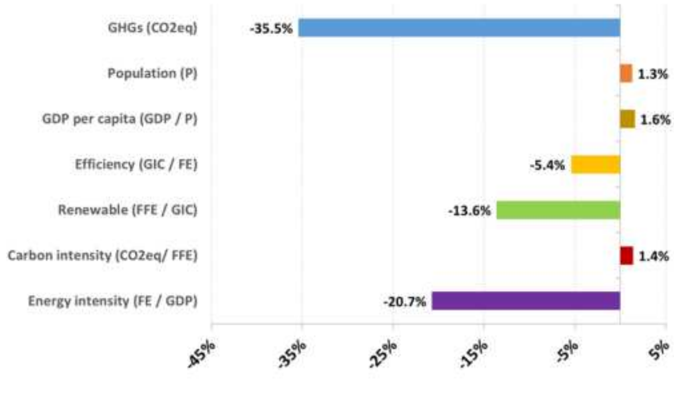
Energy and carbon intensities by economy for transport and households are calculated considering the GDP. The energy intensity of households fluctuates around an average without a clear tendency downward or upward (17.3±1.3 toe/M€), while the carbon intensity shows a downward trend since 1995 (from 34.5 t CO_2eq/M€ in 1995 to 20.8 t CO_2eq/M€ in 2023; -39.8%). The trend of GHGs emissions by GDP witnesses the sector's change of energy mix in the final consumption, with increasing contribution of biomass leading to lower carbon intensity but not reducing energy intensity.



The energy intensity of transport decreased by 15.9%, from 23 toe/M€ to 19.3 toe/M€ from 1995 to 2023. A quite parallel decreasing trend was observed for carbon intensity with a reduction by 21.6%, from 72.6 t CO_2eq/M€ to 56.9 t CO_2eq/M€, showing some decarbonization also in this sector. However, an in-depth analysis shows that for transport there is no real decoupling between energy and carbon intensities. Households' carbon and energy intensities by GDP show a growing distance since 2005, due to the decrease of GHGs compared to energy consumption.

Kaya identity and decomposition analysis

Decomposition analysis is a technique for studying the variation of an indicator in each time interval in relation to the variation of its driving factors. In other words, the variation of a parameter is decomposed in the variation of the parameters that determine it. The starting point of the analysis is the construction of an identity equation, where the variable whose variation over time is to be studied is represented as the product of components considered as the causes of the observed variation. In the identity equation the examined variable is indicated as a product of the driving factors, expressed as ratios where the denominator of a factor is the numerator of the next one. This identity, called Kaya by the economist Yoichi Kaya, is provided *a priori,* and must be realized according to a conceptual model consistent with the physical constraints of the studied variable, in addition to the considerations related to the availability of data and the objectives of the analysis.

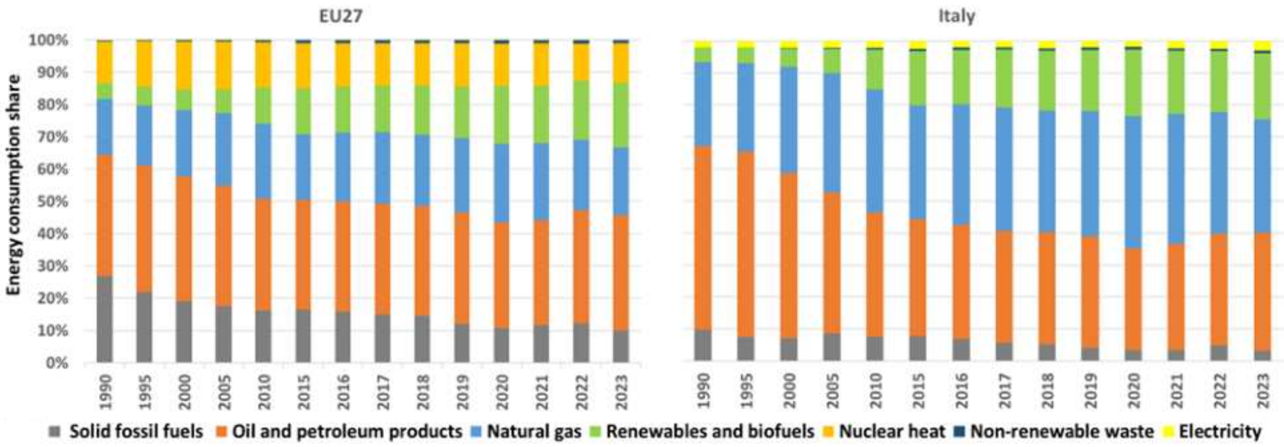


GHG emissions are decomposed in six driving factors to assess the change from 2005 to 2023: 1) population; 2) economic growth per capita; 3) efficiency; 4) renewable energy deployment; 5) carbon intensity from fossil fuels; 6) final energy intensity. The outcomes of decomposition analysis, carried out according *Logarithmic mean Divisia index* (Ang, 2005), shows that the effect of the factors that led to a reduction of emissions in the period 2005-2023 overcome the effect of the factors that led to an increase of emissions. The three factors which led to the growth of emissions contributed collectively with +4.3%. The remaining factors have led to a reduction of GHGs. The final energy intensity (final energy consumption / GDP) played the main role (-20.7%) followed by the share of renewable energy (fossil energy consumption / gross inland energy consumption; -13.6%) and the efficiency factor (gross inland consumption / final energy consumption; -5.4%). The overall contribution of each factor leads to -35.5% of GHGs over the period 2005-2023.

ITALY AND THE BIGGEST EUROPEAN COUNTRIES

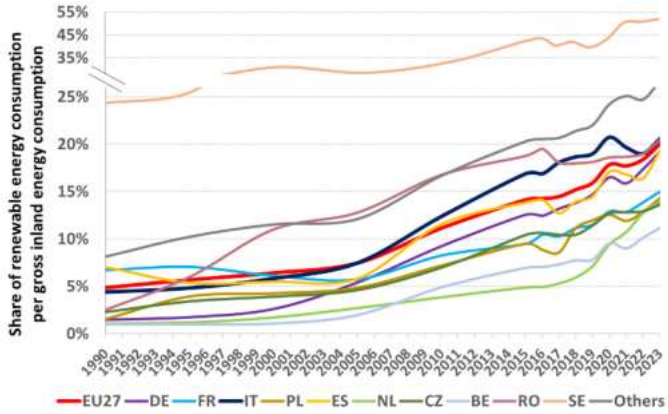
Efficiency and decarbonization indicators

Comparison among Italy and the largest European countries has been carried out for decarbonization and efficiency indicators. The EU Member States with more than 3% of EU27 GHG emissions or more than 3% of EU27 GDP in 2020 are considered for comparison (GDP at chain linked volumes, reference year 2020). The countries examined (Germany, France, Italy, Spain, Poland, the Netherlands, Belgium, Romania, and Sweden) represented 81.6% of the population in EU27 in 2020, 81.6% of GHGs and 83.2% of GDP. The gross inland energy consumption accounted for 82.5% of the energy consumption of EU27.



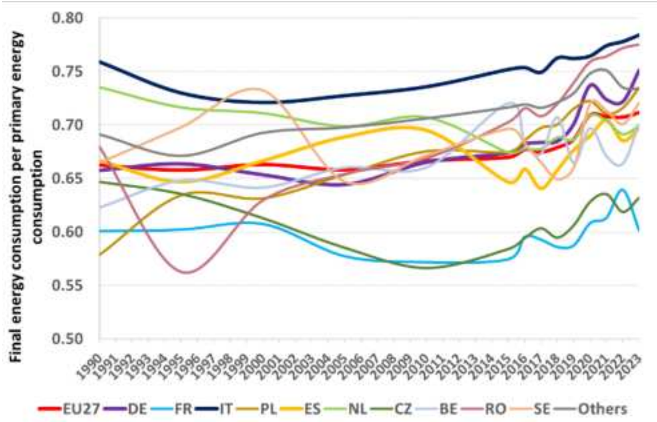
Energy consumption and gross domestic product

Since 1990, European environmental policies have led to a significant change of the energy mix in the Member States. The nuclear energy represented 12.2% of EU27 gross inland consumption in 2023, with a slight increase compared to the previous year, mainly due to the increase recorded in France. The nuclear phase out of Germany goes on and in 2023 the share is 0.7%. Solid fuels energy in EU27 faces significant contraction since 1990, from 26.9% to 9.9% in 2023. All countries reduced their shares, even though there are still significant shares in Germany (16.6% in 2023), Poland (34.7%), and Czechia (27.9%). Oil and petroleum products show a very modest reduction at European level (from 37.6% in 1990 to 35.8% in 2023) with different trends among the States. Natural gas energy consumption shows a considerable increase in almost all States and at EU27 level ranges from 17.1% in 1990 to 21% in 2023, quite lower than the share recorded in 2021 and 2020 (23.9% and 24.4%, respectively). The share of fossil fuels decreased since 1990, from 82% to 67.7% in 2023, while renewable energy increased significantly, from 4.9% to 20.1%.

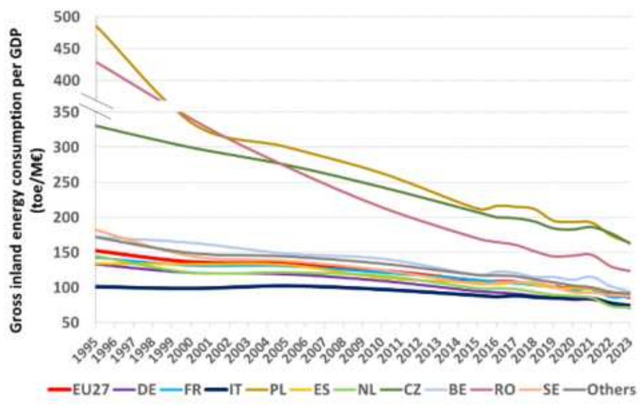


The Italian share of solid fuels, mainly bituminous coal, in gross inland consumption decreased from 9.9% in 1990 to 3.4% in 2023, resuming the downward trend interrupted in 2022. The share of natural gas grew from 26.3% to 35.4%, with a downward trend since 2020 (41.2%), while the share of oil and petroleum products decreased from 57.3% to 36.4% and renewable share grew from 4.4% to 20.5%. Italy's renewable share in gross inland consumption is among the highest in the countries examined, only Sweden's share is higher than the Italian one. However, the European target of renewable share in 2030 concerns the gross final consumption and Italy's overall share is below the European average in 2023 (19.6% vs 24.6%). The 2030 target for Italy is lower than the European average target (38.7% *vs* 42.5%).

The share of fossil fuels decreased significantly in almost all European countries. The EU27 average decreased from 82% in 1990 to 67.7% in 2023. Among the examined countries, the Netherlands and Poland shares are still higher than 85%, respectively 85.1% and 85.3%.



The ratio between the final energy consumption (including non-energy uses) and gross inland consumption is an indicator of energy efficiency. Since 1990 this indicator has always been higher for Italy than for the European average. To evaluate energy transformation efficiency, it is useful to consider energy consumption without non-energy uses. In other words, the ratio between final energy consumption and primary energy. The Italian energy transformation efficiency is higher than any other Countries examined.



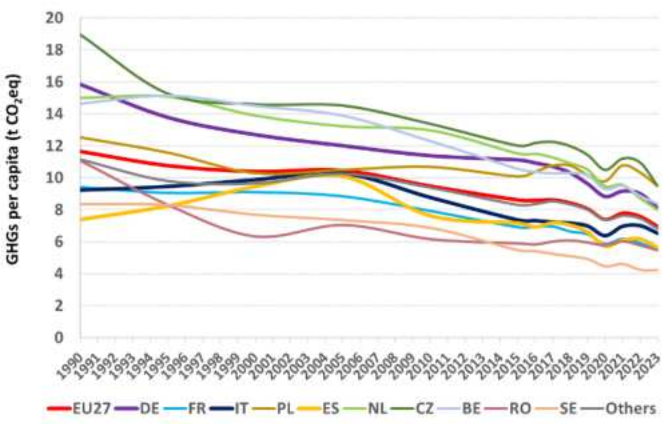
The gross inland energy consumption per gross domestic product (GDP) is an indicator of the country's economic and energy efficiency (energy intensity by economy). Italy was one of the European countries with lowest energy intensity since 1995, then lost positions and in 2023 has the 7th lower values among the 27 countries. Among the biggest EU27 countries, Italy continues having one of the lowest energy intensities, after Germany and the Netherlands.

The final energy intensity (ratio between final energy consumption, including non-energy uses, and gross domestic product) follows similar trends of gross energy intensity with a sharp reduction in the European countries which, starting from higher levels than Italy, reach Italian figures and in some cases exceed them. Since 1995 Italy shows considerable energy and economic efficiency, the final energy intensity reduced by 22.4% from 1995 to 2023 considering GDP at chain linked volumes (reference year 2020), by 54.9% considering GDP at purchasing power standards. Much higher reductions have occurred in the other European countries (EU27: -39.2% GDP at chain linked volumes and -64.7% with GDP at purchasing power standards). The reasons for the reduction in energy intensity observed are manifold such as the increase in building efficiency, industrial efficiency improvement, the electrification of final consumption and the shift of economy towards activities with high value added and low energy consumption as services to the detriment of industrial sectors.

European countries show a wide range of electrification of final energy consumption (energy uses only), ranging in 2023 from 14.3% in Latvia to 39.2% in Malta. Italy is below the EU27 average with 22.2% *vs* 22.9%. Among the biggest countries, Sweden, France, and Spain have higher levels of electrification than Italy, respectively 33.2%, 26.6%, and 24.7%. At the lowest end there are Romania and Poland with 15.3% and 16.6% respectively.

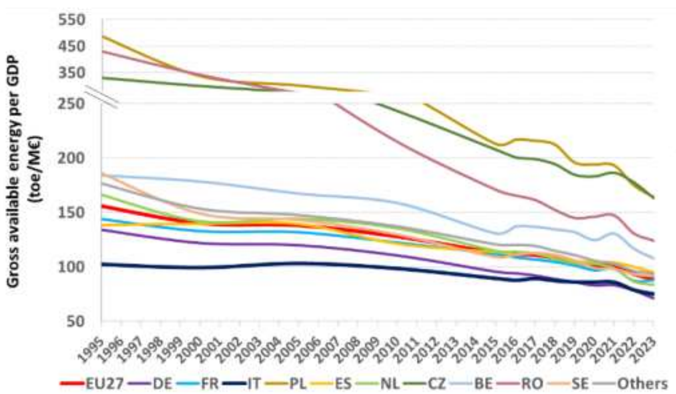
At sectoral level, the Member States' electrification shows different figures although with a common growing trend. The electrification of industry in Italy is among the highest in Europe (39% in 2023) is the highest among the biggest countries and much higher than EU27 average (32.6%). Services show the highest percentages of electrification among sectors. The Italian share in 2023 is 48.4%, lower than EU27 average (51.2%). The electrification of Italian households is much lower than the EU27 (19.8% *vs* 25.9%). The transport sector shows the lowest percentages of electrification in all EU countries. The EU27 average is 2.2% and among the biggest countries the highest percentages are in Sweden (5.8%) and the Netherlands (3.5%). The Italian value is 2%.

GHGs and energy consumption



Italy's average GHGs per capita from 1990 to 2023 is 8.7±1.3 t CO_2eq. Italian GHGs per capita (6.3 t CO_2eq in 2023) have always been below the European average (6.9 t CO_2eq in 2023).

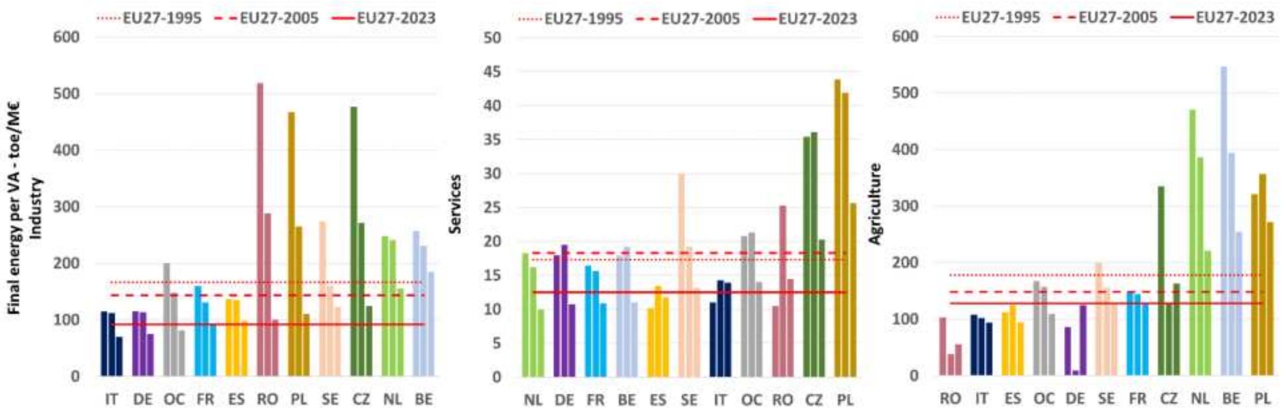
The carbon intensity, GHGs by energy consumption, decreased in all countries since 1990. Such indicator is sensible to the country's energy mix and sources without GHG emissions, like renewables and nuclear. Carbon intensity in Italy is higher than the European average (2.71 t CO_2eq/toe *vs* 2.39 t CO_2eq/toe in 2023). By unbundling nuclear power from gross inland consumption in the European countries, Italy's value is just below the EU27 average (2.71 t CO_2eq/toe *vs* 2.72 t CO_2eq/toe in 2023).



The ratio between GHGs and gross domestic product is the carbon intensity of the economy dimension. Such indicator is sensible to the country's energy mix, as the carbon intensity related to energy, and even more sensible to economy structure: share of services and industry. Moreover, it should be considered that countries' GDP is also driven by activities linked to international bunkers, whose emissions are memo items in the emissions inventories submitted to UNFCCC and not included in sectoral or total emissions statistics. All European countries reduced the carbon intensity of economy and Italy's figures, considering chain linked volumes GDP, have always been below the EU27 average, but in the last years the trajectories are approaching (in 2023 Italy's intensity is 0.2 t CO_2eq/k€ *vs* 0.21 t CO_2eq/k€ in EU27). The same pattern is confirmed considering purchasing power standards GDP (0.19 t CO_2eq/k€ *vs* 0.21 t CO_2eq/k€). Sweden and France have the lowest values: 0.09 t CO_2eq/k€ and 0.15 t CO_2eq/k€, respectively (chain linked volumes). Poland and Czechia are at the upper end with 0.58 t CO_2eq/k€ and 0.44 t CO_2eq/k€, respectively (chain linked volumes).

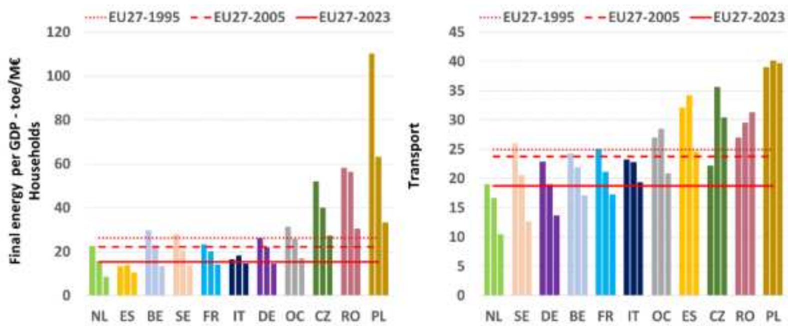
The inclusion of international bunkers in the elaboration of energy intensity and carbon intensity per unit of GDP changes the ranking of countries' ranking, according to the relative share of energy consumption and emissions by international bunkers. Considering the purchasing power standards GDP Italy's carbon intensity is only higher than those recorded in France and Sweden, where the role of energy with zero GHGs (nuclear energy in both countries and bioenergy in Sweden) is notable.

The comparison of efficiency and decarbonization indicators at sectoral level among Member States shows a rather heterogeneous portrait. As for industry in Italy, the ratio between final energy consumption and value added (final energy intensity) has always been the lowest among the biggest countries, with a decreasing trend. Among the European countries only Ireland, Denmark, and Malta have lower industry energy intensities than Italy in 2023. Among the countries examined the Netherlands and Belgium show the highest energy intensities for industry. The average annual rate of the sector energy intensity from 2005 to 2023 decreased of -2.6% for Italy and -2.4% in EU27.



In commercial and public services Italy shows an intensity close to the European average, higher than Germany. Italy is the only State, among the biggest ones, whose energy intensity in this sector did not decrease so much since 2005. The outcome is also due to the accounting of energy consumed by heat pumps, whose data accounting for Italy started from 2017 in Eurostat database, although previously present. The energy intensity from 2005 to 2023 decreased by -0.1% yearly in Italy *vs* -2.1% in EU27.

The agriculture sector shows a general decrease of energy intensity in EU27. In 2023, among the considered countries, only Romania has lower energy intensity than Italy. The energy intensity from 2005 to 2023 decreased of -0.5% yearly for Italy *vs* -0.8% in EU27.

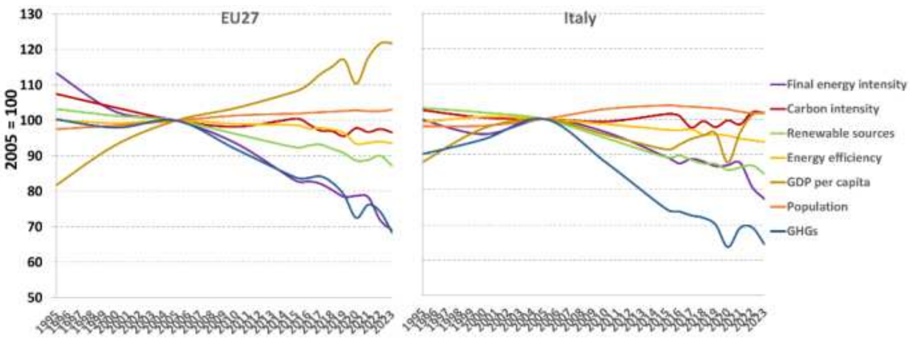


In the households, from 2005 to 2023 the biggest countries show significative reductions of energy consumption per GDP: from -1.3% per year in Italy to -3.5% per year in Poland. The energy intensity for transport in Italy is over the EU27 average. The ranking of the examined countries for households and transport shows that the Italian energy intensity is near the EU27 average. Transport in Italy have wide room for improvement.

What is seen for energy intensity is reflected in the carbon intensity (t CO_2eq/M€). This indicator is more sensible to the role of renewable energies, nuclear power and electricity import in the countries' energy balance, because such sources do not produce GHGs. The Italian industry in 2023 has carbon intensity higher than Sweden and Germany among the biggest countries. As for agriculture Italy recorded the lowest intensity. The Italian intensities for industry and agriculture are respectively 9.1% and 44.6% lower than EU27. On the other hand, carbon intensity of services in Italy is the highest among the biggest countries. Households and transport intensities in Italy are just over the EU27 average (+16.3% for households, +7.2% for transport in 2023), showing some potential to reduce GHGs in households, especially considering that the electrification of final consumption in such sector is much lower than the EU27 average (households: 19.8% *vs* 25.9% in 2023).

Kaya identity and decomposition analysis

The trend of *kaya identity* parameters for EU27 and Italy in the period 1995-2023 shows the different role for the driving factors in GHG reductions. The most powerful factor in EU27 is the final energy intensity, while in Italy both renewable sources and final energy intensity (final energy consumed per GDP) are the driving factors. Moreover, in EU27 population and GDP increased, while in Italy such factors recorded downward trends. The GHGs change is the integrated result of the driving factors change. In EU27 there is an absolute decoupling between economy and GHGs, while in Italy only a relative decoupling is recorded for many years.



The outcomes of decomposition analysis show that in Italy the final energy efficiency played a less important role than in other countries because of the better performance of the indicator in Italy already in 2005. Moreover, unlike Italy, most countries recorded the sensible increase of GDP per capita since 2005.

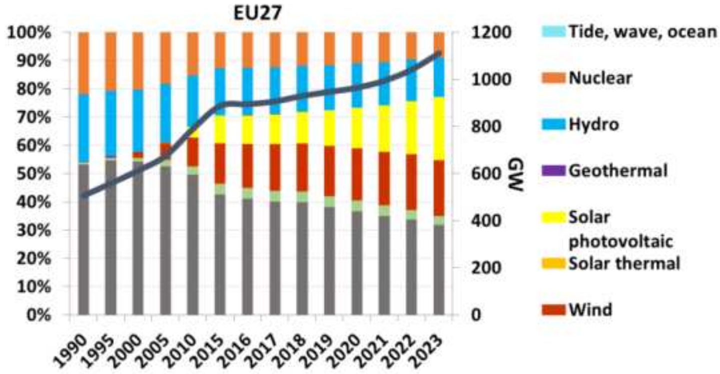
The decoupling does not necessarily correspond to emission reductions in line with the targets. Decomposition analysis focuses on the relative change of the parameters, without assigning any weight to the starting points. The economic and energy efficiency of the Italian system is among the highest in Europe. The last edition of the *International Energy Efficiency Scorecard*, issued by ACEEE in 2022, reported for Italy the drop of four ranks since the previous edition in 2018, mainly due to buildings section, but Italy managed to rank within the top five, after France, UK, Germany, and the Netherlands. The ACEEE International Energy Efficiency Scorecard evaluates the efficiency policies and performance of 25 of the most energy-consuming countries globally. ACEEE used 36 metrics, both policy and performance-oriented metrics, to score each country's efforts to save energy and reduce GHGs across four categories: buildings, industry, transportation, and overall national energy efficiency progress. "*Policy metrics highlight best practices in government actions and can be either qualitative or quantitative. Examples include national targets for energy efficiency, building and appliance labelling, and fuel economy standards for vehicles. The performance-oriented metrics are quantitative and measure energy use per unit of activity or service extracted. Examples include the efficiency of thermal power plants, energy intensities of buildings and industry, and average on-road vehicle fuel economy.*" (Subramanian *et al.*, 2022).

The efficiency improvement cannot be separated from the assessment of the potential and cost effectiveness of the energy system change. Moreover, a mindful assessment of the country's economic structure must be considered, especially concerning the role of services and industry which have very different energy intensities and carbon footprints.

Power sector

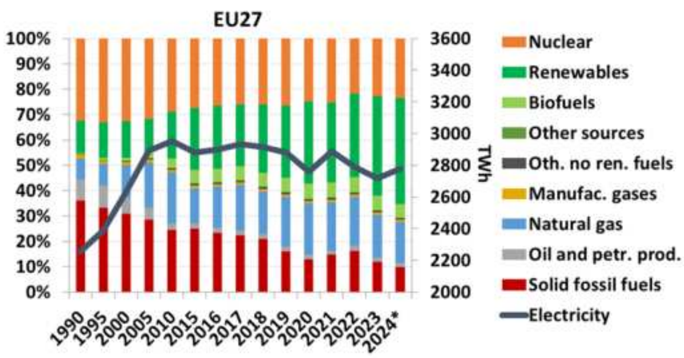
Power capacity and electricity production

The power sector is one of the main targets of measures aimed to decarbonize the economy, both for the amount of emissions and potential of renewable energy deployment. The countries examined for comparison with Italy account for 82.6% of EU27 gross electricity production in 2023.



The installed capacity in 1990 consisted mainly of thermoelectric plants (54% in EU27), nuclear (21.8%) and hydroelectric (24%). Wind and photovoltaic sources had marginal shares. In 2023 the thermoelectric capacity was 35%, 9.1% nuclear, 13.8% hydroelectric, 19.7% wind, and 22.1% photovoltaic. The total capacity has increased by 64.2% in 2023 compared to 2005, from 676 GW to 1,110 GW. The nuclear capacity is the only one with a relevant reduction, from 123 GW to 101 GW (-18%), mainly due to the downward trend in Germany, Sweden, and Belgium. It is also noteworthy the increase of bioenergy net capacity from 15.8 GW in 2005 to 36.7 GW in 2023, representing 9.5% of total thermoelectric capacity. All countries experienced considerable decreasing share of the thermoelectric capacity since 1990, as well as for nuclear capacity (except Czechia and Romania).

There is considerable heterogeneity of power capacity among countries. In Poland, there is a clear prevalence of thermoelectric plants with a minor role for bioenergy. The nuclear plants, which are not present in Italy and Poland among the considered countries, make up significant share of the capacity in France (40.9% in 2023), Sweden (13.6%), Belgium (14.4%), and Czechia (19.4%), although the shares of other countries are not negligible (from 0.9% in the Netherlands to 7.1% in Romania). Since 1990, hydroelectric capacity has accounted for a considerable amount of traditional renewable sources in Romania, Spain, France, Italy and Sweden. Wind power has increased in all countries since 2005. Photovoltaic plants begun to have significant shares only after 2010 and in 2023 is the most relevant renewable source in EU27.

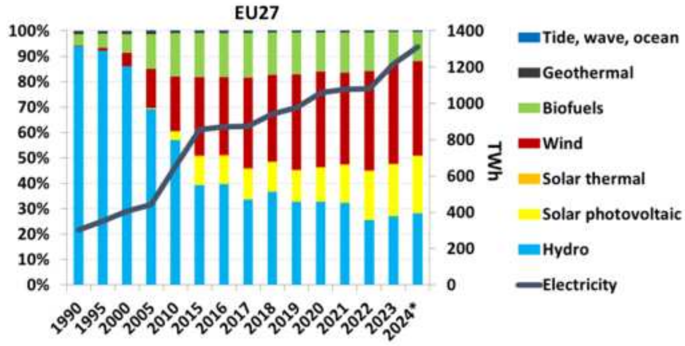


Gross electricity production in Europe increased from 1990 to 2015 with an annual average rate of 1%, in the following years up to 2019 wide oscillation was recorded and 2019 level is approximately the same of 2015. In 2020 the electricity fell, due to measures adopted to contain SARS-CoV-2 pandemic. In 2021 there was a recovery, followed by a new slowdown up to 2023. From 2015 to 2023 the annual average rate has been -0.7%. Preliminary data issued by Eurostat show an increase of electricity production in 2024.

The energy share of EU27 electricity production without pumping in 2023 is 11.9% from solid fuels and 16.9% from natural gas. Oil and petroleum products account for less than 1%. Nuclear source accounts for 22.8%, while 44.8% comes from renewable energy (renewables and biofuels). All considered countries, except Germany and Romania, increased the electricity production since 1990, from 13.7% in Sweden to 85% in Spain. In Romania and Germany, the electricity production decreased by 10.6% and 7.5%, respectively. Preliminary data for 2024 show the further shrinking of fossil share, particularly evident for solid fuels (from 11.9% in 2023 to 9.9% in 2024). The share for natural gas decreases to 16%, while electricity by nuclear power and renewables reaches 23.4% and 47.3%, respectively.

The energy mix in the examined countries is quite heterogeneous, mainly as far as fossil fuels are concerned. In 2023, solid fuels make up 59.5% of electricity production in Poland, 39.4% in Czechia, and 24.7% in Germany. France has the highest share of electricity production from nuclear plants in Europe (65% in 2023), followed by Belgium, Czechia (both with 40%), Sweden (29.2%), Spain (20.3%), and Romania (19.5%). In the other biggest countries, the nuclear electricity ranges from 1.3% in Germany to 3.3% in the Netherlands. Poland and Italy do not have nuclear plants. Italy and the Netherlands have the highest share of electricity by natural gas (44.7% and 35.9% respectively in 2024).

The renewable electricity share in EU27 has increased since 1990, from 13.4% to 44.8% in 2023. All countries recorded a notable increase of renewable electricity production with a strong acceleration since 2005. After 2013 the average growth rate slowed down up to 2017 and has resumed in recent years, although with different rates among the States. Sweden has one of the highest renewable shares in Europe. According to preliminary data, in 2024 the share of renewable electricity in EU27 should reach 47.3%.



Efficiency of thermal power plants

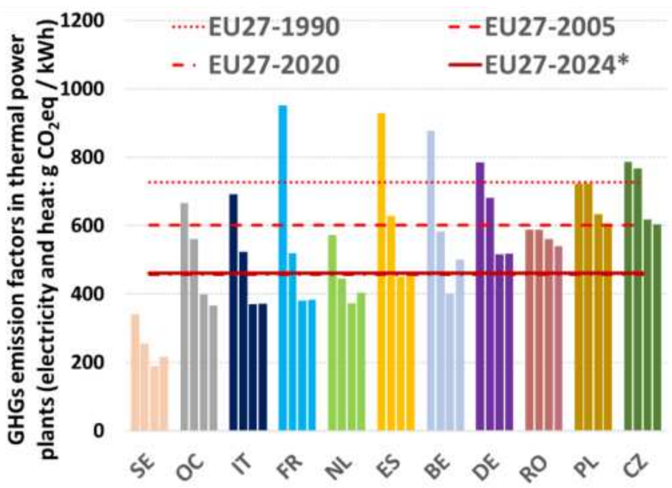
The most important parameter to assess the efficiency of power systems is the transformation efficiency of fuels to produce electricity and heat. The electrical efficiency of Italian non-cogeneration plants in 2023 is just over the EU27 average (0.45 *vs* 0.419). As concerns the electrical efficiency of CHP plants, Spain shows the highest value among the main European countries (0.625), far higher than the EU27 average (0.38). Italy's electrical efficiency is 0.456. The total efficiency, for electricity and heat production, of the Italian cogeneration plants (0.55) is below the EU27 average (0.625).

The Italian electrical efficiency for all power plants (CHP and electricity only) in 2023 is 0.453, exceeded by the Netherlands, Spain, and Belgium, from 0.461 to 0.489. Sweden has the lowest electrical efficiency among the examined countries (0.283), well below the EU27 average (0.397). The overall efficiency of Italian plants, for electricity and heat production, is 0.509, below the EU27 average (0.532). Sweden shows the highest value (0.781), due to the highest ratio between heat and electricity recorded in this country in CHP plants (about 1.76), followed by Czechia (1.59).

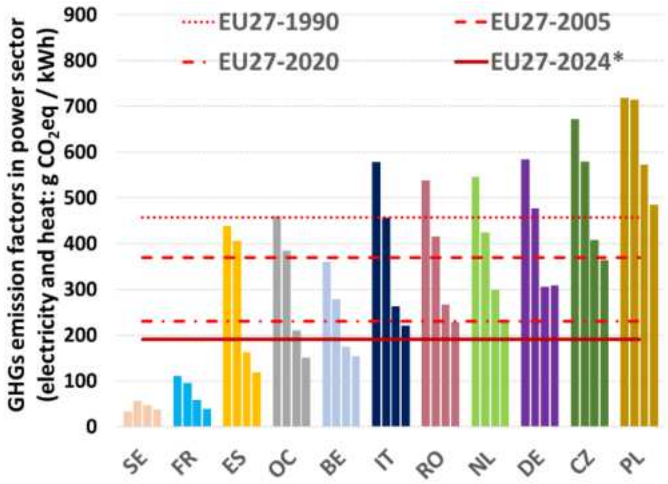
GHGs from the power sector

Since 1990 there has been a decoupling between electricity production and GHGs by power sector in almost all European countries, although emissions show a significant decrease only after 2005, with an increasing decoupling mainly due to the growing share of renewables.

GHG emissions factor for electricity and heat production due to fuel combustion in thermal power plants reduced since 1990. According to the preliminary data, in 2024 the emissions factor in Italy, 371.1 g CO_2eq/kWh, is lower than EU27 average, 461.1 g CO_2eq/kWh. The average reduction since 2005 (-23.2% in EU27) ranges from -8.3% in Romania to -29.2% in Italy.



The emissions factor for total electricity and heat production by the whole power sector, including renewable and nuclear power production, in Italy is higher than the European average (221.2 *vs* 191 g CO_2eq/kWh). All countries with lower emissions factor than Italy have relevant amount of electricity by nuclear plants and/or higher renewable share.



The average EU27 emissions factor shows a reduction of 48.4%, compared to the 2005 level. Italy reduced the emissions factor by 51.6%. Spain recorded the highest reduction rate since 2005, -70.8%. On the other side, Poland and Sweden have the lowest ones, -32.1% and -33.4% respectively, but Sweden has the lowest absolute emissions factor, with very lower reduction margin than all other countries. The emissions factor in Germany, which has the highest share of European GHGs by power sector, decreased by -35.4% since 2005.

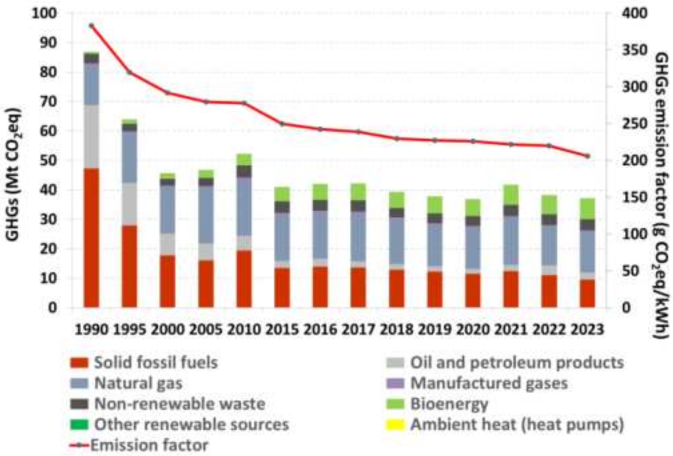
As concerns electricity production the outcomes allow to conclude that, among the biggest European countries, Italy's thermal power plants are in the lowest end of the GHGs emissions factor's range, apart France, the Netherlands, and Sweden which have much lower share of solid and oil fuels then Italy. Italy has the median position among all the European countries, well below the EU27 average. The Italian fuels mix, with greater share of natural gas than many other countries and the contribution of bioenergy, is a driving factor for the emissions factor in thermal power plants. On the other side, as for the whole power sector, therefore also considering the no thermal renewables and nuclear power plants, the Italian emissions factor loses positions compared to other countries and is higher than European average.

As concerns the power sector, Germany, Poland, and Italy are the three biggest emitters in Europe. Because of many factors (fuel mix shift, efficiency, share of renewables) Italy reduced the emissions factor for electricity production by -63.3% from 1990 to 2024 and by -55.7% since 2005. The reduction in Germany was -51.5% since 1990 and -37.9% since 2005, while the figures in Poland was -42.1% since 1990 and -35.9% since 2005. The three Countries account for almost 60% of EU27 GHGs from power sector.

Heat-only producers

Heat production accounts for a significant share of energy transformation processes. Plants dedicated to heat production for district heating and other uses (mainly for industry) consume an important share of the energy in the European balance. In 2023 the energy consumption of such plants in EU27 was 17.6 Mtoe of which 0.7 Mtoe from geothermal and solar thermal, and 0.35 Mtoe from heat pumps. The energy consumption by fuels was 16.5 Mtoe, of which 6.5 Mtoe from bioenergy.

Total energy consumption in 2023 is about 31.6% lower than 1990 level. A marked fuel shift occurred, with sensible decrease of solid and liquid fuels being replaced by natural gas and bioenergy. The contribution of other renewable sources (geothermal energy and solar thermal) and heat pumps recorded an increasing trend and in 2023 represent 6% of total consumption.



As a result of fuel shift and decreasing energy consumed (-31.6% in 2023 compared to 1990) and heat production (-20.5%), GHGs registered a sharp decrease by 57.2% since 1990. GHGs emissions factor decreased by 46.1%. At EU27 level the GHGs from these plants were 37.2 Mt CO_2eq in 2023. Since 2005 the emissions factor decreased by 26.3% in EU27 (from 279.7 to 206.2 g CO_2eq/kWh). Italy's emissions factor in 2023 is 14% lower than the EU27 average. The relevant solid fuels or non-renewable waste consumption in Poland and Germany results in higher emissions factor, respectively 98.1% and 45.4% higher than the Italian one.

CONCLUSIONS

The results show that Italy has one of the more efficient economies among the biggest countries in Europe, in terms of energy consumption by GDP. The energy intensity per GDP in Italy is one of the lowest among the European countries, despite the still relevant role of industry in the Italian economy. Low energy intensity often corresponds to more service-based economies with a minor role of industrial activities. EU27's carbon intensity per energy consumed is on average lower than Italian one, since in several countries is present a not negligible share of nuclear energy, while on the renewables side, after Sweden, Italy recorded the highest share on gross inland consumption among the biggest countries.

GHGs trends depend on many factors. The emission reductions in European countries are mainly due to the decreasing energy intensity and increasing renewable energy consumption. Independently from contingencies, there is a clear decoupling between GDP and GHGs in the European countries, although decoupling does not necessarily correspond to the emission reductions in line with the targets. The potential for reducing emissions must be assessed also considering the starting points of the driving factors and the costs to change the energy system, as well as the economy structure, especially concerning the ratio between services and industry.

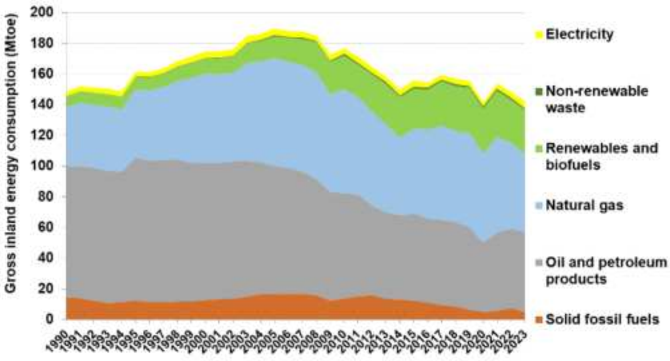
Sectoral decarbonization indicators in Italy show sectors, such as industry and agriculture, with energy and carbon intensities by GDP among the lowest in Europe and sectors, such as households and transport, showing wide room of improvement. The Italian electrification level in households is well below the European average. Transport sector has wide room for reducing emissions, mainly in the segment of cars. Italian GHGs per capita for such transport segment are over the European average and one of the highest values among the biggest countries. Such outcomes are consistent with the worrying distance of Italian GHGs projections from the target to be achieved in 2030. The targets are focused on the partition between biggest energy and manufacturing industries (subject to emissions trading system, ETS) and other sectors (ruled by Effort Sharing Regulation, ESR). The country's emission targets are set only for sectors not subject to the ETS, i.e. transport, services, households, agriculture, waste and small industry, while emissions from large plants as thermal power plants, refineries, cement plants, steel plants, etc. are in the European cap and trade system of emissions trading. Such commitment does not change with the introduction of the so called ETS-2, which will come into operation in 2027 for buildings, road transport and additional sectors, e.g. fuel combustion by industry not covered by the existing ETS.

SOMMARIO (Italiano)

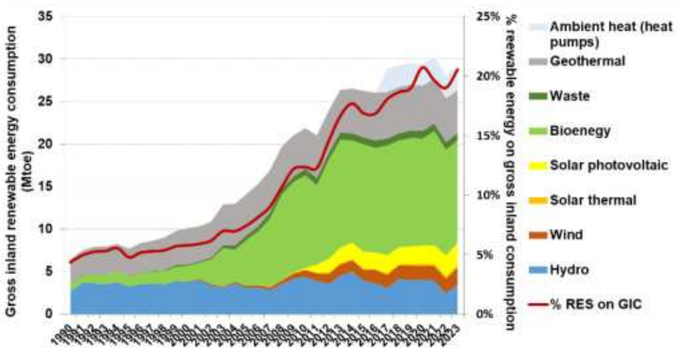
DATI NAZIONALI

Consumi di energia ed emissioni di gas serra

Il consumo interno lordo di energia in Italia è aumentato dal 1990 al 2005, con il picco di 189,4 Mtep. Successivamente si è registrata una riduzione, accelerata dalla crisi economica del 2008, con il valore minimo di 149,8 Mtep nel 2014 e la successiva ripresa. Dopo il calo del 2020, a causa della pandemia da SARS-CoV-2, nel 2021 si è registrato un rimbalzo dei consumi (+8,8% rispetto al 2020; 154 ktep), seguito da un'ulteriore battuta d'arresto nel 2022 e nel 2023, che è solo 0,4% più alto del 2020.



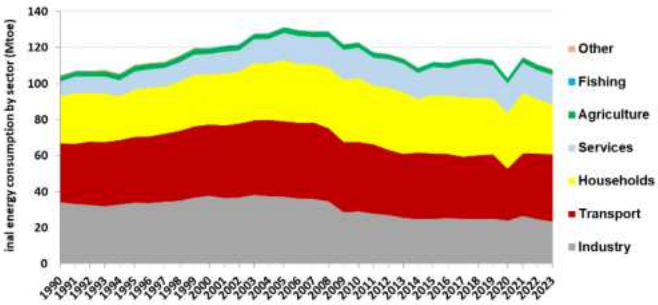
I combustibili fossili sono i principali vettori del sistema energetico nazionale. Dal 1990 al 2007, la quota media di combustibili fossili nel consumo interno lordo è stata superiore al 90%, anche se in lieve diminuzione. Dopo il 2007 la quota di energia fossile si è fortemente ridotta. Dal 1990 al 2023 la quota è scesa dal 93,6% al 76,4%. La riduzione è diventata particolarmente marcata dal 2007. Il mix nazionale di combustibili è cambiato considerevolmente dagli anni '90. I prodotti petroliferi rappresentavano la componente predominante con il 57,3% del consumo interno lordo nel 1990. La quota di questi combustibili è costantemente diminuita fino al 31,7% nel 2020, con un rimbalzo negli anni successivi. La quota di gas naturale segue un andamento speculare, con un aumento costante dal 1990 al 2020 (da 26,3% a 41,2%), seguito da un decremento (35,4% nel 2023). La quota dei combustibili solidi, dopo una costante riduzione dal 2012 al 2021 (da 9,6% a 3,6%), ha registrato un rimbalzo al 5% nel 2022 e una riduzione fino al 2024, circa 1.5%.



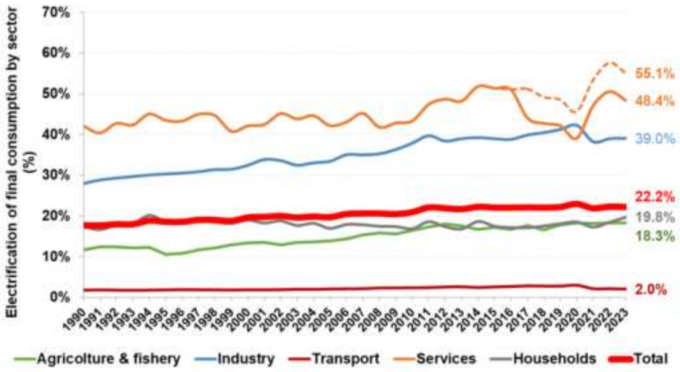
La quota di energia da fonti rinnovabili è complementare a quella osservata per i combustibili fossili. Dal 1990 al 2007 si è registrato un costante aumento della quota, passando da 4,4% a 9%. Dopo il 2007 la quota ha accelerato raggiungendo il 20,7% del consumo interno lordo nel 2020, seguita da una battuta d'arresto nel 2021 (19,6%) e 2022 (19%) e un incremento nel 2023 (20,5%). I dati preliminari per il 2024 confermano un ulteriore incremento della quota che dovrebbe attestarsi intorno al 21.7%.

Fino al 2000 le principali fonti di energia rinnovabile sono state la geotermia e l'idroelettrico, che hanno rappresentato oltre l'80% del consumo interno lordo di energia rinnovabile. La quota rimanente era costituita principalmente da biomasse e rifiuti rinnovabili (bioenergia). Dal 2000 la bioenergia ha mostrato una crescita considerevole, raggiungendo il picco della serie storica nel 2008 con una quota del 50,9%. Nel 2023 la quota di bioenergia è del 44,1%. Negli ultimi anni anche l'energia solare (termica e fotovoltaica) ed eolica hanno assunto un ruolo significativo e insieme rappresentano il 16,9% del consumo di energia rinnovabile. Dal 2017 l'energia delle pompe di calore è registrata dall'Italia nel bilancio Eurostat. Tale voce nel 2023 rappresenta il 9,8% del consumo interno lordo di rinnovabili.

I consumi finali di energia mostrano peculiarità strutturali per ciascun settore, con diverse sensibilità a fattori contingenti, come la crisi economica dal 2008 o il *lockdown* del 2020 che hanno colpito soprattutto i settori produttivi. Dal 1990 al 2023 l'industria mostra un calo dei consumi finali di energia del 31,1%, mentre i servizi mostrano un aumento del 103,1%. L'andamento dei consumi finali nel settore domestico è molto variabile a seconda delle condizioni climatiche che influenzano i consumi. Il consumo del settore nel 2023 è aumentato del 5,9% rispetto al livello del 1990. Il consumo nei trasporti è aumentato del 13,4% dal 1990 al 2023, dopo il calo del 2020 dovuto alle misure di confinamento per fermare la pandemia di SARS-CoV-2.

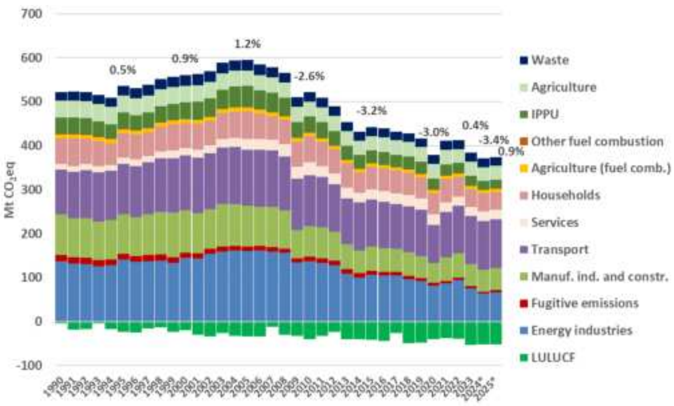


A partire dagli anni '90, la struttura dei settori in termini di consumo energetico è cambiata notevolmente. I servizi rappresentano una quota crescente dei consumi finali, passando da 7,8% nel 1990 a 15,4% nel 2023, mentre l'industria riduce la sua quota da 32,6% a 21,8% nello stesso periodo. I consumi nelle famiglie mostrano un andamento in crescita fino al 2010 seguito da una leggera diminuzione con forti oscillazioni dovute principalmente alla temperatura media. La quota media dei consumi negli altri settori, principalmente agricoltura e pesca, è circa il 3%.



L'elettrificazione dei consumi finali è una strategia fondamentale per ridurre i gas serra se perseguita parallelamente alla diffusione delle energie rinnovabili per la produzione di energia elettrica. La quota di energia elettrica nel consumo finale di energia è aumentata dal 1990 e nel 2023 è pari al 22,2%. Il livello di elettrificazione dei consumi finali dei settori è molto eterogeneo. I servizi presentano la quota più elevata, con oltre il 50% dei consumi finali del settore. Il tasso di elettrificazione nell'industria è in costante aumento dal 1990, con il 39% di elettricità del 2023. Le ampie oscillazioni registrate negli ultimi anni per servizi e industria sono dovute anche a un significativo cambiamento nella metodologia di contabilizzazione dei consumi. L'elettrificazione dei settori domestico e dei trasporti non mostra aumenti significativi nel lungo termine e nel 2023 è stata rispettivamente del 19,8% e 2%. L'agricoltura e la pesca mostrano un aumento dell'elettrificazione, analogamente all'industria, e nel 2023 il livello è stato del 18,3%.

In questo rapporto sono state considerate le emissioni di gas serra presentate a UNFCCC dall'Italia e dagli altri paesi europei ad aprile 2025, anche se una revisione di tali emissioni è stata effettuata dalla Commissione Europea. I risultati della revisione, finalizzati alla fine di agosto 2025, hanno determinato correzioni tecniche che saranno acquisite nel successivo inventario da presentare nel 2026.



Le emissioni totali di gas serra mostrano una tendenza all'aumento fino al 2005, seguita da una diminuzione accelerata dalla crisi economica del 2008. Nel 2020 le misure di lockdown per contenere la pandemia di SARS-CoV-2 hanno determinato la riduzione dei gas serra (380 Mt CO_2eq; -27,3% nel 2020 rispetto al 1990 e -36,3% rispetto al 2005). Tutti i settori hanno ridotto le emissioni, anche se con tassi diversi. Nel 2021 e nel 2022 i gas serra sono aumentati, anche se al di sotto del livello del 2019. Nel 2023 si registra una diminuzione del 26,4% rispetto al 1990 e del 35,5% rispetto al 2005. I dati preliminari per il 2024 confermano una ulteriore diminuzione di gas serra (circa -3,4% rispetto al 2023), mentre per il 2025 è stimato un nuovo incremento (circa +1% rispetto all'anno precedente).

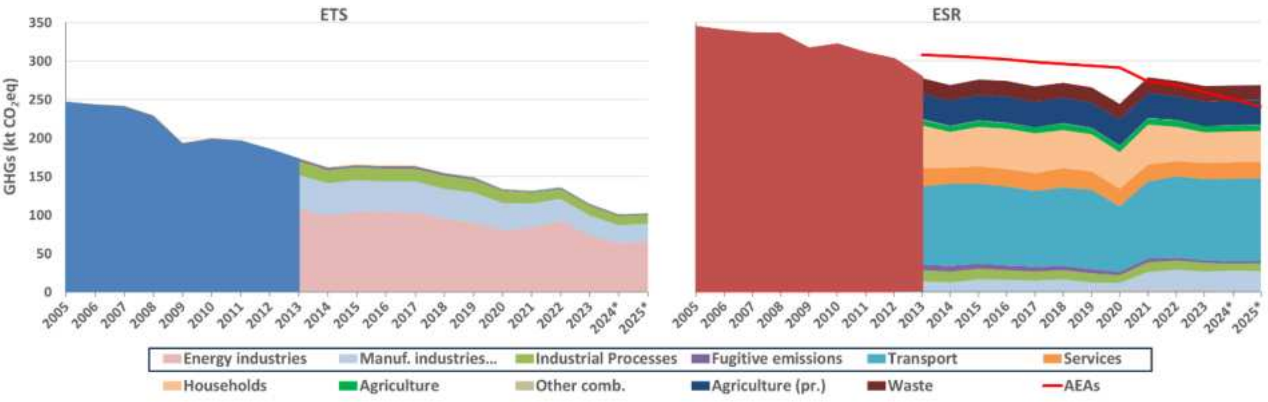
Le emissioni del settore manifatturiero e delle costruzioni sono diminuite del 45,3% dal 2005 al 2023. I trasporti sono aumentati costantemente con un'inversione di tendenza solo dopo il 2007 e il forte calo nel 2020; le emissioni del 2023 sono inferiori del 15,1% rispetto al 2005, ma ancora superiori al livello del 1990 (+6,7%). Il settore residenziale ha ridotto le emissioni del 31% rispetto al 1990, mentre nei servizi aumentano del 78,1%.

I gas serra pro-capite sono passati da 9,2 t CO_2eq nel 1990 a 10,3 t CO2eq nel 2004, negli anni successivi si è registrato un rapido calo fino a 6,4 t CO_2eq nel 2020, seguito da un incremento negli anni successivi. Nel 2023 il livello è sceso a 6,5 t CO_2eq. I gas serra pro-capite sono diminuiti dal 2005 al 2023 con un tasso medio annuo del -2,5% (-1% dal 1990).

Gas serra da ETS and ESR

Per monitorare il raggiungimento degli obiettivi di riduzione i gas serra devono essere allocati nei due comparti: ETS (EU Emissions Trading System, EU ETS) e ESR (Effort Sharing Regulation), definiti secondo la normativa europea.

Nel 2023 l'ETS rappresenta il 29,8% dei gas serra nazionali. La quota di tali emissioni è diminuita dal 2005, quando era del 41,5%. L'ambito di applicazione dell'ESR rimane sostanzialmente invariato rispetto al periodo precedente fino al 2020, ma dal 2021 solo la CO_2 proveniente dall'aviazione nazionale è esclusa dal settore ESR, non più NF3, come fino al 2020. Nel 2023 le emissioni in ESR rappresentano il 69,6% delle emissioni nazionali; la quota è aumentata dal 2005, quando era quasi del 58%. Dal 2005 al 2023 i gas serra sono diminuiti sia in ETS che in ESR, anche se in ETS con un tasso più che doppio rispetto a ESR, rispettivamente -53,6% e -22,6%. Inoltre, l'obiettivo ESR prevede una soglia annuale che negli ultimi anni è stata sempre superata: 5,5 MtCO_2eq nel 2021, 5.4 MtCO_2eq nel 2022, 8.2 MtCO_2eq in 2023. Le correzioni tecniche menzionate Le citate correzioni tecniche effettuate dalla Commissione Europea determinano un aumento di tali valori di circa 1,8 MtCO_2eq all'anno.



I dati preliminari nel 2024 mostrano un superamento di circa 19 MtCO_2eq, sebbene la stima sia caratterizzata da incertezza. Le prime stime per il 2025, caratterizzate da notevole incertezza, mostrano un superamento della soglia emissiva consentita di circa 30 MtCO_2eq.

Sul versante ETS il ruolo dominante è svolto dalle industrie energetiche (64,1% dei gas serra del comparto nel 2023) le cui emissioni sono quasi totalmente incluse in ETS, solo una quota marginale è in ESR. In quest'ultimo comparto il ruolo dominante è svolto dai trasporti con il 39,5% dei gas serra nel 2023, la quota esigua in ETS per tale settore è interamente dovuta al trasporto via gasdotto/oleodotto. I gas serra delle industrie manifatturiere e delle costruzioni, insieme ai processi industriali, rappresentano il 33,3% in ETS e il 13,4% in ESR. Le emissioni fuggitive in ETS riguardano solo la CO_2 derivante dal flaring nelle raffinerie, mentre tutte le altre fonti e gli altri gas serra sono in ESR. I gas serra derivanti dai servizi sono quasi totalmente in ESR e rappresentano il 7,8% delle emissioni del comparto. I gas serra dei settori residenziale (14,9% in ESR), agricoltura (sia da combustione che da processi; 14,9%) e rifiuti (7,6%) sono totalmente in ESR. I settori con quote elevate dovrebbero essere gli obiettivi prioritari delle politiche e misure volte a conseguire l'obiettivo di riduzione dei gas serra fissato per le emissioni di ESR.

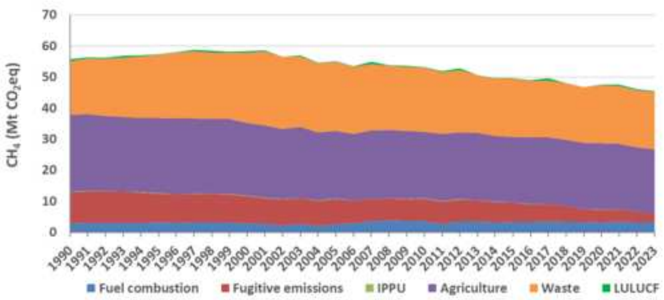
Emissioni di metano

Il metano è un potente gas serra, secondo solo all'anidride carbonica in termini di contributo al riscaldamento globale (IPCC, 2021). Il metano ha un potenziale di riscaldamento globale (GWP) circa 85 volte superiore a quello della CO_2 in un periodo di 20 anni, sebbene la CO_2 abbia una vita in atmosfera di migliaia di anni, mentre il metano scompare in circa 10-15 anni. Il rapido decadimento del metano e il suo elevato impatto sulla temperatura atmosferica ne fanno un obiettivo primario per frenare in modo tempestivo ed efficace il cambiamento climatico.

Secondo il rapporto dell'Agenzia Internazionale dell'Energia (IEA, 2025) e dell'IPCC (2022) la riduzione delle emissioni antropogeniche di metano è una delle strategie più efficaci, anche in termini economici, per contribuire in modo significativo agli sforzi per limitare l'aumento della temperatura globale.

Le emissioni nazionali di metano, senza il contributo delle fonti naturali, rappresentano in media il 10,6%±0,8% delle emissioni totali dal 1990 al 2023. Le emissioni di metano senza LULUCF sono diminuite da 55 a 45,2 Mt CO_2eq dal 1990 al 2023 (-17,9%). La riduzione delle emissioni di metano è inferiore alla riduzione dei gas serra totali (-26,4%). Inoltre, i gas serra diversi dal metano si riducono del 27,4% rispetto al 1990. Questi tassi evidenziano la necessità di ridurre le emissioni di metano dalle principali fonti.

Tra le principali fonti, le emissioni di metano da rifiuti nel 2023 sono risultate superiori ai livelli del 1990 (+6,8%), anche se il trend è in netta discesa dal 2005 (-17,1%). Dal 1990 l'agricoltura è diminuita del 15,6% e le emissioni fuggitive del 72,6%. Considerando solo le emissioni di metano, l'agricoltura contribuisce con il 46,1% nel 2023, mentre il settore dei rifiuti rappresenta il 40,9%. Le emissioni fuggitive rappresentano il 6,2% e il metano incombusto nel settore energetico il 6.8%.

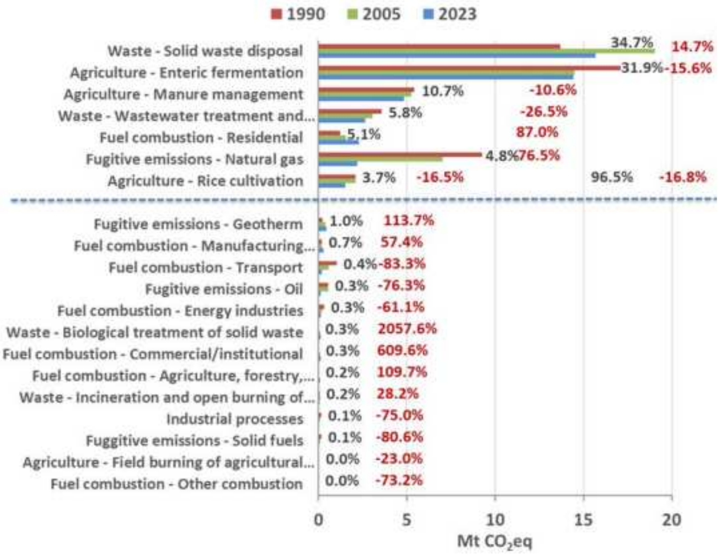


La fonte di gran lunga più importante del settore agricolo è rappresentata dalla fermentazione enterica, ovvero i processi digestivi degli animali da allevamento. Questa fonte rappresenta il 69,3% delle emissioni di metano dell'agricoltura nel 2023, seguita dalla gestione del letame con il 23,3% e dalla coltivazione del riso con il 7,3%. Le emissioni da combustione di residui agricoli in campo rappresentano il 0,06%.

Nel settore dei rifiuti, la fonte dominante di metano è lo smaltimento dei rifiuti solidi, responsabili dell'84,8% delle emissioni di metano del settore, la fonte successiva è il trattamento delle acque reflue, con il 14,2%. Le altre due fonti, il trattamento biologico dei rifiuti solidi e l'incenerimento e la combustione in campo, rappresentano una quota inferiore all'1%.

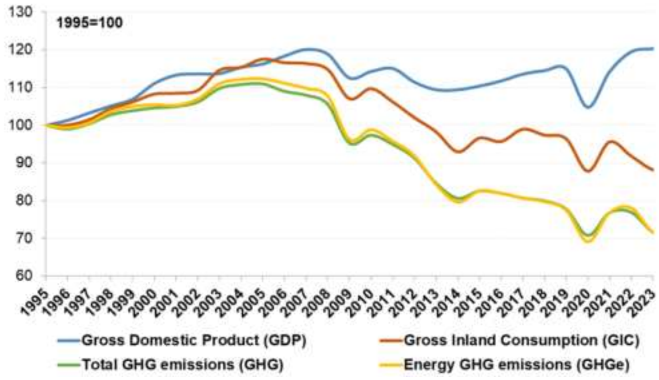
La maggior parte delle emissioni fuggitive di metano sono dovute alla filiera del gas naturale (produzione, trasporto e distribuzione) che nel 2023 rappresenta il 78% delle emissioni fuggitive di metano con una quota che è diminuita significativamente dal 1990, quando era del 91,2%. Le filiere di approvvigionamento del petrolio e del gas naturale hanno registrato riduzioni delle emissioni di metano di oltre il 76,5% dal 1990.

Le emissioni di metano incombusto nel settore energetico sono dovute principalmente alla fonte dominante del settore civile (principalmente residenziale) con l’81% delle emissioni di metano del settore energetico, seguito dall'industria manifatturiera e delle costruzioni con il 9,6%, dai trasporti con il 5,5% e dall'industria energetica con il 3,8%.



Disponendo in ordine decrescente le emissioni di metano del 2022 da tutte le fonti, si può notare che il 96,5% del metano proviene da sette fonti chiave che emettono 43,6 Mt CO_2eq. Le emissioni provenienti dalle principali fonti sono diminuite del 16,8% dal 1990. Le emissioni dalle fonti minori, che sono cumulativamente responsabili del 3,5% delle emissioni, sono inferiori del 39,9% rispetto al livello del 1990. Lo smaltimento dei rifiuti solidi urbani è la prima fonte chiave con il 34,4% delle emissioni totali di metano, seguito dalla fermentazione enterica con il 31,9%. Le prime due fonti sono responsabili di due terzi delle emissioni di metano.

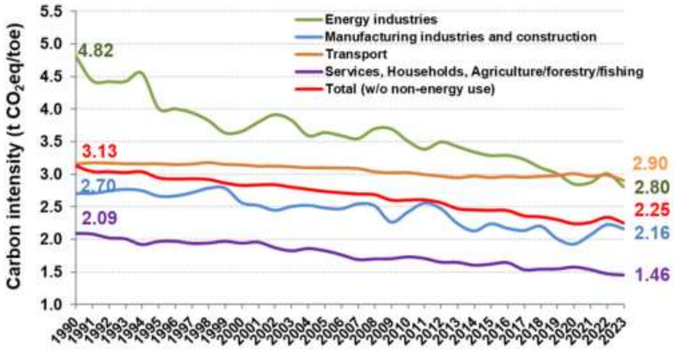
Intensità energetica e indicatori di decarbonizzazione



Per valutare le relazioni tra consumo energetico, economia ed emissioni di gas serra, sono stati analizzati gli andamenti del consumo interno lordo di energia (GIC), del prodotto interno lordo (PIL a valori concatenati con anno di riferimento 2020) e delle emissioni. Il PIL e il GIC hanno andamenti paralleli fino al 2005. Successivamente i due parametri iniziano a divergere mostrando un disaccoppiamento sempre maggiore. La crescita delle emissioni di gas serra è stata più lenta di quella del PIL fino al 2005, evidenziando un relativo disaccoppiamento. Dopo il 2005, la divergenza tra i due parametri diventa sempre più marcata mostrando anche un disaccoppiamento assoluto quando il PIL è aumentato e i gas serra sono diminuiti (2015-2019).

Il disaccoppiamento è evidente anche dalla tendenza al ribasso del rapporto tra GIC e PIL dal 2005. La tendenza alla diminuzione delle emissioni di gas serra per unità di consumo di energia primaria è dovuta principalmente alla sostituzione di combustibili a più alto tenore di carbonio con gas naturale, principalmente nel settore energetico e nell'industria, e all'aumento della quota di energie rinnovabili. Le stesse tendenze sono confermate per il consumo finale di energia (al netto degli usi non energetici) per unità di PIL e per le emissioni di gas serra per unità di energia finale consumata.

Nel periodo 1995-2023 il consumo interno lordo di energia per PIL è sceso da 101,1 tep/M€ a 74 tep/M€ (-26,8%). Nello stesso periodo, i gas serra per PIL sono diminuiti del 40,5%, passando da 336,7 t CO_2eq/M€ a 200,3 t CO_2eq/M€, mentre le emissioni da combustione per consumo di energia primaria passano da 2,81 t CO_2eq/tep a 2,21 t CO_2eq/tep, con una riduzione del 21,3%. Dal 2005 si è registrata un'accelerazione del tasso di diminuzione di intensità energetica per unità di PIL e della decarbonizzazione dell'economia nazionale fino al 2019/2020, evidenziando ancora una volta il crescente disaccoppiamento tra attività economica, consumo di energia ed emissioni di gas serra. Le cause possono essere molteplici e tra le principali c'è la contrazione delle attività industriali, più energivore rispetto ai servizi caratterizzati da minore intensità energetica e maggiore valore aggiunto. I gas a effetto serra per energia consumata (primaria e finale) sono diminuiti rapidamente dal 2005, principalmente a causa dell'aumento della quota di energia rinnovabile dal 2007. Dopo il 2020 gli indicatori mostrano una tendenza al rialzo dovuta all'aumento dei combustibili petroliferi (2021 e 2022) e dei combustibili solidi (2022), mentre nel 2023 riprendono l'andamento decrescente.



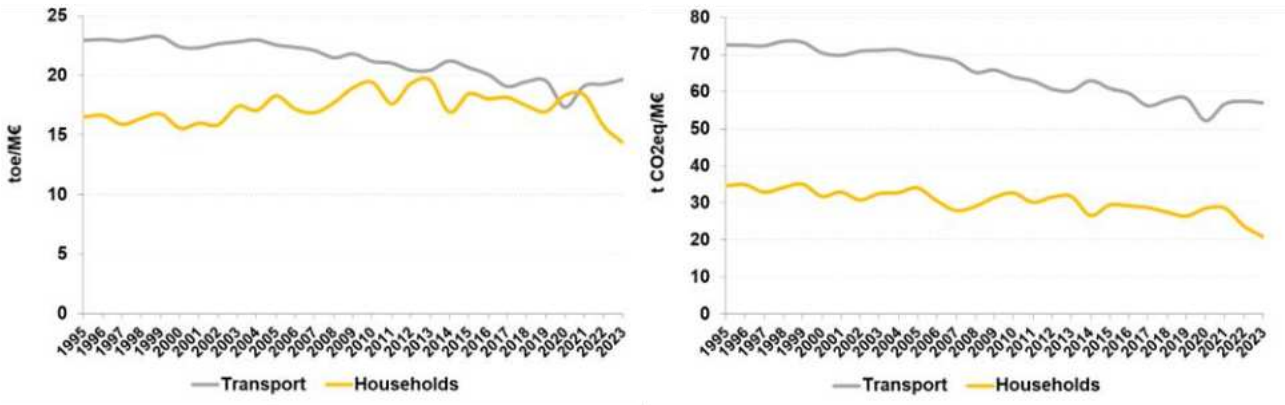
La decarbonizzazione a livello settoriale può essere valutata in base alle emissioni energetiche e al consumo di energia per settore. L'intensità di carbonio per energia è il rapporto tra i gas serra e il consumo di energia. L'intensità media di carbonio per settore varia notevolmente da un settore all'altro, a seconda della diversa diffusione delle fonti rinnovabili e dell'elettrificazione dei consumi finali. L'intensità di carbonio delle industrie energetiche diminuisce del 41,8% nel 2023 rispetto al 1990, passando da 4,82 t CO_2eq/tep a 2,8 t CO_2eq/tep. L'intensità di carbonio dell'industria manifatturiera nel 2023 è 2,16 t CO_2eq/tep, in calo del 20,2% rispetto al 1990. L'intensità di carbonio dei trasporti è 2,9 t CO_2eq/tep (-8,2% rispetto al 1990) e mostra il valore più alto degli ultimi anni tra i settori, con la pendenza decrescente più lenta dal 1990. L'intensità di carbonio nel settore civile è pari a 1,47 t CO_2eq/tep, in calo del 29,5% rispetto al 1990. La riduzione delle intensità di carbonio è statisticamente significativa per il test di Mann-Kendall ($p<0{,}001$). Complessivamente, l'intensità di carbonio per il consumo energetico considerato, pari al 93,6%±1,2% del consumo interno lordo di energia dal 1990 al 2023, è 2,25 tCO_2eq/tep nel 2023 (-28,1% rispetto al 1990).

Indicatori dell'energia e dell'economia a livello settoriale

Gli indicatori di decarbonizzazione e di intensità energetica per settore sono stati calcolati confrontando i gas a effetto serra per settore con il rispettivo consumo di energia e valore aggiunto o PIL per i settori residenziale e trasporti. Le emissioni settoriali comprendono solo le emissioni dirette e le emissioni derivanti dall'autoproduzione di energia elettrica nell'industria manifatturiera. Le emissioni indirette dovute al consumo di energia elettrica prelevata dalla rete non sono considerate poiché comprese nelle industrie energetiche. I gas serra dei tre settori (agricoltura, industria, servizi)rappresentano in media il 34,5±0,8% dei gas serra totali.

Nel complesso, le emissioni sono diminuite del 28,9% nel 2023 rispetto al 1995. Le emissioni da combustione e da processi sono diminuite del 30,2% e del 26,8% rispettivamente. Nel 2023 l'intensità energetica (tep/M€) dell'industria è ben al di sotto del livello del 1995 (-34,9%), mentre i servizi sono più alti (+26,3%), anche se negli ultimi anni l'intensità del settore diminuisce in modo significativo. L'agricoltura, dopo una tendenza al ribasso dal 2003 al 2015 mostra un aumento dell'intensità ma il livello del 2023 è -8,2% rispetto al 1995. Dal 1995 al 2023 l'intensità energetica aggregata dei tre settori è diminuita del 26,7%. L'intensità di carbonio, il rapporto tra gas serra e valore aggiunto, diminuisce a causa della crescente quota di energia rinnovabile e di combustibili a basso contenuto di carbonio, come il gas naturale. Le intensità di carbonio per valore aggiunto sono molto diverse da un settore all'altro. L'agricoltura ha i valori più alti, mentre i servizi registrano quelli più bassi. Nel 2023 l'intensità dell'agricoltura è inferiore del 16,8% rispetto al livello del 1995, mentre quella dei servizi è superiore del 12,3%. L'industria mostra una forte diminuzione (-45,8% nel 2023 rispetto al 1995) che determina l'andamento dell'intensità aggregata (-43,3% nel 2023).

L'intensità energetica e l'intensità di carbonio dei trasporti e delle famiglie è stata calcolata considerando il PIL. L'intensità energetica delle famiglie oscilla intorno a una media senza una chiara tendenza (17,3±1,3 tep/M€), mentre l'intensità di carbonio mostra un andamento decrescente dal 1995 (da 34,5 t CO_2eq/M€ nel 1995 a 20,8 t CO_2eq/M€ nel 2023; -39,8%). L'andamento delle emissioni di gas serra rispetto al PIL testimonia il cambiamento del mix energetico nei consumi finali del settore, con un contributo crescente della biomassa che riduce l'intensità di carbonio ma non l'intensità energetica.

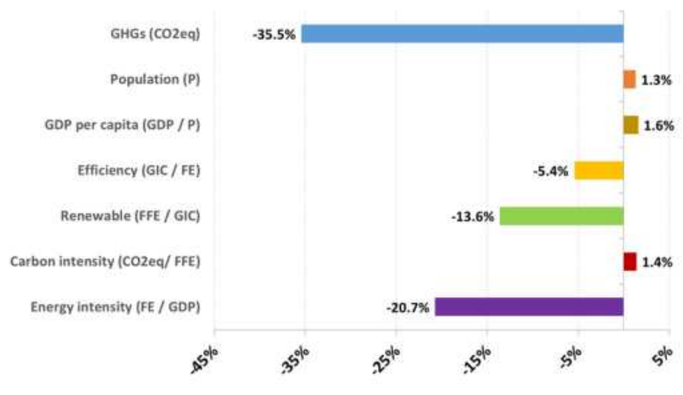


L'intensità energetica dei trasporti è diminuita del 15,9%, passando da 23 tep/M€ a 19,3 tep/M€ dal 1995 al 2023. Un andamento parallelo è stato osservato per l'intensità di carbonio con una riduzione del 21,6%, da 72,6 t CO_2eq/M€ a 56,9 t CO_2eq/M€, mostrando una certa decarbonizzazione anche in questo settore. Tuttavia, un'analisi più approfondita mostra che nei trasporti non c'è un vero e proprio disaccoppiamento tra consumi di energia e emissioni. Dal 2005 le due intensità, energetica e di carbonio, nel settore residenziale mostrano una distanza crescente, a causa della diminuzione dei gas a effetto serra rispetto al consumo di energia.

Identità di Kaya e analisi della decomposizione

L'analisi di decomposizione è una tecnica per studiare la variazione di un indicatore in ogni intervallo di tempo in relazione alla variazione dei suoi fattori determinanti. In altre parole, la variazione di un parametro viene scomposta nella variazione dei parametri che lo determinano. Il punto di partenza dell'analisi è la costruzione di un'equazione di identità, dove la variabile studiata è rappresentata come il prodotto di componenti considerate come le cause della variazione osservata. Per l'identità, i componenti devono essere rapporti, dove il denominatore di un componente è il numeratore del successivo. Questa identità, chiamata Kaya dall'economista Yoichi Kaya, è fornita *a priori*, e deve essere realizzata secondo un modello concettuale coerente con i vincoli fisici della variabile studiata, oltre alle considerazioni relative alla disponibilità dei dati e agli obiettivi dell'analisi.

Le emissioni di gas serra sono state decomposte in sei fattori per valutare la variazione tra il 2005 e il 2023: 1) popolazione; 2) crescita economica *pro capite*; 3) efficienza; 4) energie rinnovabili; 5) intensità di carbonio da combustibili fossili; 6) intensità energetica finale. I risultati dell'analisi di decomposizione, effettuata secondo il *Logarithmic mean Divisia index* (Ang, 2005), mostrano che l'effetto dei fattori che hanno ridotto le emissioni nel

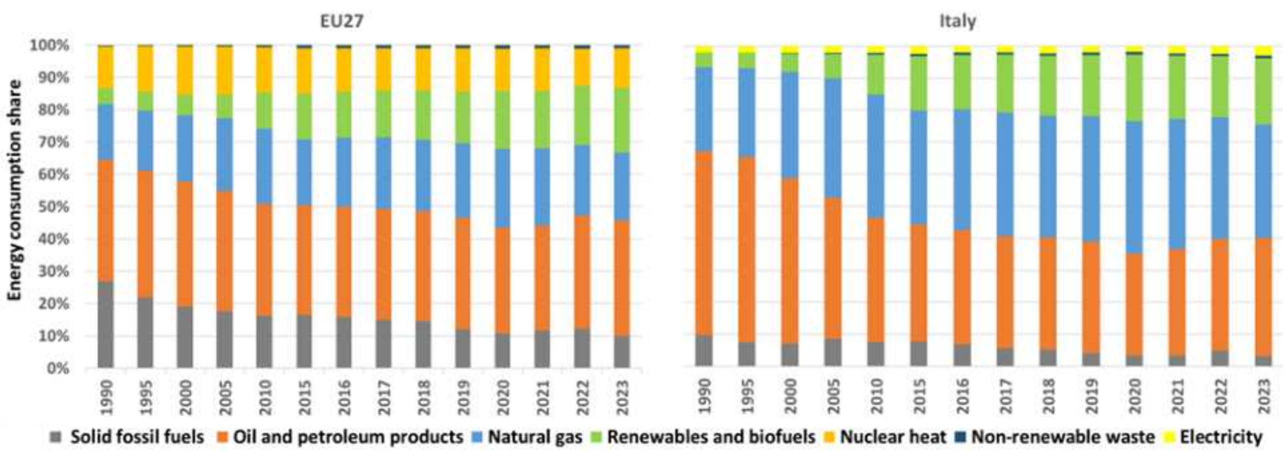


periodo 2005-2023 ha prevalso sull'effetto dei fattori che hanno portato ad un aumento delle emissioni. La popolazione, il PIL procapite e l'intensità di carbonio sono i unici fattori che hanno contribuito alla crescita delle emissioni (+4,3%). I restanti fattori hanno determinato la riduzione delle emissioni. L'intensità energetica finale (consumo finale di energia / PIL) ha svolto il ruolo principale (-20,7%) seguita dalla quota di energia rinnovabile (consumo di energia fossile / consumo interno lordo di energia; -13,6%) e dall'efficienza (consumo interno lordo / consumo di energia finale; -5,4%). Il contributo complessivo dei fattori determina la riduzione del 35,5% dei gas serra nel periodo 2005-2023.

L'ITALIA E I PRINCIPALI PAESI EUROPEI

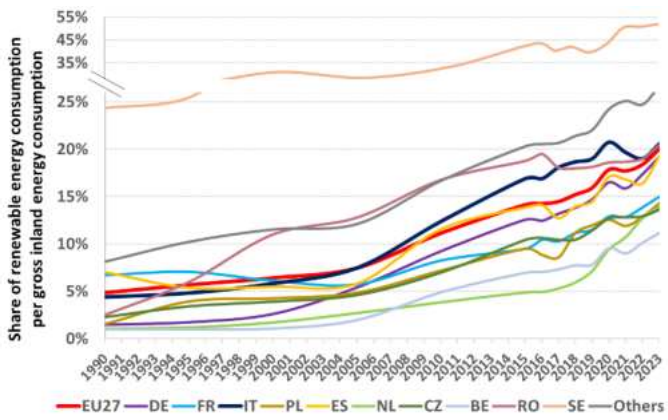
Indicatori di efficienza e decarbonizzazione

Sono stati confrontati gli indicatori di decarbonizzazione ed efficienza nazionali e dei principali Paesi europei. Per il confronto sono stati considerati gli Stati con più del 3% delle emissioni di gas serra dell'UE27 o più del 3% del PIL dell'UE27 nel 2020. Gli Stati membri esaminati (Germania, Francia, Italia, Spagna, Polonia, Paesi Bassi, Belgio, Romania e Svezia) rappresentavano nel 2020 l'81,6 % della popolazione dell'UE27, l'81,6 % dei gas serra e l'83,2 % del PIL. Il consumo interno lordo di energia rappresentava l'82,5% del consumo energetico dell'UE27.



Consumo di energia e prodotto interno lordo

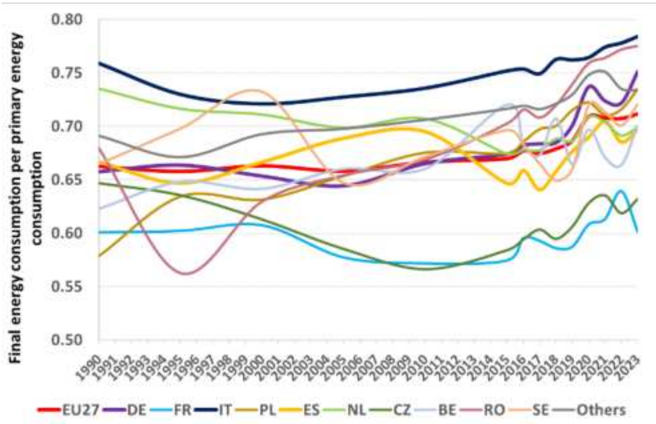
Dal 1990, le politiche ambientali europee hanno determinato una variazione del mix energetico negli Stati europei. L'energia nucleare rappresenta il 12,2% del consumo interno lordo dell'UE27 nel 2023, in leggero aumento rispetto all'anno precedente, soprattutto per l'incremento registrato in Francia. L'uscita della Germania dal nucleare continua, con una quota dello 0,7% nel 2023. L'energia da combustibili solidi ha subito una contrazione significativa dal 1990. La quota dell'UE27 nel 2023 è del 9,9%, mentre nel 1990 era del 26,3%. Vi sono ancora quote significative di combustibili solidi in alcuni degli Stati più grandi come Germania (16,6%), Polonia (34,7%) e Cechia (27,9%). Petrolio e prodotti petroliferi, invece, mostrano una modesta riduzione a livello europeo (da 37,6% nel 1990 a 35,8% nel 2023) con andamenti diversi tra gli Stati. Il consumo di energia da gas naturale mostra un aumento considerevole in quasi tutti gli Stati e a livello europeo cresce da 17,1% nel 1990 a 21% nel 2023, nettamente inferiore alla quota registrata nel 2021 e nel 2020 (rispettivamente 23,9% e 24,4%). L'energia rinnovabile in EU27 aumenta da 4,9% a 20,1% dal 1990 al 2023.



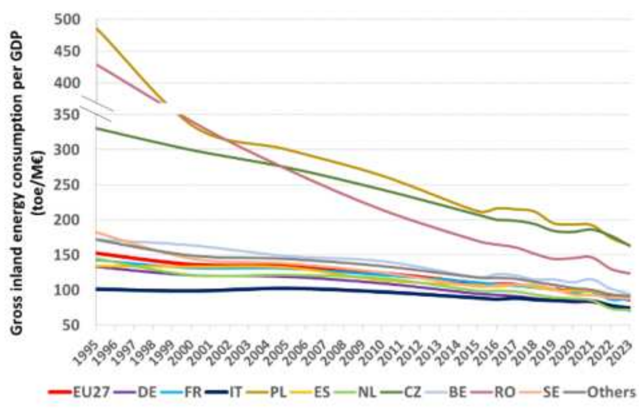
La quota italiana dei combustibili solidi, principalmente carbone, nel consumo interno lordo è scesa da 9,9% nel 1990 a 3,4% nel 2023. La quota di gas naturale passa da 26,3% a 35,4%, in diminuzione dal 2020 (41,2%). La quota di petrolio e prodotti petroliferi passa da 57,3% a 36,4% e la quota di rinnovabili aumenta da 4,4% a 20,5%. In Italia la quota di rinnovabili sul consumo interno lordo è tra le più alte dei Paesi esaminati, solo la quota della Svezia è superiore a quella italiana. Tuttavia, l'obiettivo europeo al 2030 della quota di rinnovabili riguarda il consumo finale lordo e la quota dell'Italia è inferiore alla media europea nel 2023 (19,6% vs 24,6%), riflettendo l'obiettivo per l'Italia che è inferiore a quello europeo (38,7% *vs* 42,5%).

La quota di combustibili fossili è diminuita significativamente in quasi tutti i Paesi europei. La media dell'UE27 è scesa da 82 % nel 1990 a 67,7% nel 2023. Tra i Paesi esaminati, le quote nei Paesi Bassi e Polonia sono ancora superiori all'85%, rispettivamente 85,1% e 85,3%.

Il rapporto tra consumo finale di energia (compresi gli usi non energetici) e consumo interno lordo è un indicatore dell'efficienza energetica. Dal 1990 questo indicatore è sempre stato più alto per l'Italia rispetto alla media europea. Per valutare l'efficienza della trasformazione dell'energia, è utile considerare il consumo di energia senza usi non energetici. In altre parole, il rapporto tra consumo di energia finale e di energia primaria. L'efficienza energetica italiana è superiore a quella degli altri Paesi esaminati.



Il consumo interno lordo di energia per unità di prodotto interno lordo (PIL) è un indicatore dell'efficienza economica ed energetica del Paese (intensità energetica). L'Italia è stata uno dei Paesi europei a più bassa intensità energetica fino al 1995, quando era dietro solo alla Danimarca, poi ha perso posizioni e nel 2023 ha il 7° valore più basso. Tra i maggiori Paesi dell'UE27, l'Italia continua ad essere tra i Paesi con la più bassa intensità energetica, dopo Germania e Paesi Bassi.

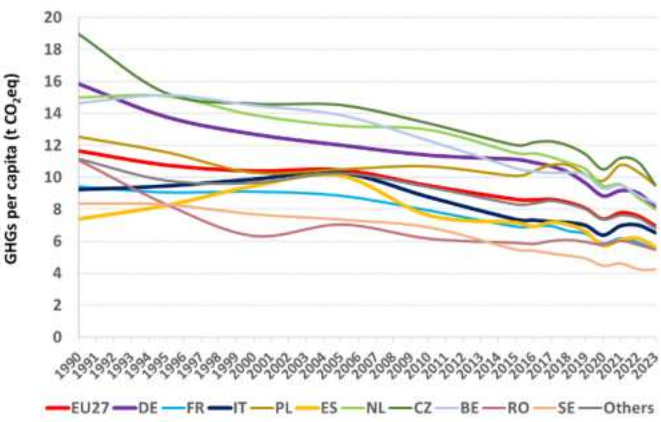


L'intensità energetica finale (rapporto tra consumi energetici finali, compresi gli usi non energetici, e PIL) segue andamenti analoghi all'intensità energetica lorda con una repentina riduzione nei Paesi europei che, partendo da livelli superiori a quelli italiani, raggiungono i valori italiani e in alcuni casi li superano. Dal 1995 l'Italia mostra una notevole efficienza energetica ed economica, l'intensità energetica finale si è ridotta del 22,4% dal 1995 al 2023, considerando il PIL a valori concatenati, e del 54,9% considerando il PIL a parità di potere d'acquisto. Negli altri Paesi europei si sono verificate riduzioni molto più elevate (-39,2% nell'UE27 con il PIL a valori concatenati e -64,7% con il PIL a parità di potere d'acquisto). Le ragioni della riduzione dell'intensità energetica osservata sono molteplici, come l'aumento dell'efficienza degli edifici, il miglioramento dell'efficienza industriale, l'elettrificazione dei consumi finali e lo spostamento dell'economia verso attività di servizi ad alto valore aggiunto e a basso consumo energetico a scapito dei settori industriali.

I Paesi europei mostrano un ampio intervallo di elettrificazione dei consumi finali di energia (solo usi energetici), che nel 2023 va da 14,3% in Lettonia a 39,2% in Malta. Il livello di elettrificazione dell'Italia è inferiore alla media UE27, 22,2% contro 22,9%. Tra i Paesi considerati, Svezia, Francia e Spagna hanno livelli di elettrificazione più elevati dell'Italia, rispettivamente 33,2%, 26,6% e 24,7%. All'estremo inferiore ci sono Romania e Polonia, rispettivamente con 15,3% e 16,6%.

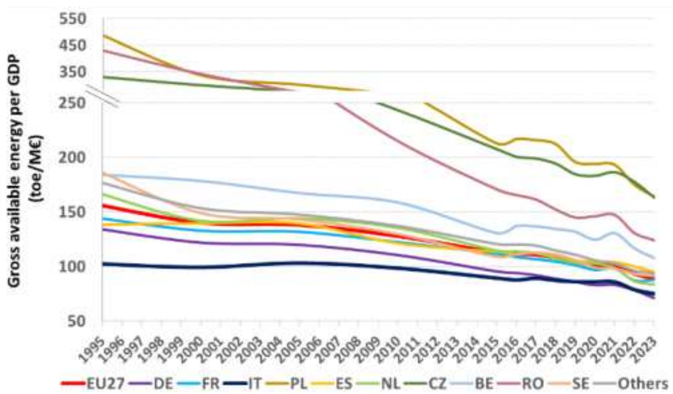
A livello settoriale, l'elettrificazione degli Stati membri mostra cifre diverse, anche se con una comune tendenza alla crescita. L'elettrificazione dell'industria italiana è tra le più alte in Europa (39% nel 2023), molto superiore alla media UE27 (32,6%). I servizi mostrano le quote più alte tra i settori. La quota italiana nel 2023 è del 48,4%, in linea con la media UE27 (51,2%), mentre l'elettrificazione del settore residenziale in Italia è molto inferiore a quella dell'UE27 (19,8% vs 25,9%). Il settore dei trasporti mostra le percentuali più basse di elettrificazione in tutti i Paesi. La media UE27 nel 2023 è del 2,2% e tra i principali Paesi le percentuali più alte si registrano in Svezia (5,8%) e Paesi Bassi (3,5%). Il dato nazionale è del 2%.

Emissioni di gas serra e consumo energetico



In Italia la media di gas serra pro capite dal 1990 al 2023 è pari a 8,7±1,3 t CO_2eq. I gas serra pro capite italiani (6,3 t CO_2eq nel 2023) sono sempre stati inferiori alla media europea (6,9 t CO_2eq nel 2023).

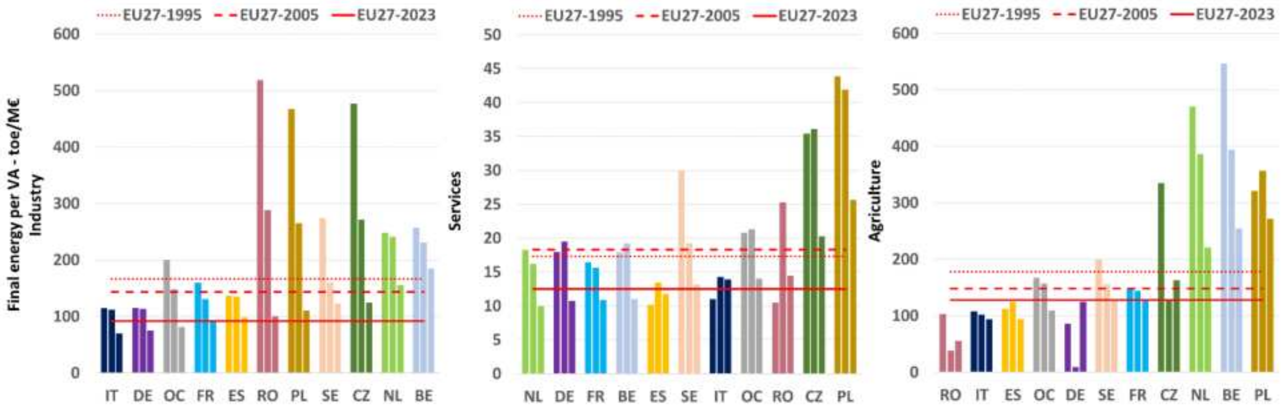
Dal 1990 i gas serra per consumo energetico sono diminuiti in tutti i Paesi. Tale indicatore è sensibile al mix energetico del Paese. L'intensità di carbonio dell'Italia è superiore alla media europea (2,71 t CO_2eq/tep *vs* 2,39 t CO_2eq/tep nel 2023). Scorporando l'energia nucleare dal consumo interno lordo, il valore dell'Italia è inferiore alla media europea (2,71 t CO_2eq/tep *vs* 2,82 t CO_2eq/tep nel 2023).



Il rapporto tra gas serra e PIL è l'intensità di carbonio correlata all'economia. Tale indicatore è sensibile al mix energetico del Paese, come l'intensità di carbonio relativa all'energia, e ancor più sensibile alla struttura dell'economia: quota di servizi e industria. Inoltre, va considerato che il PIL dei paesi è determinato anche da attività legate ai bunkeraggi internazionali, le cui emissioni sono voci "memo" negli inventari delle emissioni presentati all'UNFCCC e non considerate nelle statistiche nazionali sulle emissioni. Tutti i Paesi europei hanno ridotto l'intensità di carbonio dell'economia e i dati dell'Italia, considerando il PIL a valori concatenati, sono appena al di sotto della media UE27 nel 2023 (0,2 t CO_2eq/k€ vs 0,21 t CO_2eq/k€). Lo stesso andamento è osservato con il PIL a parità di potere di acquisto (0,19 t CO_2eq/k€ *vs* 0,21 t CO_2eq/k€). Svezia e Francia hanno i valori più bassi: rispettivamente 0,09 t CO_2eq/k€ e 0,15 t CO_2eq/k€ (a valori concatenati). Polonia e Cechia si collocano all'estremità superiore con 0,58 t CO_2eq/k€ e 0,44 t CO_2eq/k€ (a valori concatenati).

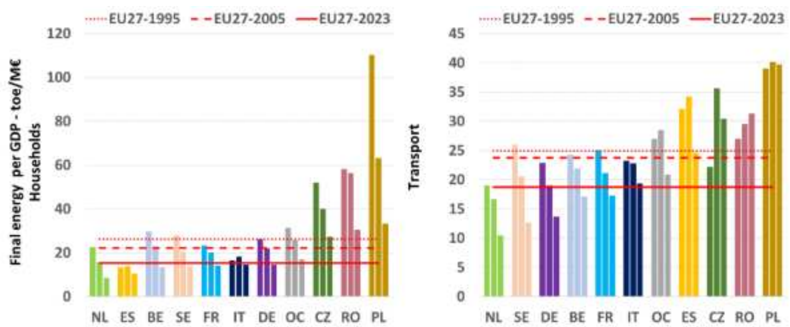
L'inclusione del contributo dei bunker internazionali nell'elaborazione dell'intensità energetica e dell'intensità di carbonio per unità di PIL dimostra che l'Italia e la Germania hanno le intensità energetiche più basse tra i principali Paesi. L'intensità di carbonio italiana è maggiore di quelle registrate in Francia e Svezia, che beneficiano del contributo dell'energia nucleare.

Il confronto degli indicatori di efficienza e decarbonizzazione a livello settoriale tra gli Stati membri mostra un quadro piuttosto eterogeneo. Per quanto riguarda l'industria in Italia, l'intensità energetica finale, rapporto tra consumi finali di energia e valore aggiunto, è sempre stata la più bassa tra i maggiori Paesi con un trend decrescente. Tra i Paesi europei solo Irlanda, Danimarca e Malta hanno un'intensità energetica industriale inferiore a quella dell'Italia nel 2023. Tra i Paesi esaminati, Paesi Bassi e Belgio mostrano le più alte intensità energetiche per l'industria. Il tasso medio annuo dell'intensità energetica del settore dal 2005 al 2023 è diminuito del -2,6% per l'Italia e -2,4% per la media europea.



Nei servizi l'Italia mostra un'intensità vicina alla media europea, superiore a quella della Germania. L'Italia è l'unico Paese, tra i più grandi, la cui intensità energetica in questo settore non è diminuita in maniera rilevante dal 2005. Il risultato è dovuto anche all'energia consumata dalle pompe di calore, che l'Italia ha iniziato a contabilizzare dal 2017 nel database Eurostat, sebbene presenti anche in anni precedenti. L'intensità energetica italiana è diminuita con un tasso medio annuo dello 0,1% dal 2005 al 2023, contro una diminuzione media annua di -2,1% per EU27.

Il settore dell'agricoltura mostra una generale diminuzione dell'intensità energetica nell'UE27. Nel 2022, tra i Paesi considerati, solo la Romania ha un'intensità energetica inferiore a quella dell'Italia. L'intensità energetica italiana diminuisce con un tasso medio annuo di -0,5% dal 2005 al 2023, contro il -0,8% della media europea.

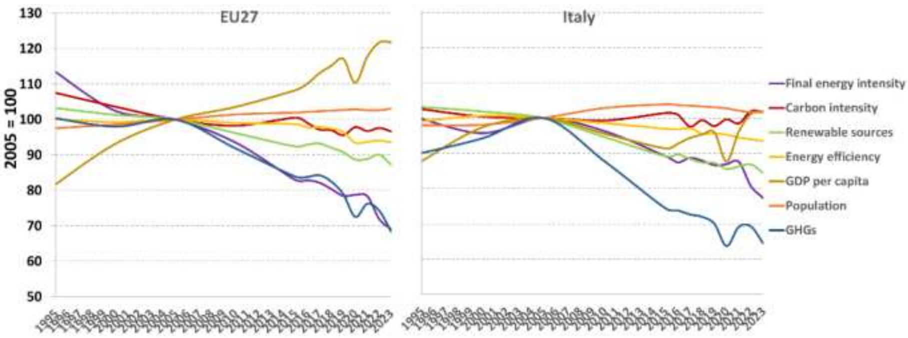


Nel settore domestico, dal 2005 al 2023 i principali Paesi mostrano significative riduzioni dei consumi energetici per unità di PIL: da -1,3% annuo in Italia a -3,5% annuo in Polonia. Per i trasporti l'intensità energetica in Italia è maggiore della media europea. La classifica dei Paesi esaminati nei settori residenziale e trasporti mostra che l'intensità energetica italiana è vicina alla media UE27, con ampi margini di miglioramento nei trasporti.

Quanto detto per l'intensità energetica si riflette nell'intensità di carbonio (t CO_2eq/M€). Questo indicatore è più sensibile al ruolo delle energie rinnovabili, dell'energia nucleare e dell'importazione di energia elettrica nel bilancio energetico dei Paesi, perché tali fonti non generano gas serra. L'industria italiana nel 2023 ha intensità di carbonio superiori solo a quelle di Svezia e Germania tra i principali Paesi. L'agricoltura nazionale ha il valore più basso di intensità di carbonio. Le intensità nazionali per industria e agricoltura sono inferiori alla media europea del 9,1% e 44,6%, rispettivamente. D'altra parte, l'intensità di carbonio dei servizi in Italia è la più elevata tra i principali Paesi. Le intensità nei settori residenziale e trasporti in Italia sono superiori alla media UE27 (+16,3% per il residenziale, +7,2% per i trasporti nel 2023), mostrando un importante potenziale di riduzione dei gas serra per il Paese, soprattutto considerando che l'elettrificazione dei consumi finali del residenziale che nel 2023 è molto al di sotto della media UE27 (19,8% vs 25,9%).

Identità di Kaya e analisi della decomposizione

I parametri dell'identità di Kaya per UE27 e Italia nel periodo 1995-2023 mostrano un andamento molto diverso per quanto riguarda i fattori determinanti la riduzione dei gas serra. Mentre nell'UE27 il fattore principale è l'intensità energetica finale, in Italia sia le fonti rinnovabili che l'intensità energetica finale (energia finale consumata per PIL) sono i fattori trainanti. Inoltre, in UE27 la popolazione e il PIL aumentano, mentre in Italia tali fattori hanno mostrato una tendenza al ribasso. La diminuzione dei gas serra è il risultato integrato della variazione dei fattori determinanti. Quindi, in UE27 è evidente un disaccoppiamento assoluto tra economia e gas serra, mentre in Italia si registra un disaccoppiamento relativo.



I risultati dell'analisi di decomposizione mostrano che in Italia l'efficienza energetica finale ha avuto un ruolo meno importante rispetto ad altri Paesi a causa della migliore performance dell'indicatore in Italia già nel 2005. Inoltre, a differenza dell'Italia, la maggior parte dei Paesi ha registrato un sensibile aumento del PIL pro capite a partire dal 2005.

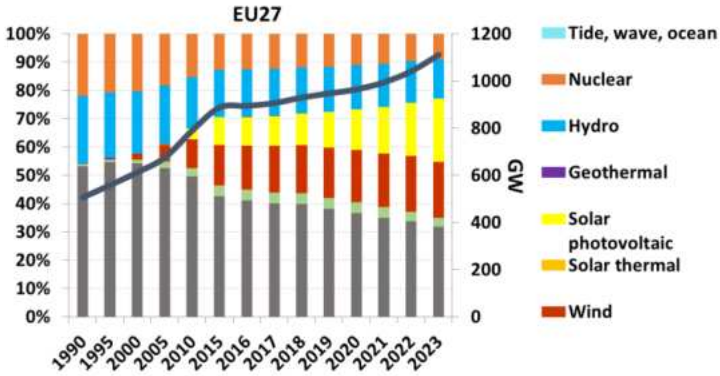
Il disaccoppiamento non corrisponde necessariamente a riduzioni delle emissioni in linea con gli obiettivi. L'analisi di decomposizione si concentra sulla variazione relativa dei parametri, senza assegnare alcun peso ai punti di partenza. L'efficienza economica ed energetica del sistema italiano è tra le più alte d'Europa. L'ultima edizione dell'International Energy Efficiency Scorecard, pubblicata da ACEEE nel 2022, ha segnalato per l'Italia il calo di quattro posizioni rispetto alla precedente edizione del 2018, principalmente a causa della sezione edifici, ma l'Italia è riuscita a posizionarsi tra i primi cinque Paesi, dopo Francia, Regno Unito, Germania e Paesi Bassi. L'International Energy Efficiency Scorecard valuta le politiche di efficienza e le prestazioni di 25 dei Paesi più energivori a livello globale. ACEEE ha utilizzato 36 metriche, sia politiche che orientate alle prestazioni, per valutare gli sforzi di ciascun Paese per risparmiare energia e ridurre le emissioni di gas serra in quattro categorie: edifici, industria, trasporti e progressi complessivi nell'efficienza energetica nazionale. "Le metriche politiche evidenziano le migliori pratiche nelle azioni governative e possono essere qualitative o quantitative. Ne sono un esempio gli obiettivi nazionali per l'efficienza energetica, l'etichettatura degli edifici e degli elettrodomestici e le norme sul risparmio di carburante per i veicoli. Le metriche orientate alle prestazioni sono quantitative e misurano il consumo di energia per unità di attività o servizio fornito. Ne sono un esempio l'efficienza delle centrali termiche, l'intensità energetica degli edifici e dell'industria e il risparmio medio di carburante dei veicoli su strada". (Subramanian et al., 2022).

Il miglioramento dell'efficienza non può prescindere dalla valutazione delle potenzialità e dell'efficacia in termini di costi del cambiamento del sistema energetico. Inoltre, è necessario valutare la struttura economica dei Paesi, in particolare per quanto riguarda il ruolo dei servizi e dell'industria, che hanno intensità energetiche e impronte di carbonio molto diverse.

Settore elettrico

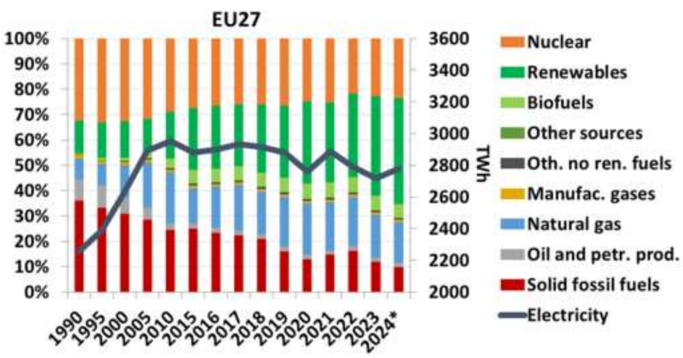
Capacità e produzione di energia elettrica

Il settore elettrico è uno dei principali obiettivi delle misure volte a decarbonizzare l'economia, sia per la quantità di emissioni provenienti dal settore che per il potenziale di diffusione delle energie rinnovabili. I Paesi presi in esame per il confronto con l'Italia rappresentano l'82,6% della produzione lorda di energia elettrica dell'UE27 nel 2023.



La potenza installata nel 1990 era costituita principalmente da impianti termoelettrici (54% nell'UE27), nucleari (21,8%) e idroelettrici (24%). L'eolico e il fotovoltaico avevano quote marginali. Nel 2023 la capacità termoelettrica è stata del 35%, quella nucleare del 9,1%, quella idroelettrica del 13,8%, quella eolica del 19,7% e quella fotovoltaica del 22,1%. La capacità totale è aumentata del 64,2% nel 2023 rispetto al 2005, passando da 676 GW a 1.110 GW. La capacità nucleare è l'unica con una significativa riduzione, da 123 GW a 101 GW (-18% dal 2005 al 2023), principalmente a causa della diminuzione in Germania, Svezia e Belgio. Da segnalare anche l'aumento della capacità netta di impianti alimentati da bioenergie da 15,8 GW nel 2005 a 36,7 GW nel 2023, pari al 9,5% della capacità termoelettrica totale. Tutti i Paesi hanno registrato una notevole diminuzione della quota di capacità termoelettrica dal 1990, così come per la capacità nucleare (ad eccezione di Cechia e Romania).

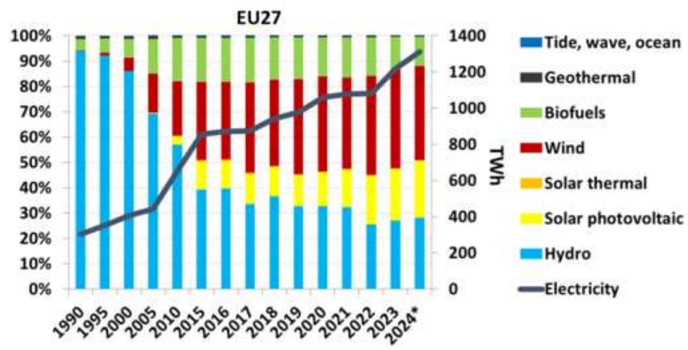
In relazione al sistema elettrico gli Stati Europei presentano una notevole eterogeneità. In Polonia c'è una netta prevalenza di centrali termoelettriche con un ruolo minore per le bioenergie. Le centrali nucleari, assenti in Italia e Polonia tra i Paesi considerati, costituiscono una quota significativa della capacità in Francia (40,9% nel 2023), Svezia (13,6%), Belgio (14,4%) e Repubblica Ceca (19,4%), sebbene le quote degli altri Paesi non siano trascurabili (da 0,9% nei Paesi Bassi a 7,1% in Romania). Dal 1990, la capacità idroelettrica ha rappresentato una parte considerevole delle fonti rinnovabili tradizionali in Romania, Spagna, Francia, Italia e Svezia. Dal 2005 la capacità eolica è aumentata in tutti i Paesi. Gli impianti fotovoltaici hanno iniziato ad avere quote significative solo dopo il 2010 e nel 2023 rappresentano la capacità rinnovabile prevalente in EU27.



La produzione elettrica lorda in Europa è aumentata dal 1990 al 2015 con un tasso medio annuo dell'1%, negli anni successivi fino al 2019 è stata registrata un'ampia oscillazione e il livello del 2019 è approssimativamente lo stesso del 2015. Nel 2020 l'energia elettrica è diminuita, a causa delle misure adottate per contenere la pandemia da SARS-CoV-2. Nel 2021 c'è stata una ripresa, seguita da un nuovo rallentamento nel 2022. Dal 2015 al 2023 il tasso medio è -0,7% per anno. I dati preliminari del 2023 mostrano un incremento della produzione elettrica a livello europeo.

Nel 2023 la quota europea di produzione elettrica da combustibili solidi e da gas naturale è stata del 11,9% e del 16,9%, rispettivamente. Il petrolio e i prodotti petroliferi rappresentano meno del 2%. Il nucleare rappresenta il 22,8%, mentre il 44,8% proviene da energie rinnovabili. Tutti i Paesi considerati, eccetto Germania e Romania, hanno aumentato la produzione di energia elettrica dal 1990, da 13,7% in Svezia a 85% in Spagna. In Romania e Germania la produzione di energia elettrica è diminuita rispettivamente del 10,6% e 7,5%. I dati preliminari del 2024 mostrano l'ulteriore diminuzione delle quote di elettricità da fonti fossili, mentre le fonti rinnovabili dovrebbero raggiungere il 47.3%.

Il mix energetico nei Paesi esaminati è piuttosto eterogeneo, soprattutto per quanto riguarda i combustibili fossili. Nel 2023 i combustibili solidi determinano il 59,5% della produzione di energia elettrica in Polonia, il 39,4% in Cechia e il 24,7% in Germania. La Francia ha la quota più alta di produzione elettrica da centrali nucleari in Europa (65% nel 2022), seguita da Belgio e Cechia (entrambi con 40%), Svezia (29,2%), Spagna (20,3%) e Romania (19,5%). Negli altri Paesi esaminati, la quota nucleare va da 1,3% in Germania a 3,3% nei Paesi Bassi. Polonia e Italia non hanno centrali nucleari. L'Italia e i Paesi Bassi hanno la quota più alta di elettricità da gas naturale (rispettivamente 44,7% e 35,9% nel 2024).



La quota di energia elettrica rinnovabile in UE27 è aumentata da 13,4% a 44,8% dal 1990 al 2023. Tutti i Paesi hanno registrato un incremento della produzione elettrica da fonti rinnovabili con una forte accelerazione dal 2005. Dopo il 2013 la crescita ha rallentato fino al 2017 ed è ripresa negli ultimi anni, anche se con tassi diversi tra gli Stati. La Svezia ha una delle quote più alte in Europa. Secondo i dati preliminari, nel 2024 l'elettricità rinnovabile dovrebbe raggiungere il 47.3% in EU27.

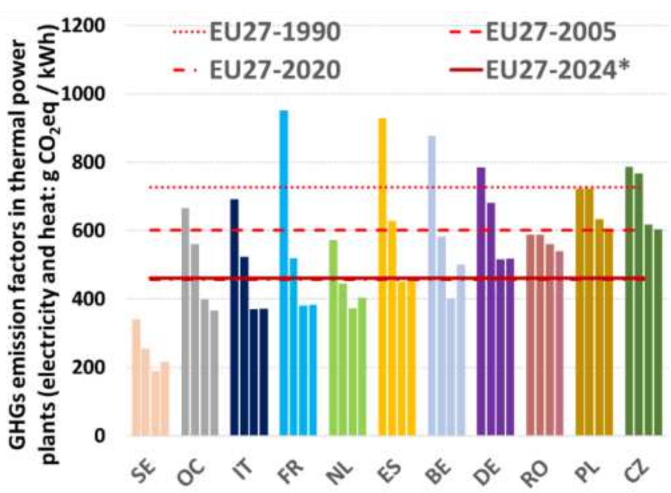
Efficienza delle centrali termiche

Il parametro più importante per valutare l'efficienza del settore elettrico è l'efficienza di trasformazione dei combustibili in elettricità e calore. Il rendimento elettrico degli impianti italiani non cogenerativi nel 2023 è di poco superiore alla media UE27 (0,45 vs 0,419). Per quanto riguarda l'efficienza elettrica degli impianti di cogenerazione, la Spagna ha il valore più alto tra i principali Paesi europei (0,625), di gran lunga superiore alla media UE27 (0,38). L'efficienza elettrica in Italia è 0,456. Il rendimento totale, per la produzione di energia elettrica e calore, degli impianti di cogenerazione italiani (0,55) è inferiore alla media UE27 (0,625).

Il rendimento elettrico italiano per tutte le centrali elettriche (cogenerative e non cogenerative) nel 2023 è 0,453, superato da Paesi Bassi, Spagna e Belgio: da 0,461 a 0,489. La Svezia ha l'efficienza elettrica più bassa tra i Paesi esaminati (0,283), al di sotto della media UE27 (0,397). L'efficienza totale degli impianti italiani è 0,509, inferiore alla media UE27 (0,532). La Svezia mostra il valore più alto (0,781) a causa del più alto rapporto tra calore ed elettricità registrato in questo Paese negli impianti di cogenerazione (circa 1,76), seguita dalla Repubblica Ceca (1,59).

Gas serra nel settore elettrico

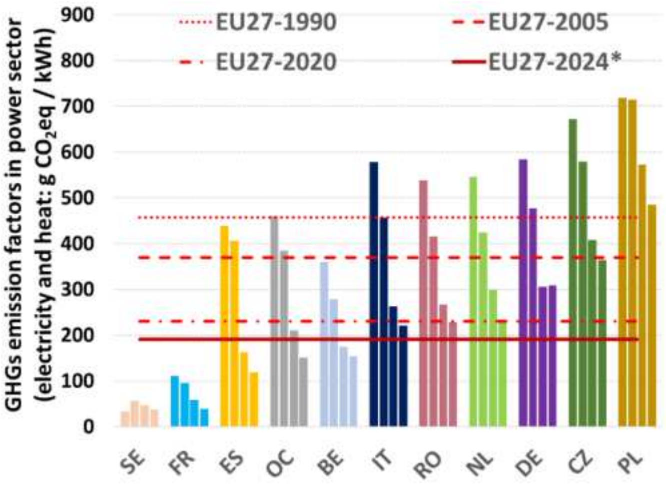
Dal 1990 si registra un disaccoppiamento tra produzione elettrica ed emissioni di gas serra nel settore elettrico di quasi tutti i Paesi europei, anche se le emissioni mostrano una significativa diminuzione solo dopo il 2005. Il disaccoppiamento è dovuto principalmente alla crescente quota di rinnovabili.



Il fattore di emissione di gas serra per la produzione di elettricità e calore nelle centrali termiche è diminuito dal 1990. Nel 2024 il fattore di emissione in Italia, 371,1 g CO_2eq/kWh, è inferiore alla media UE27, 461,1 g CO_2eq/kWh. La riduzione media dal 2005 (-

23,2%) va da -8,3% in Romania a -29,2% in Italia.

Il fattore di emissione per la produzione totale di energia elettrica e calore dell'intero settore elettrico, inclusa quindi la produzione da fonti rinnovabili e nucleare, in Italia è superiore alla media europea (221,2 *vs* 191 g CO_2eq/kWh). I Paesi con fattore di emissione inferiore all'Italia hanno una rilevante quota nucleare e/o quote superiori di fonti rinnovabili. Il fattore di emissione medio in UE27 diminuisce del 48,4% rispetto al 2005 (-51,6% in Italia). In Spagna si registra il tasso di riduzione più alto dal 2005, -70,8%, mentre Polonia e Svezia hanno quelli più bassi, rispettivamente -32,1% e -33,4%, ma la Svezia ha il fattore di emissioni più basso con minori margini di riduzione. Il fattore di emissione in Germania, che ha la più alta quota di gas serra del settore elettrico in EU27, è diminuito del -35,4% dal 2005.

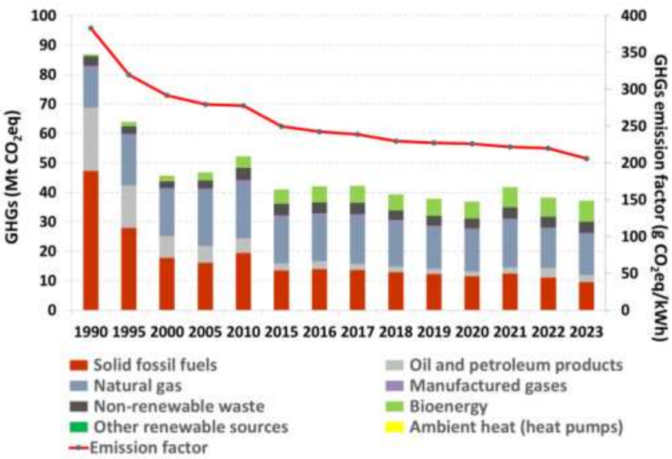


Le centrali termoelettriche italiane si trovano all'estremità più bassa dell'intervallo del fattore di emissione dei gas serra, ad eccezione di Francia, Paesi Bassi e Svezia che hanno una quota molto più bassa di combustibili solidi e petroliferi rispetto all'Italia. Il fattore di emissione italiano occupa la posizione mediana tra tutti i Paesi europei, ben al di sotto della media UE27. Il mix di combustibili italiano, con una quota di gas naturale maggiore rispetto a molti altri Paesi, e il contributo delle bioenergie sono fattori determinanti per il fattore di emissione nelle centrali termoelettriche. D'altra parte, per l'intero comparto elettrico, considerando quindi anche le rinnovabili non termiche e il nucleare, il fattore di emissione italiano perde posizioni rispetto agli altri Paesi ed è maggiore della media Europea.

Per quanto riguarda il settore elettrico, Germania, Polonia e Italia sono i tre maggiori emettitori in Europa. A causa di molti fattori (variazione del mix di combustibili, efficienza, rinnovabili) l'Italia ha ridotto il fattore di emissione per la produzione di energia elettrica del -63,3% dal 1990 al 2024 e del -55,7% dal 2005. La riduzione in Germania è stata del -51,5% dal 1990 e del -37,9% dal 2005, mentre i dati in Polonia sono stati del -42,1% dal 1990 e del -35,9% dal 2005. I tre Paesi rappresentano quasi il 60% dei gas serra dell'UE27 provenienti dal settore energetico.

Produttori di solo calore

La produzione di calore rappresenta una quota significativa dei consumi energetici nel comparto della trasformazione. Gli impianti dedicati alla produzione di calore per il teleriscaldamento e altri usi (principalmente per l'industria) consumano una quota importante dell'energia nel bilancio europeo. Nel 2023 il consumo di questi impianti in UE27 è stato di 17,6 Mtep, di cui 0,7 Mtep da geotermia e solare termico e 0,35 Mtep da pompe di calore. Il consumo energetico dei combustibili è stato di 16,5 Mtep, di cui 6,5 Mtep da bioenergia.Il consumo totale nel 2023 è inferiore di circa il 31,6% rispetto a quello registrato nel 1990 e si è verificata una marcata variazione del mix con una sensibile diminuzione dei combustibili solidi e liquidi, sostituiti dal gas naturale e da bioenergia. Il contributo delle altre fonti



rinnovabili (geotermia e solare termico) e delle pompe di calore ha registrato una crescita e nel 2023 rappresenta il 6% dei consumi totali.

A seguito della variazione del mix energetico, della diminuzione dei consumi (-31,6%) e della produzione di calore (-20,5%), i gas serra hanno registrato una riduzione del 57,2% dal 1990. Il fattore di emissione di gas serra è diminuito del 46,1%. A livello europeo, le emissioni di gas serra di questi impianti sono state 37,2 Mt CO_2eq. Dal 2005 il fattore di emissione è diminuito del 26,3% nell'UE27 (da 279,7 a 206,2 g CO_2eq/kWh). Il fattore di emissioni dell'Italia nel 2023 è inferiore del 14% rispetto alla media UE27. Il rilevante consumo di combustibili solidi o rifiuti non rinnovabili in Polonia e Germania si traduce in un fattore di emissione più elevato, rispettivamente del 98,1% e del 45,4% superiore a quello italiano.

CONCLUSIONI

I risultati mostrano che l'Italia ha una delle economie più efficienti tra i principali Paesi europei. I dati mostrano che l'intensità energetica per PIL e la produttività delle risorse sono tra le più basse in Europa, nonostante un ruolo ancora rilevante dell'industria nell'economia italiana. Una bassa intensità energetica corrisponde spesso a economie basate sui servizi, con un ruolo minore delle attività industriali. L'intensità di carbonio per energia consumata in EU27 è mediamente inferiore a quella italiana, anche per il contributo di una quota non trascurabile di energia nucleare in diversi Paesi.

L'andamento dei gas serra dipende da molti fattori. La riduzione delle emissioni nei Paesi europei è dovuta principalmente alla diminuzione dell'intensità energetica e all'aumento del consumo di energia rinnovabile. Nel 2020 le misure adottate per contenere la diffusione della pandemia da SARS-CoV-2 hanno inciso pesantemente sull'economia europea e sulle emissioni di gas serra. Indipendentemente dalle contingenze c'è un chiaro disaccoppiamento tra PIL ed emissioni serra nei Paesi europei, anche se al disaccoppiamento non corrispondono necessariamente riduzioni delle emissioni in linea con gli obiettivi. Il potenziale di riduzione delle emissioni deve essere valutato considerando anche i punti di partenza dei fattori determinanti e dei costi per modificare il sistema energetico, nonché la struttura economica, soprattutto per quanto riguarda il rapporto tra servizi e industria.

Gli indicatori settoriali di decarbonizzazione in Italia mostrano settori come l'industria e l'agricoltura con intensità energetiche e di carbonio in rapporto al PIL tra le più basse d'Europa e settori come residenziale e trasporti con ampi margini di miglioramento. Il livello di elettrificazione del settore residenziale in Italia è ben al di sotto della media europea e il settore dei trasporti ha ampi margini di riduzione delle emissioni, soprattutto nel segmento delle autovetture. Le emissioni italiane pro capite per questo segmento dei trasporti sono superiori alla media europea e tra le più alte tra i principali Paesi. Tali risultati sono coerenti con la preoccupante distanza delle proiezioni italiane dall'obiettivo di riduzione delle emissioni serra da raggiungere nel 2030. Gli obiettivi si concentrano sulla ripartizione tra le maggiori industrie energetiche e manifatturiere (soggette al sistema di scambio di quote di emissione, ETS) e altri settori (disciplinati dal regolamento sulla condivisione degli sforzi, ESR). Gli obiettivi di emissione del Paese sono fissati solo per i settori non soggetti a ETS, ovvero trasporti, servizi, residenziale, agricoltura, rifiuti e piccola industria, mentre le emissioni di grandi impianti, come centrali termoelettriche, raffinerie, cementifici, acciaierie, ecc. rientrano nel sistema europeo di scambio di quote di emissione. Tale impegno non cambia con l'introduzione del cosiddetto ETS-2, che entrerà in funzione nel 2027 per l'edilizia, il trasporto stradale e altri settori, come l'industria non coperta dall'attuale ETS.

INTRODUCTION

Country's greenhouse gas emissions (GHGs) depend on many factors related to the economic activities and citizens lifestyle. In European Union (EU27), energy emissions accounted for about 80% of total emissions. Italian GHG emissions from the energy sector are 80% in 2023. The energy system underlying economic activities is therefore the main area of investigation to understand the driving factors for GHG emissions. The fuel mix, as well as energy efficiency, in terms of transformation of primary energy and economic output, are key factors. The economic activities themselves, which are also driven by the users' demands, are driving factors of GHGs, and the reduction of such activities inevitably leads to emissions reduction. While energy efficiency can be considered as intrinsic driving factors of the energy system, the demand for goods and services can be regarded as an extrinsic economic factor, although both energy and economy systems are intertwined and difficult to be treated as separate systems. The economic crisis that has affected the world's major economies, including Italy, since 2007-2008, has made the task of discerning the driving factors of GHG emissions even more difficult. After more than a decade Italy and Greece, among the EU countries, suffered the most significant impacts of the economic crisis. Even though Italy' economy recovered since 2015, up to 2019 was the only Country which had not yet filled the gap of GDP per capita loss in EU. Moreover in 2020 the SARS-CoV-2 pandemic caused a further decline of the economy in all the European countries. In 2021 the European economy experienced a marked recovery but the Russian-Ukrainian war that broke out in the first half of 2022 adversely affected the growth projections. Such events heavily impacted on GHG emissions and European climate policy.

Climate and energy policies are undergoing an in-depth review following what was agreed at COP21 in Paris in 2015, when the Parties decided to keep the rise of global average temperature well below 2°C and to do everything possible to limit the increase to 1.5°C above pre-industrial levels, a target that will be exceeded in 2030 according to the statement released in 2023 by Jim Skea (Chair of IPCC). The historic significance of the Paris Agreement lies in the key point that virtually all the States of the world have committed to reduce their GHGs by 2030, through mitigation plans. In the context of emissions mitigation policies, the EU has already played an important role since the ratification of the Kyoto Protocol, when it committed to reducing the GHGs, in the period 2008-2012, by 8% compared to 1990. This commitment was shared among the Member States and Italy was allocated a reduction by 6.5%. In 2012, an agreement was reached among the Parties on the continuation of the Kyoto Protocol through the Doha Amendment, which sets reduction commitments for the period 2013-2020. Italy ratified the Doha Amendment with Law of 3 May 2016. The Doha Amendment entered into force on 31 December 2020, with 148 countries.

In 2007, before what was agreed at the international level, the European Council had already expressed the need for the EU to initiate a transition towards a low-carbon economy through an integrated approach that included energy policies to curb climate change. In particular, the Council set binding targets to be achieved by 2020, such as 20% reduction of GHG emissions compared to 1990, the share for renewable energy consumption set to 20% of the EU energy consumption, the use of biofuels for 10% of the amount of fuel used in the transport sector and the indicative target of reducing energy consumption by 20% compared to the 2007 Reference Scenario projections for 2020. Following the Council's conclusions, the "Climate and Energy Package" was approved, i.e. a set of legislative measures aimed at implementing the commitments was put in place.

For 2030 the European reduction targets reflected the commitments made by the EU under the Paris Agreement: reduction of GHGs by at least 40% compared to 1990, achievement of at least 32% of energy consumption from renewables and the achievement of at least 32.5% increase in energy efficiency compared to projections of the expected energy used in 2030. Another target directly related to the electricity system is the achievement of 15% for electrical interconnections in 2030. This means that each country should have in place electricity cables that allow at least 15% of the electricity produced on its territory to be transported across its borders to neighbouring countries.

In such context, Italy issued its National Energy and Climate Plan in 2019 (AA.VV. 2019). The Plan established how the country should achieve or approach the national 2030 targets on energy efficiency, renewable sources and the reduction of GHG emissions.

With the European Green Deal, the European Commission proposed in September 2020 to raise the 2030 GHG emissions reduction target, including carbon removals from forestry activities, to at least 55% compared to 1990, with a view to achieving carbon neutrality by 2050 as established in the European Commission's Long-Term Strategy (2018a, 2018b). In this context, as required for each EU Member State by article 15 of the Regulation (UE) 2018/1999 (Governance Regulation), Italy adopted its National Long-Term Strategy on the reduction of GHGs (LTS) in January 2021 (AA.VV., 2021), identifying the possible pathways that could allow to achieve a condition of carbon neutrality by 2050, i.e. the balance between GHGs and CO_2 removals, with the possible use of geological capture and storage systems or CO_2 reuse.

On 14 July 2021 the European Commission presented a proposal for amending the Renewable Energy Directive increasing the target to at least 40% renewable energy sources in the EU's overall energy mix by 2030. Relevant actions are required across all sectors to achieve the new targets, including increased energy efficiency and renewable energy. Such actions were considered in the Italy's Recovery and Resilience Plan submitted in 2021 to European Commission in compliance with EU's extraordinary recovery effort, Next Generation EU: the plan agreed by EU leaders in July 2020 to overcome the economic and social impact of the pandemic facing the environmental, technological, and social challenges of our time.

The Commission started the process of making detailed legislative proposals by July 2021 (Fit-for-55 package) to implement and achieve the increased ambition that will enable EU to move towards a climate-neutral economy by 2050 – an economy with net-zero GHG emissions. Among other measures the Commission put forward a proposal for a recast directive on energy efficiency. The proposal raised the level of ambition of the EU energy efficiency target and makes it binding by requiring EU countries to collectively ensure a reduction in primary energy consumption of 9% compared to the reference trend established in the PRIMES 2020 scenario. Moreover, the Fit-for-55 package put forward several legislative proposals to translate the European hydrogen strategy into concrete European hydrogen policy framework.

In reaction to the Russian invasion of Ukraine since 24th February 2022, there was growing support across the European Parliament to increase the EU's 2030 renewable energy target ending the EU's dependence on Russian fossil fuels (EC, 2022a). Currently, just over 23% of Europe's energy final consumption comes from renewables. From the 40% renewable energy target by 2030 proposed by European Commissions in July 2021, the European Parliament set to push for the target to be increased to 45%. On 18 May 2022 European Commission presented the REPowerEU Plan to phase out EU dependency on Russian fossil fuels faster through energy savings, diversification of energy supplies, and accelerated deployment of renewable energy to replace fossil fuels in buildings, industry, and power generation. Moreover, as for the hydrogen the ambition is to produce 10 Mt and import 10 Mt of renewable hydrogen in the EU by 2030 (EC, 2022b).

At present, the European target of reducing net GHG emissions by at least 55% by 2030 compared to 1990 levels, as reported in the second NDC transmitted by the EU in compliance with the Paris Agreement and fit-for-55 package. The raise of the European target from the previous -40% to the current -55% of emissions compared to 1990 determined a radical increase of the effort in reducing emissions through all sectors.

The emission reduction target of ETS passed from -42% to -62% in 2030 compared to 2005 at European level, whereas the non ETS emission target, ruled by Effort Sharing Regulation, passed from -30% to -40% at European level. The new ETS target covers an expanded scope compared to the previous one. Beyond the emissions from power generation, energy-intensive industries, and aviation as previously legislated, the new structure will add carbon dioxide emissions from maritime transport from 2024, further extended to methane and nitrous oxide from 2026. Moreover, with Directive (EU) 2023/959 of 10 May 2023 amending Directive 2003/87/EC, a new emissions trading system will be established (ETS-2), for buildings, road transport and additional sectors, e.g. fuel combustion by industry not covered by the existing EU ETS. The ETS-2 is an upstream system regulating fuel suppliers rather than households and car users. It will become fully operational in 2027, while the monitoring and reporting of emissions will start in 2025. The cap is set to achieve an emission reduction of 42% by 2030 compared to 2005 levels. Emissions from sectors covered by the ETS-2 remain covered by Member States' emission reduction targets under the

Effort Sharing Regulation (ESR). This means that the ETS-2 complements national efforts to reduce emissions in the ESR sectors. It is estimated that by 2030, half of the ESR emissions will be covered under the ETS-2. The ETS-2 does not cover non-CO_2 emissions which are mainly from agriculture and waste management. (EEA, 2023). The carbon price set by the ETS-2 will provide a market incentive for investments in building renovations and low-emissions mobility.

Whereas the target for ETS is defined at European level, the GHG reduction targets for sectors included in the Effort Sharing Regulation (ESR) and the objectives for the LULUCF sector are on Member States with burden shared according to the different capacities of Member States to act by differentiating targets. Collective national targets result in a 2030 emission reduction at European level of 40% compared to 2005. This value was proposed by the European Commission and approved by the European Parliament on March 14, 2023. The target for Italy, determined in accordance with Article 4(3) of the Effort Sharing Regulation, is -43.7%. The European target of 55% emissions cut also includes the emissions and removals by LULUCF, ruled by Regulation (EU) 2018/841. The revision of the mentioned Regulation set the emissions neutrality by 2025 (2021-2025), and further removals target by 2030 of 310 $MtCO_2eq$. The Italian target is -35.8 $MtCO_2eq$ by 2030.

As for the renewable energy use, the European Parliament and the Council reached on 30 March 2023 a provisional agreement to raise the binding renewable energy target to at least 42.5% by 2030 but aiming for 45% (EC, 2023). On the energy efficiency side, the EU concluded the revision of the Energy Efficiency Directive on 25 July 2023. The current legislation set new binding target of reducing EU final energy consumption by 11.7% by 2030, compared to the projected energy use for 2030 (based on the 2020 reference scenario).

The National Energy and Climate Plan (NECP) issued in 2019 has been recently updated (MASE, 2024) to embody the new targets set by European Commission. The updated NECP encompasses policies and measures addressed to achieve the European targets on GHGs emissions, renewable share, and efficiency.

Regardless any specific target the negotiating processes among EU countries cannot ignore the peculiarities of Member States energy systems as well as the technical and economic potentials to change their systems. The development of a country's productive structure involves not only technological aspects but also the economic and social ones affecting the daily lives of millions of people. The definition of climate targets must therefore consider several factors. If GDP is an essential factor, as an expression of a country's investment capacity, it is equally essential to consider other aspects of energy and economy systems, such as industry share, fuel mix used by each country and the cost effectiveness for changes. In other words, the inertia of any complex systems and the decreasing returns of investments aimed at changing a particular equilibrium state cannot be ignored. This does not mean that a given situation cannot be changed, but any country should be aware of both the resources needed and the consequences. As far as energy sources are concerned, there are different reduction potentials between countries with a significant share of high-carbon fuels and countries with a very small share of high carbon content fuels. It can be misleading to consider only GDP as the investment capacity, without looking at the different reduction potentials and the related costs.

This report does not aim to analyse energy and production systems but at the analysis of Italian performance indicators and the comparison with the largest European countries concerning energy consumption and climate-changing emissions. The analysis will not go into details on factors determining the energy needs of the countries, such as the geographical-climatic factor or demographic and social factors. No indicator is immune to criticism and weaknesses: the energy intensity (energy consumption per GDP) in the buildings sector is affected by climatic factors, not only by efficiency; the industry sector includes a wide range of activities with very different energy requirements, so the relative shares of activities is a crucial factor for sector’s intensity. While aware of the role played by these factors on energy demand and efficiency, the target of the analysis is to examine at macroscopic level the main indicators of decarbonization and energy efficiency in the European countries *rebus sic stantibus*. If the former indicators provide information on GHGs emissions per unit of energy used or per unit of wealth produced, the latter ones provide information on how efficiently energy is used to produce wealth. The two families of indicators are strongly interlinked, because if the production of goods and services cannot be separated from energy consumption, the consumption of energy by fossil fuels in turn determines GHGs emissions.

The economy decarbonization can be pursued by acting both on the energy sources used to produce commodities and on the efficiency of energy use, acting on both fronts is the most virtuous path that can be taken. Concerning the energy sources, useful strategies point to shift towards a fuel mix with lower carbon content, therefore mainly made up of natural gas, or increasing the renewable share of energy that are not without other environmental worries, e.g. the combustion of biomass and the consequent emission of atmospheric contaminants harmful to air quality or the consumption of soil by wind and photovoltaics power plants. On the energy efficiency side, the goal is obviously optimization, which consists in achieving more with less. In other words, to reduce as much as possible the losses and inefficiencies to produce commodities (e.g. buildings heating system, moving by vehicles, production of steel, cement, paper, textiles and so on).

In a highly interconnected system, the identification of the causes of a given phenomenon, such as GHG emissions, is a thorny issue, however it is possible to assess the role of the different driving factors according to a conceptual model that establishes coherent relationships between the factors considered. To assess the role of the factors behind the change in GHG emissions, Kaya analysis and decomposition analysis was applied to study the variation of a parameter in a time interval in relation to the variation of its driving factors.

The power sector is a key stone of any energy system. The electricity generation accounts for a significant share of the energy sector, around one third of European energy GHG emissions. The EU long-term strategy by 2050 (EC, 2018a, b) examines different development scenarios and highlights how electricity will become the main energy carrier, from 22% of final energy consumption in 2015, to 41%-53% in 2050. The growing role of the power sector requires an examination of electricity generation systems in the Member States. The analysis in the largest European countries was therefore carried out concerning the fuel mix, the transformation efficiency, and the GHGs emissions factors. The same analysis, although less detailed, was carried out for plants producing only heat that represent a significant share of energy consumption, especially in the countries of Northern Europe.

In this report the GHGs accounting follows the approach required to elaborate the national inventory reports of GHGs under the UNFCCC frame. Only emissions from fuel combustion occurring in the national territory are considered. As for the combustion of bioenergy, it is considered a net zero CO_2 emitting process; only CH_4 and N_2O are accounted. However, as already mentioned, the deployment of bioenergy is not without other environmental concerns (air quality, biodiversity, forest degradation, etc.) or serious troubles on agricultural land loss and food system. Even on the GHGs side IPCC (2022) reports that "the use of bioenergy can lead to either increased or reduced emissions, depending on the scale of deployment, conversion technology, fuel displaced, and how, and where, the biomass is produced."

1 NATIONAL DATA

Energy data of Italy have been downloaded from the Eurostat database in the complete energy balances section (https://ec.europa.eu/eurostat/data/database, last update 02 May 2025).

The inventory of GHG emissions has been submitted by ISPRA to EU on 15 January 2025 and to UNFCCC on 15 April 2025. In this report the data submitted to UNFCCC are considered for Italy and other countries, although later on a comprehensive review was carried by European Commission in accordance with Article 38(1a) of Regulation (EU) 2018/1999 ('Governance Regulation'). The outcome of the review, which can result in important changes in the GHG emissions, has been presented to the member States at the end of August 2025 and will be considered in the GHG inventory to be submitted in 2026. Only for Italy the technical corrections carried out by the EC are briefly mentioned relatively to the effects on the gap with the ESR targets to be achieved in the period 2021-2023.

The purpose of the comprehensive review is to enable the Commission to set out the annual emission allocations (AEAs) of EU member States for the years from 2026 to 2030, in terms of tonnes of CO_2eq, as required by Article 4(3) of Regulation (EU) No 2018/842 (the 'Effort Sharing Regulation', ESR). The reviewers carried out checks to verify the transparency, accuracy, consistency, comparability and completeness of the national GHG inventory for the years 2021, 2022 and 2023 submitted in 2025 pursuant to Article 26(4) of the Governance Regulation. The comprehensive review was carried also for LULUCF to set out the annual limit values for the years from 2026 to 2030, in terms of tonnes of CO_2eq, as required by Article 4(4) of Regulation (EU) No 2018/841 (the 'LULUCF Regulation'). The reviewers carried out checks to verify the transparency, accuracy, consistency, comparability and completeness of the national GHG inventory for the years 2016, 2017 and 2018 as well as 2021, 2022 and 2023 submitted in 2025.

Preliminary estimates of GHGs emissions in 2024 have been carried out by ISPRA, based on data issued by SNAM for the distribution of natural gas, MASE (Ministry of Environment and Energy Security) for coal and petroleum products consumptions; all data updated to 31 December 2024.

Very early extrapolation of GHGs emissions in 2025 are also carried out according to the data updated to the first seven months of the year in the power sector (TERNA, Monthly Report on the electricity system, July 2025), and data on fuel consumptions issued by SNAM and MASE: distribution of natural gas up to the end of August, coal and petroleum products consumptions up to the end of June and July, respectively.

Preliminary estimates are characterized by considerable uncertainty and will be revised with final data.

1.1 Energy consumption and GHGs

Energy statistics follow the nomenclature of energy balance issued by Eurostat. GHGs by sector are reported according to the Common Reporting Tables submitted to UNFCCC.

1.1.1 Gross and final energy consumption

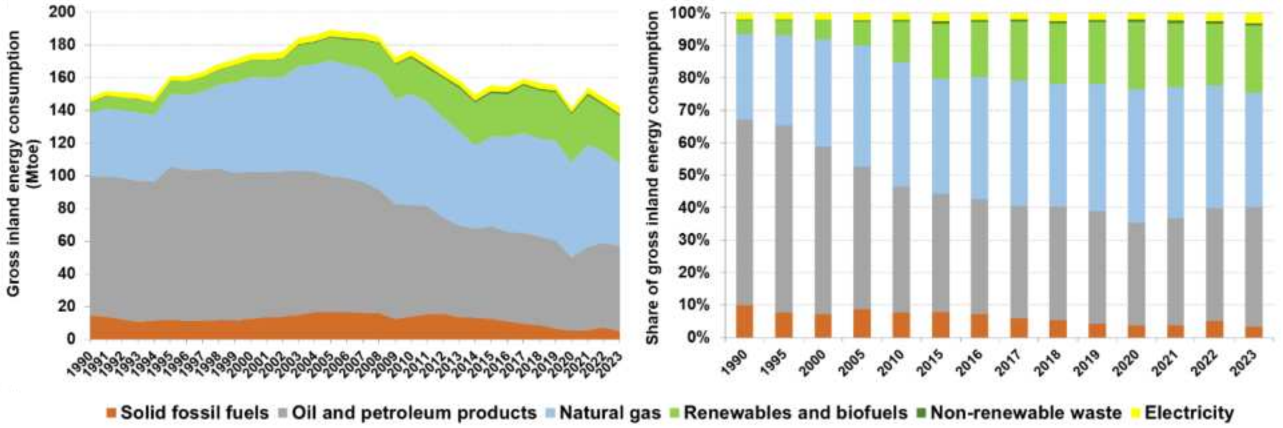
National gross inland energy consumption shows an increasing trend from 1990 to 2005, when it peaked at 189.4 Mtoe (toe: tonnes of oil equivalent), then there was a reduction accelerated by the economic crisis started in 2008, with the minimum value of 149.8 Mtoe reached in 2014 and a recovery in the following years. Gross energy consumption in 2020 furtherly decreased as consequence of lockdown to contain SARS-CoV-2 pandemic (-8.9% lower than 2019 level and -4.4% lower than 1990 level). In 2021 it was recorded a rebound of consumption (+8.8% higher than 2020), with 154.1 ktoe, followed by further setback in 2022 and 2023, which is only 0.4% higher than 2020. Preliminary data in 2024 show a slight decrease of energy consumption, while early extrapolation for 2025, although uncertain, show an upward trend.

Table 1.1 – Gross inland energy consumption by energy source (Mtoe).

Energy source	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	*2024**	*2025[x]*
Solid fossil fuels	14.6	12.3	12.6	16.5	13.7	12.3	5.1	5.5	7.4	4.8	*2.2*	*2.1*
Oil and petroleum products	84.9	93.2	89.9	83.3	68.4	56.7	44.9	51.0	51.5	52.2	*52.9*	*52.8*
Natural gas	39.0	44.7	57.9	70.7	68.1	55.3	58.3	62.4	56.1	50.3	*50.5*	*52.2*
Renewables and biofuels	6.5	7.7	10.1	14.1	21.9	26.3	29.3	30.3	28.2	29.2	*30.7*	*30.5*
Non-renewable waste	0.2	0.2	0.3	0.7	1.0	1.1	1.2	1.2	1.2	1.2	*1.2*	*1.2*
Electricity	3.0	3.2	3.8	4.2	3.8	4.0	2.8	3.7	3.7	4.4	*4.4*	*4.4*
Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*	*0.0*
Total	**148.1**	**161.2**	**174.5**	**189.4**	**176.8**	**155.7**	**141.6**	**154.1**	**148.1**	**142.2**	***141.9***	***143.0***

* Preliminary data; [x] early extrapolation from data available up to the end of August 2025.

Figure 1.1– Gross inland energy consumption and share by energy source.



Fossil fuels are the main carriers in the national energy system. From 1990 to 2005, the average ratio of fossil fuels over the gross domestic consumption was more than 90%, although with a slight decline. Later, the share of fossil energy is severely reduced. From 1990 to 2023 the share of fossil energy decreased from 93.6% to 76.4%. The decline has become particularly steep since 2007. In 2022 it is worth noting the slight increase of fossil share compared to the previous year, mainly due to the contraction of hydro energy and increase of solid fuels share: the first factor due to drought, the second one to cope the natural gas contraction following the Russia-Ukraine war. The increase of hydro energy and the decrease of solid fuels in 2023 has led the fossil share downward. Moreover, preliminary data for 2024 and early extrapolation for 2025 record further decrease of solid fuels, while for hydro energy the increase in 2024 should be followed by a contraction.

The fuel mix has changed since the 1990s. Oil products accounted for the predominant component, with 57.3% of gross domestic consumption in 1990. The share of oil products has steadily decreased up to 31.7% in 2020, with a steady increase in the following years. In 2023 the share of oil products (36.7%) came back over the level of 2015 and preliminary data for 2024 show that such fuels are still increasing their share, while in 2025 a slight slowdown is expected. The share of natural gas follows a specular trend with constant increase since 1990 up to 2020 (from 26.3% to 41.2%), followed by a decreasing trend (35.4% in 2023) that should go on in 2024. The share of solid fuels, after a decreasing trend since 2012 up to 2021 (from 9.6% to 3.6%), recorded a rebound to 5% in 2022, followed by a downward trend up to 2025, less than 1.5%. It is noteworthy that after 2020 the share of electricity in gross inland consumption shows a relevant increase. From 1990 to 2020 the average is 2.2%, while in 2023 the share is 3.1%.

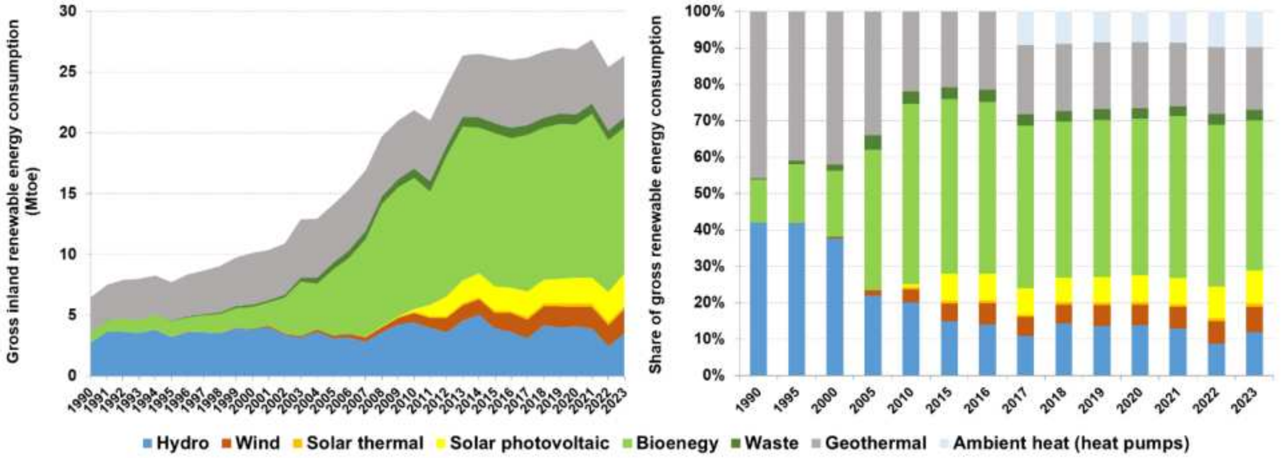
The share of renewable energy is complementary to that observed for fossil fuels. From 1990 to 2007 there was a steady increase in the share of renewables from 4.4% to 9%. After 2007 the share accelerated up to 20.7% of gross inland consumption in 2020, followed by a setback in the following two years (19.6% in 2021 and 19% in 2022) and a rebound in 2023 (20.5%). According to the preliminary data for 2024, the renewable energy on gross inland consumption should increase to about 21.7%.

Table 1.2 – Gross inland renewable energy consumption by energy source (Mtoe).

Energy source	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	*2024**	*2025ˣ*
Hydro	2.7	3.2	3.8	3.1	4.4	3.9	4.1	3.9	2.4	3.5	*4.5*	*3.7*
Wind	0.0	0.0	0.0	0.2	0.8	1.3	1.6	1.8	1.8	2.6	*1.9*	*2.0*
Solar thermal	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.3	0.3	*0.3*	*0.3*
Solar photovoltaic	0.0	0.0	0.0	0.0	0.2	2.0	2.1	2.2	2.4	2.6	*3.1*	*3.6*
Biomass	0.8	1.2	1.8	5.4	10.8	12.6	12.6	13.5	12.5	12.0	*12.1*	*11.9*
Waste	0.0	0.1	0.2	0.6	0.8	0.8	0.8	0.8	0.8	0.8	*0.8*	*0.8*
Geothermal	3.0	3.2	4.3	4.8	4.8	5.5	5.3	5.3	5.2	5.1	*5.0*	*5.0*
Heat pump	0.0	0.0	0.0	0.0	0.0	0.0	2.5	2.6	2.8	2.9	*2.9*	*3.1*
Total	**6.5**	**7.7**	**10.1**	**14.1**	**21.9**	**26.3**	**29.3**	**30.3**	**28.2**	**29.2**	***30.7***	***30.5***

* Preliminary data; ˣ early extrapolation from available up to the end of August 2025.

Figure 1.2 – Gross inland renewable energy consumption trend and share by energy source.



From 1990 to 2000 the main sources of renewable energy have been geothermal and hydro, which accounted for more than 80% of gross inland consumption of renewable energy. The remaining share was mainly met by biomass and wastes (bioenergy). Since 2000, the bioenergy has shown a considerable growth, reaching the peak of time series in 2008 with a share of 50.9% on renewable sources. After 2008 the share of bioenergy decreased (44.1% in 2023) in the aftermath of the increase of other sources, as solar (thermal and photovoltaic) and wind. Solar and wind sources have assumed significant role and together represent 16.9% of total renewable energy consumption in 2023. The energy by heat pumps has been recorded by Italy in the Eurostat budget since 2017. Such item in 2023 was 9.8% of renewable gross inland consumption.

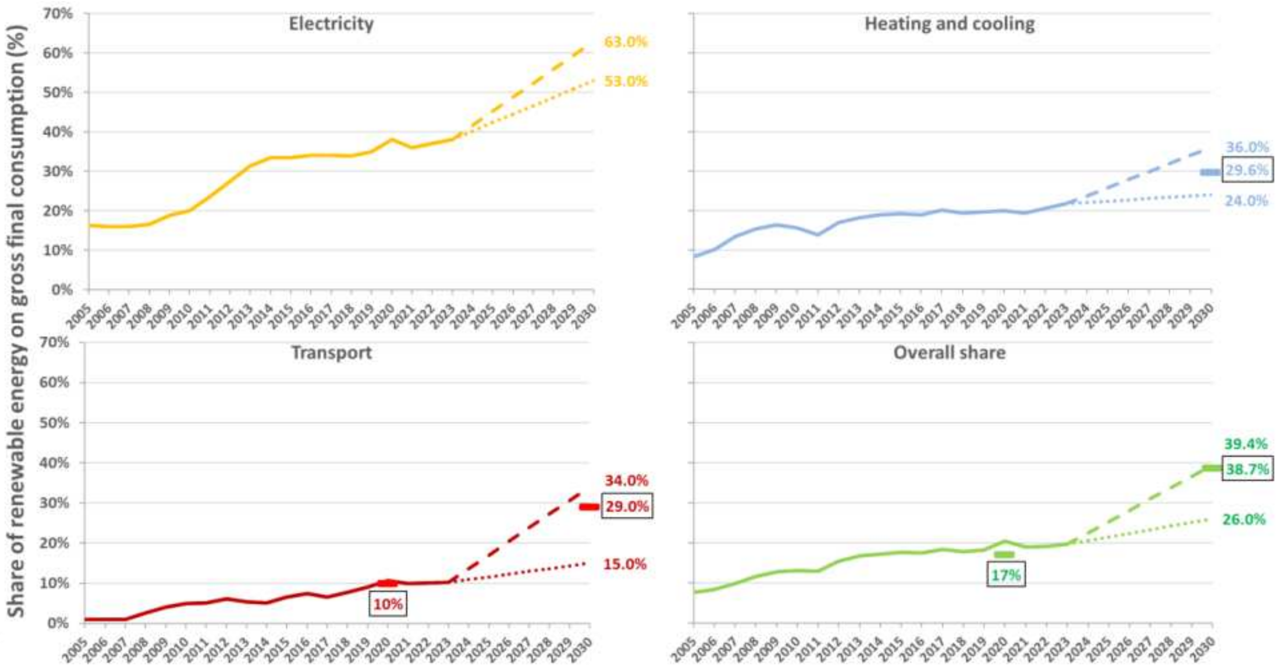
As concerns the European renewable targets, Directive 2009/28/EC established the shares of energy from renewable sources on gross final consumption by 2020 for each country of the European Union; the mandatory target for Italy was 17% which was overachieved, with 20.4%. The fall of energy demand in 2020, due to COVID-19 pandemic, pushed up the renewable energy share. The level in 2023, calculated according to Directive (EU) 2018/2001, was 19.6%, showing a slight increase compared to 2022 (19.1%). The overall mandatory target to be achieved in 2030 for Italy, calculated according to the Directive (EU) 2023/2413 (so called RED III), is 38.7% (MASE, 2024). The policy scenario, issued with the National Energy and Climate Plan (MASE, 2024), shows that Italy should overachieve the target, with 39.4%. Such result can be reached only with a robust acceleration of renewable energy final consumption. From 2005 to 2023 the share increased by 0.67 percentage points per annum (from 7.5% to 19.6%), while the increase should be 2.83 percentage points per annum since 2023 up to 2030 (from 19.1% to 39.4%) and 2.73 percentage points per annum to achieve the target.

Even more challenging is the achievement of the mandatory target for transport. The historical data show an average increase of 0.51 percentage points per year from 2005 to 2023, while the annual average increase required to achieve the mandatory target of 29% in 2030 must be 2.68 percentage points up to

2030 (3.39 points per year to reach the share of policy scenario of NECP). Even the renewable share for heating and cooling (H&C) must accelerate to achieve the mandatory target of 29.6%. The average increase of renewable share in such sector was 0.75 percentage points per year from 2005 to 2023, while the required rate to achieve the target must be 1.13 points per year (2.04 per year to reach the share of policy scenario of NECP). Renewable for electricity consumption have not a mandatory target but even for such sector is necessary to speed up the annual rate of the past. The annual average increase was 1.21 percentage points per year from 2005 to 2023. From 2010 to 2014 has been recorded the highest increase with an average of 3.3 points per year. The required rate per year to achieve the levels reported in the NECP should be 2.13 points for the reference scenario and 3.56 points for the policy scenario.

All sectors contribute to the achievement of the overall renewable target but should be also considered the share of each sector in the gross final consumption. Electricity, which recorded the highest rate of renewable development and will see the highest increase in the future according to the projections, accounted for about a quarter of gross final consumption in 2023, while transport and H&C accounted for about 33% and 43%, respectively showing the relevance of such final uses to achieve the overall target.

Figure 1.3 – Share of renewable energy gross final consumption by sector. Actual trends up to 2023 are shown and projections up to 2030 as reported in the NECP (dotted lines: reference scenario; dashed lines: policy scenario). The figures in the box are mandatory targets.



Primary energy is the gross inland energy consumption without non-energy consumption. Non-energy consumption from 1990 to 2023 represented an average of 5.1% of gross domestic consumption with a decreasing trend: from 7% in 1990 to 3.2% in 2023.

Final energy consumption, including non-energy uses, is on average 80% of primary energy in the period 1990-2023. Primary and final energy consumption peaked in 2005. A sharp reduction in energy consumption has been observed up to 2014 in the aftermath of the economic crisis started in 2008. The decline from 2005 to the lowest value in 2014 (142.7 Mtoe of primary energy and 116 Mtoe of final consumption) was 21.1% for primary energy and 17.2% for final consumption. After 2014 the final consumption increased with wide fluctuations and a drastic fall in 2020. In 2021 a rebound has been recorded (+9.8% compared to 2020), followed by a new setback in 2022 and 2023. Primary energy consumption in 2023 is -21.3% below the 2005 level, while final energy without no energy use is -17.5% lower than 2005 level. No-energy final consumption in 2023 recorded a reduction of 47.9% compared to 2005 level.

Table 1.3 – Primary energy consumption by energy source (Mtoe).

Energy source	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Solid fossil fuels	14.6	12.1	12.4	16.3	13.5	12.2	5.1	5.5	7.4	4.8
Oil and petroleum products	76.1	84.5	82.6	75.9	59.5	50.8	38.8	45.8	46.4	48.2
Natural gas	37.3	43.7	57.0	69.7	67.5	54.7	57.6	61.8	55.6	49.9
Renewables and biofuels	6.5	7.7	10.1	14.1	21.9	26.3	29.3	30.3	28.2	29.2
Non-renewable waste	0.2	0.2	0.3	0.7	1.0	1.1	1.2	1.2	1.2	1.2
Electricity	3.0	3.2	3.8	4.2	3.8	4.0	2.8	3.7	3.7	4.4
Primary energy	**137.7**	**151.4**	**166.1**	**180.8**	**167.3**	**149.1**	**134.8**	**148.2**	**142.4**	**137.7**
Primary energy (EED)*	**137.7**	**151.4**	**166.1**	**180.8**	**167.3**	**149.1**	**132.3**	**145.6**	**139.6**	**134.8**

* This indicator monitors progress towards energy efficiency targets implemented by Directive 2012/27/EU on energy efficiency and Directive (EU) 2023/1791 on energy efficiency (recast). The indicator measures the level of energy consumption and distance to 2020/2030 targets.

Table 1.4 – Final energy consumption by energy source (Mtoe).

Energy source	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Solid fossil fuels	2.7	2.0	1.5	1.3	0.6	0.5	0.4	0.3	0.3	0.3
Oil and petroleum products	52.7	52.1	55.0	56.0	45.6	41.2	32.2	38.9	41.0	41.0
Manufactured gas	0.9	0.8	0.3	0.0	0.0	0.2	0.1	0.1	0.1	0.1
Natural gas	28.7	33.7	37.6	40.6	38.5	33.0	31.8	36.6	31.6	29.5
Renewables and biofuels	0.9	1.4	1.7	4.5	9.1	8.4	10.7	11.9	11.3	11.4
Non-renewable waste	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.3	0.3	0.3
Electricity	18.5	20.5	23.5	25.9	25.7	24.7	23.7	25.1	24.7	24.0
Heat	0.0	0.0	0.0	3.1	3.3	3.9	3.9	1.5	1.5	1.4
Final energy	**104.5**	**110.5**	**119.7**	**131.5**	**123.1**	**112.1**	**103.1**	**114.7**	**110.8**	**107.9**
No energy final consumption	**10.4**	**9.8**	**8.4**	**8.6**	**9.6**	**6.6**	**6.8**	**5.9**	**5.7**	**4.5**
Final energy (EED)*	**106.0**	**112.4**	**122.6**	**134.5**	**126.2**	**115.3**	**102.1**	**113.8**	**110.9**	**108.7**

* This indicator monitors progress towards energy efficiency targets implemented by Directive 2012/27/EU on energy efficiency and Directive (EU) 2023/1791 on energy efficiency (recast). The indicator measures the level of energy consumption and distance to 2020/2030 target.

Table 1.3 and Table 1.4 show also the indicators to monitor energy efficiency targets. Primary and final energy consumption in 2023, respectively 137.7 Mtoe and 107.9 Mtoe, should be compared with the targets to be achieved in 2030, set according to the Fit for 55 and REPower EU, respectively 111 Mtoe and 93 Mtoe (MASE, 2024). The targets on energy consumption are mandatory at EU level but indicative at member State level. Such thresholds result in average reduction from 2023 to 2030 of -2.7% per year for primary energy consumption and -2.2% per year for final energy consumption. The average annual rate of energy consumption decreased since 2005 by -1.6% for primary energy and -1.2% for final energy up to 2023. According to the policy scenario issued in the National Energy and Climate Plan (MASE, 2024), Italy would not reduce the energy consumption, as required by the target, and the projected energy consumption in 2030 should be 123 Mtoe for primary energy and 102 Mtoe for final energy. The projected energy consumption should decrease with lower annual average rates than those recorded in the past, from 2005 to 2023 (Figure 1.4).

Figure 1.4 – Primary and final energy consumption. Actual trends up to 2023 are shown and projections up to 2030 as reported in the NECP (dotted lines: reference scenario; dashed lines: policy scenario).

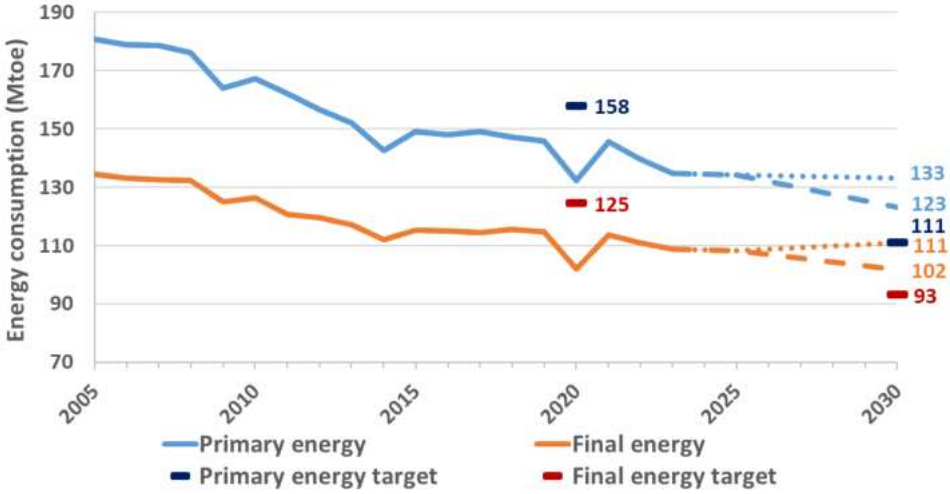
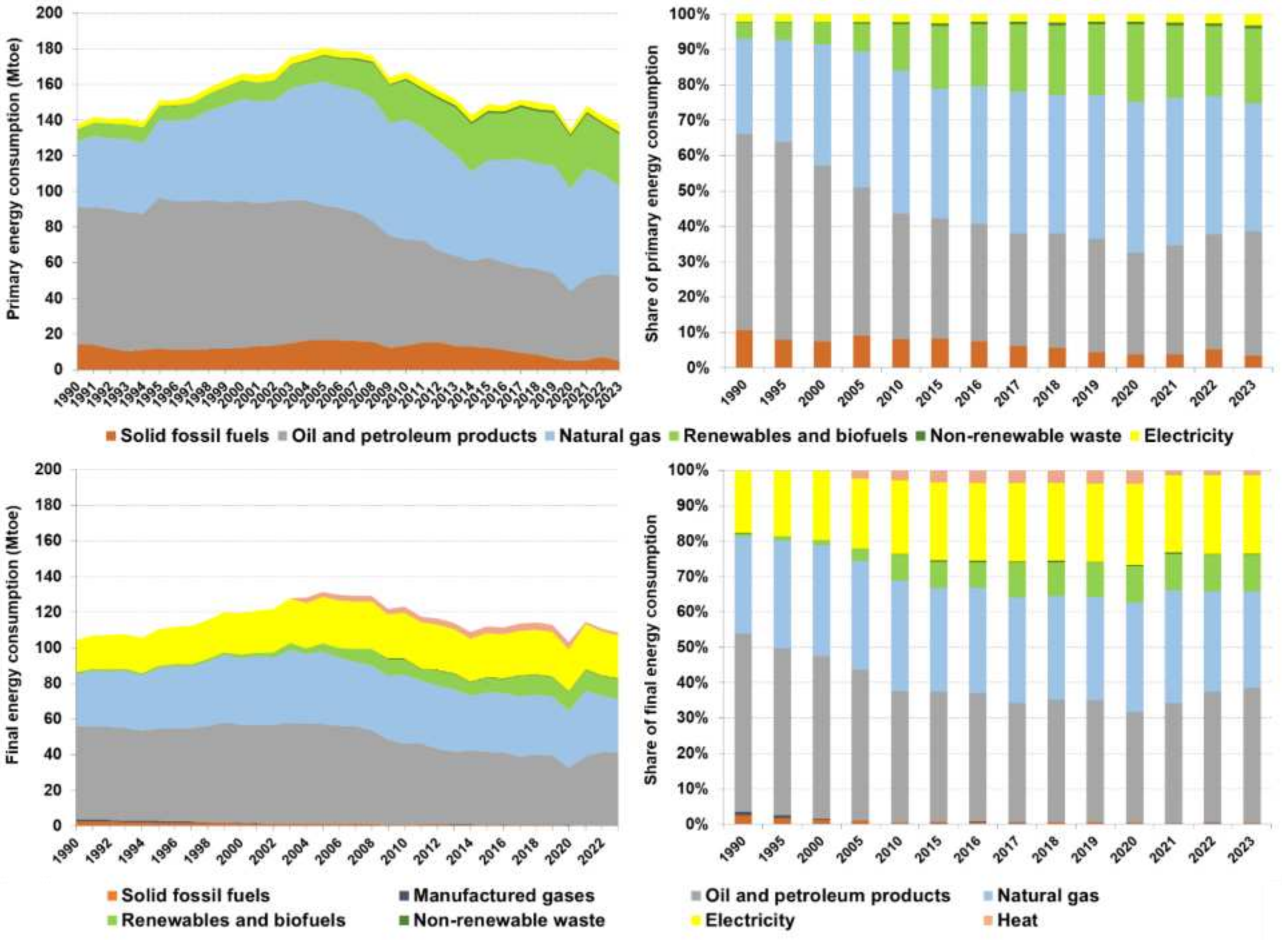


Figure 1.5 – Primary and final energy consumption trends by sources.



In Table 1.5 the gross inland energy consumption is split by final uses and transformation and losses energy.

Table 1.5 – Energy consumption by sector.

Sectors	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Transformation & losses	31.5	38.4	42.9	46.9	41.9	34.9	30.8	32.1	33.2	28.5
Industry	34.1	33.9	37.6	37.2	29.0	24.9	23.9	26.4	24.6	23.5
Transport*	34.2	38.6	42.5	44.8	41.7	39.5	30.5	36.4	39.5	40.7
Households	26.1	26.3	27.6	33.9	35.4	32.5	30.7	33.4	30.0	27.6
Services	8.2	9.8	11.5	15.1	17.0	15.4	16.6	16.8	16.1	16.6
Agriculture	2.9	3.0	2.9	3.0	2.7	2.7	2.8	3.0	2.9	2.8
Fishing	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Others	0.4	0.6	0.2	0.2	0.2	0.1	0.0	0.1	0.2	0.2
No energy final use	10.4	9.8	8.4	8.6	9.6	6.6	6.8	5.9	5.7	4.5
Statistical differences	0.1	0.5	0.6	-0.5	-0.9	-1.1	-0.6	-0.2	-4.4	-2.4
Total	**148.1**	**161.2**	**174.5**	**189.4**	**176.8**	**155.7**	**141.6**	**154.1**	**148.1**	**142.2**

* Including international aviation

Figure 1.6 shows trends and shares of energy consumption by sector. Sectors with more than 20% share of consumption in 2023 are transformation and losses (20.1%) and transport with international aviation (28.6%). Households consume 19.4%, while industry and services take 16.5% and 11.7%, respectively. Industry in Eurostat energy balance includes the subsector of construction.

Figure 1.6 – Energy consumption trend and share for transformation and final users.

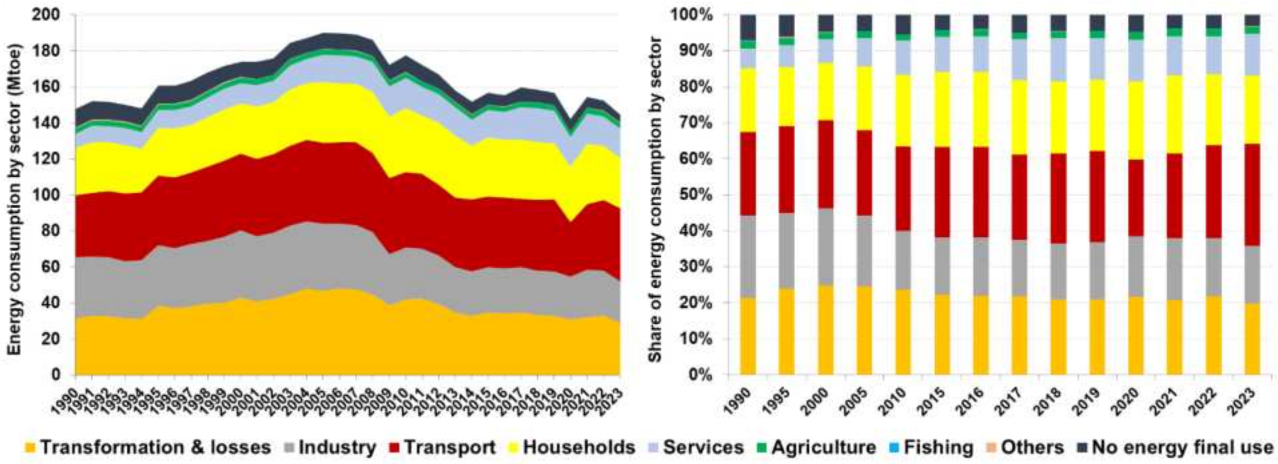
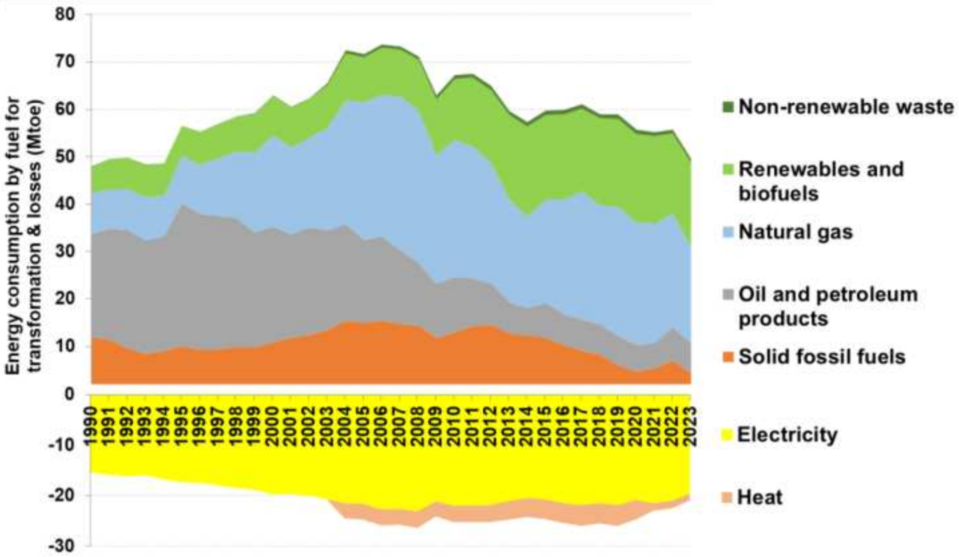


Figure 1.7 zooms in the transformation and losses and makes clear the shrinking of solid fossil fuels since 2012 and the rebound after 2020 up to 2022. Even more clear is the decrease of oil & petroleum products and the corresponding increase of natural gas and the increasing share of renewable sources.

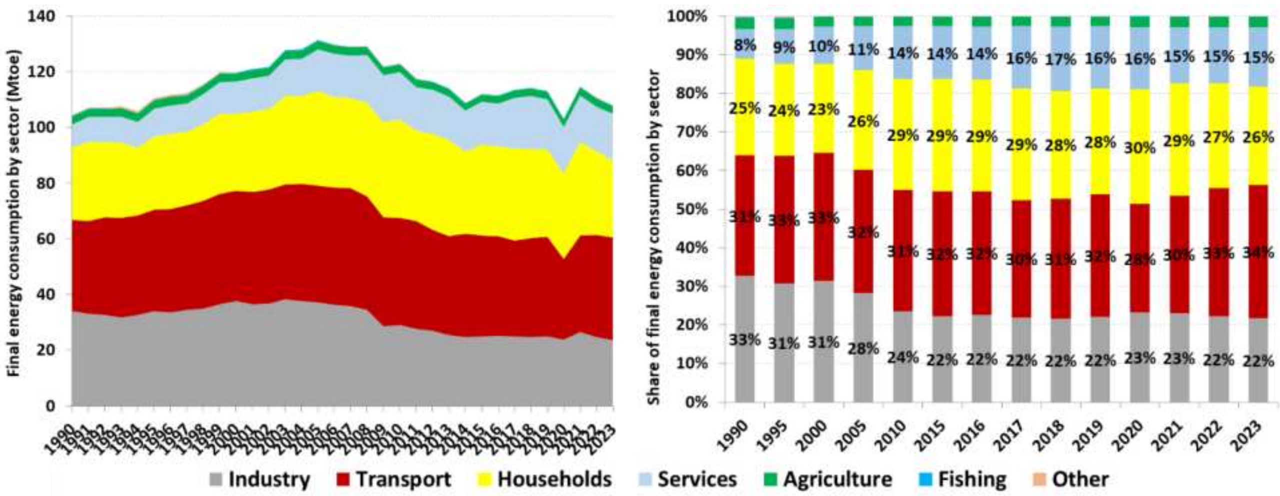
Figure 1.7 – Energy consumption trend by fuel for transformation and losses.



The final energy consumption by sector shows structural peculiarities for each sector and different sensitivities to contingent factors, such as economic crisis since 2008 or 2020 lockdown, which have mainly affected the productive sectors. The final energy consumption of industry decreased by 31.1% from 1990 to 2023, while the final consumption of services is more than twofold the 1990 level (+103.1%). The trend of final consumption in the households is quite swinging depending upon climatic conditions that affect energy demand. The consumption of such sector in 2023 is 5.9% over the 1990 level. Transport increased by 13.4% compared to 1990, after the fall in 2020 due to the lockdown measures.

Since the 1990s, the structure of sectors in terms of energy demand has changed considerably. Services account for an increasingly share of final consumption from 7.8% in 1990 to 15.4% in 2023, while industry reduced the share from 32.6% to 21.8% over the same period. Consumption in the households shows a growing trend until 2010 followed by a slight decrease with large fluctuations mainly due to the average temperature. The average share of energy consumption in the other sectors, mainly agriculture and fisheries, is about 3%.

Figure 1.8 – Final energy consumption trend and share by sector. Transport with international aviation.



The details of final energy consumption by energy sources and sector show the peculiar consumption structure for each sector. Oil & petroleum products are the dominant energy source in transport (91.3% in 2023), which records a very small amount of electricity consumption (2%). Biofuels share for transport is 4.1%. Industry has more diversified energy sources, high level of electricity consumption (39%) and small renewable share (2.4%). Natural gas feed 41.2% of sector's energy demand. In the household's sector there is a growing share of renewable energy since 2000 (25.5% in 2023 *vs* 4.7% in 2000), mainly represented by solid biomass (84.4% of renewable energy in 2023). In the services the renewable energy was quite negligible up to 2016. Italy begins to record energy consumption by heat pumps since 2017, as required by Eurostat. The renewable energy consumption in 2023 is 13.4%. As for electricity consumption in 2023 the households share is 19.8%, while the services share is 48.4%. Natural gas feed 46.7% of household's demand and 33.5% of services' demand.

A relevant change of data reporting in the Eurostat energy balance occurred for Italy starting from 2021, even though the current data reporting has been required by Eurostat since many years. Data from 2021 encompass the revision of reporting criteria concerning the energy needed for industrial heat auto producers. In data before 2021 all the energy for heat production is accounted in the transformation sector. Since 2021 only the energy to produce the heat transferred to third parties is accounted in transformation, while the energy consumed by industrial plants for heat self-production is accounted in industry. Such change determined an increase of the final energy consumption in industry and affects the electrification rate; the sharp decline of industry electrification observed since 2021 is uniquely due to the reporting criteria. Moreover, electricity consumption reporting has been revised, mainly for services which since 2021 contain the consumption for water supply, previously included in industry.

Figure 1.9 – Final energy consumption trend and share by energy source.

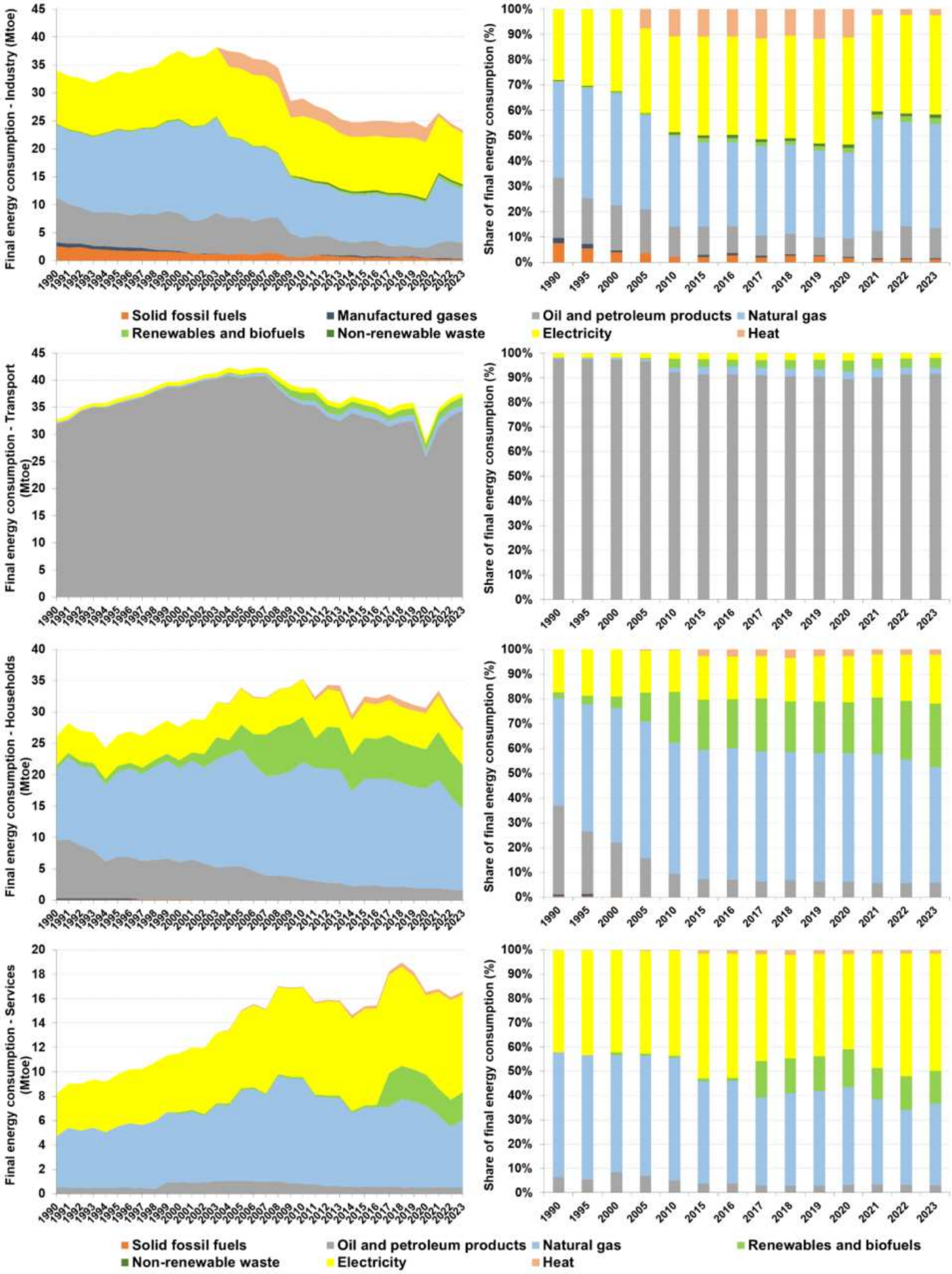
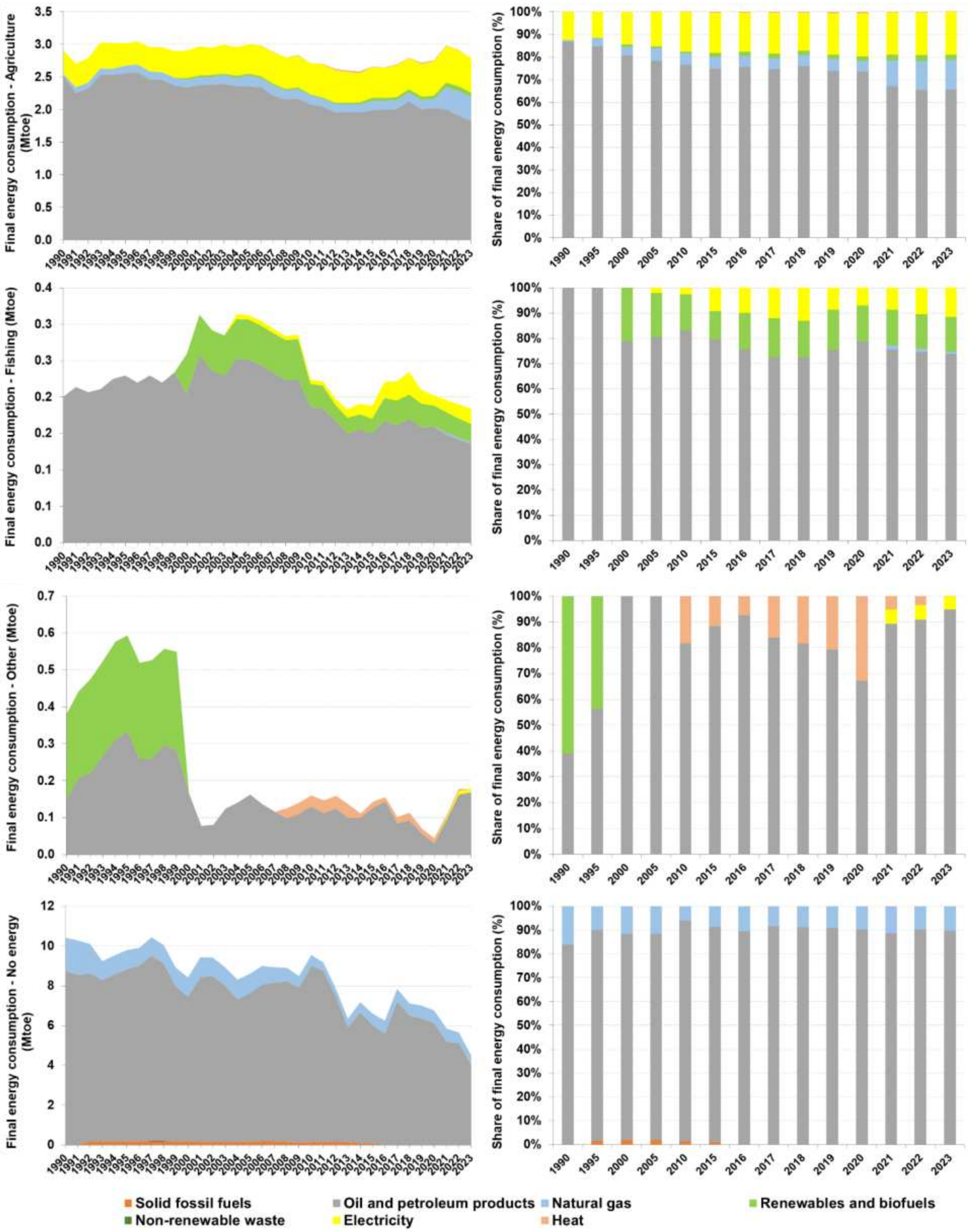


Figure 1.10 shows the energy consumption for sectors with lower energy consumption and no energy uses. All sectors have significant share of oil & petroleum products consumptions even though sectors as agriculture and fishing show a growing share of electricity. In the fishing sector, a relevant share of renewable energy is recorded since 2000.

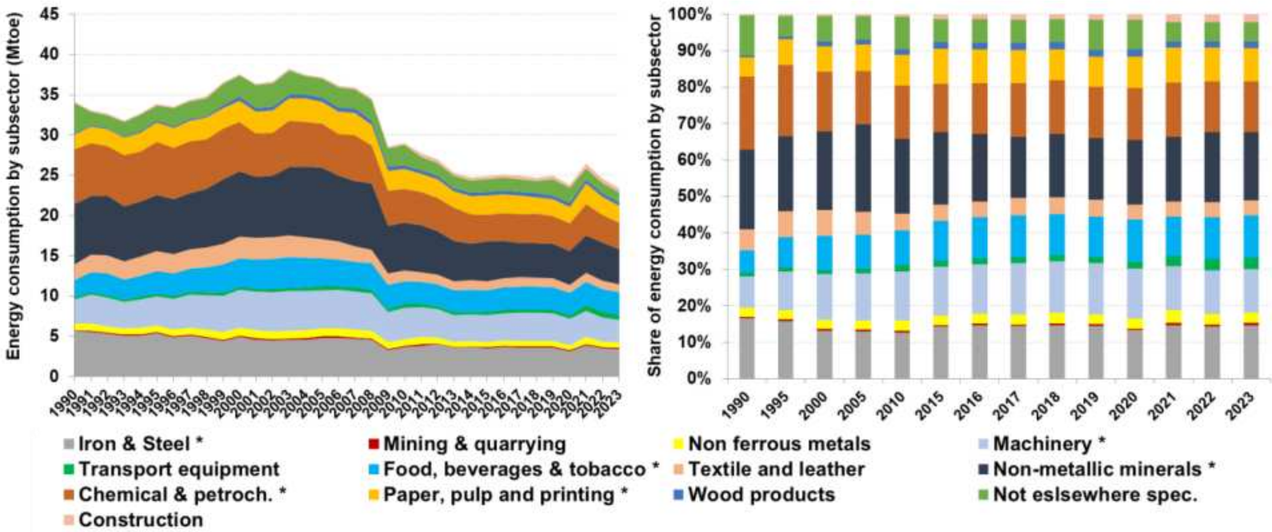
Figure 1.10 – Final energy consumption trend and share by energy source.



Further details are available for industry. Six subsectors, marked with * in Figure 1.11, demand about 83% of final energy consumptions in manufacturing industry (industry sector without mining & quarrying and construction) in 2023. Figure 1.11 shows how the final consumption of each subsector shrunk in 2009 in the aftermath of the economic crisis. The contraction concerned all subsectors in a quite homogeneous way, as the relative shares of energy consumption did not change significantly before and after the economic crisis. The structure of final consumption among manufacturing industry subsectors shows little change since 2005. The greatest change occurred in food industry whose share on manufacturing industries demand increased from 9.4% to 12% in 2023. The shares of energy demand in iron & steel, transport equipment, and paper industries increased just below two percentage points. The greatest decrease has been recorded in non-metallic minerals, from 24.2% in 2005 to 19.2% in 2023. Textile and leather decreased its share from 6.5% to 4.1% in the same period. All other industry subsectors changed their shares below the range of ±1%.

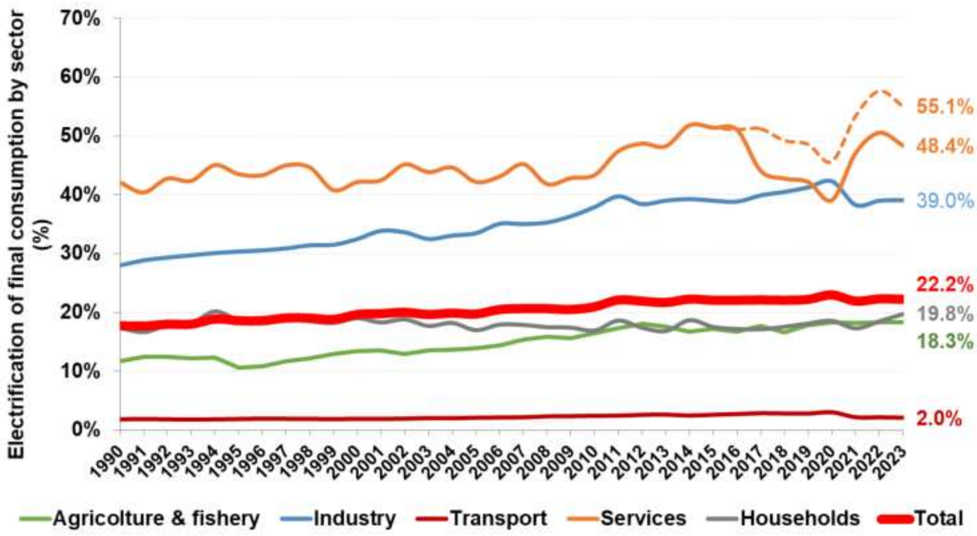
The share of construction on industry final energy demand changed from 0.6% to 2.3% from 2005 to 2023.

Figure 1.11 – Final energy consumption in industry subsectors. * Subsectors which cumulatively demand 83% of final energy consumption in manufacturing industry in 2023.



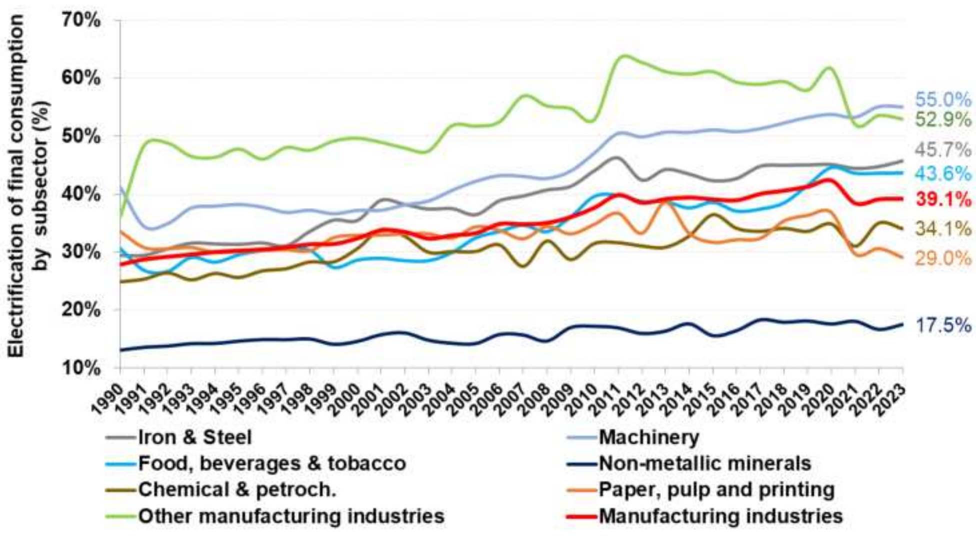
The electrification of final energy consumption is a key strategy to mitigate GHGs emission, if pursued in parallel with the spread of renewable energy for electricity production. The share of electricity in final energy consumption increased since 1990 and in 2023 is 22.2%. The electrification by sector is quite different (Figure 1.9 and Figure 1.10). Services show the highest share of electricity consumption, with a significant increase from 2008, reaching more than 50% of the sector's final consumption in 2014 and 2015. Since 2017 the share decreased up to 2020 to grow again in the last years. The sharp decrease is mainly due to countability reason: Italy reported the final consumption of ambient heat from heat pumps since 2017, before such year these data did not appear in the national energy balance. Without such item, the electrification of the sector in 2023 is 55.1%, while including all items the share is 48.4%. The sharp increase from 2021 is due to the allocation in this sector of water services, previously accounted in industry. The electrification in industry has been steadily increasing since 1990, with the rate clearly accelerating since 2005. In this sector, electricity consumption represents 39.2% in 2023. Even for this sector the fall recorded in 2021 is due to countability reason, as previously reported. The electrification of households and transport shows no significant increases in the long run; in 2023 the electricity shares were respectively 19.8% and 2%. Agriculture and fisheries show a long-term increase of electrification, similarly to industry; in 2023 the share is 18.3%.

Figure 1.12 – Electrification of final energy consumption by sector. The dashed line refers to the energy consumption without the heat pumps.



As for manufacturing industries the electrification of the six main subsectors (cumulatively consuming 83% of final energy, see Figure 1.11) is shown in Figure 1.13. Such subsectors required 76.1% of electricity consumption in manufacturing industry in 2023. The highest rate is recorded for machinery with 55% of energy demand supplied by electricity in 2023. On the other end, there are non-metallic minerals, with 17.5%. The average level for manufacturing industry is 39.1%. All main subsectors increased the electrification rate since 1990, with the only exception of paper industry whose electrification rate decreased by 4.5 percentage points since 1990 and reached its highest rate in 2013 with 39.1%. The other manufacturing industries, represented by minor subsectors (non-ferrous metals, transport equipment, textile and leather, wood products, and not elsewhere specified), have average electrification rates higher than the biggest ones, with 52.9% in 2023 and a wide range of time variability. The long term increasing trend since 1990 for such minor subsectors changed direction after 2011, when the top level of 63.2% was reached. Paper, pulp and printing as well as the minor subsectors was the ones mainly affected by the already mentioned accountability change occurred from 2021, with the allocation of water services, previously accounted in industry, in the sector of services.

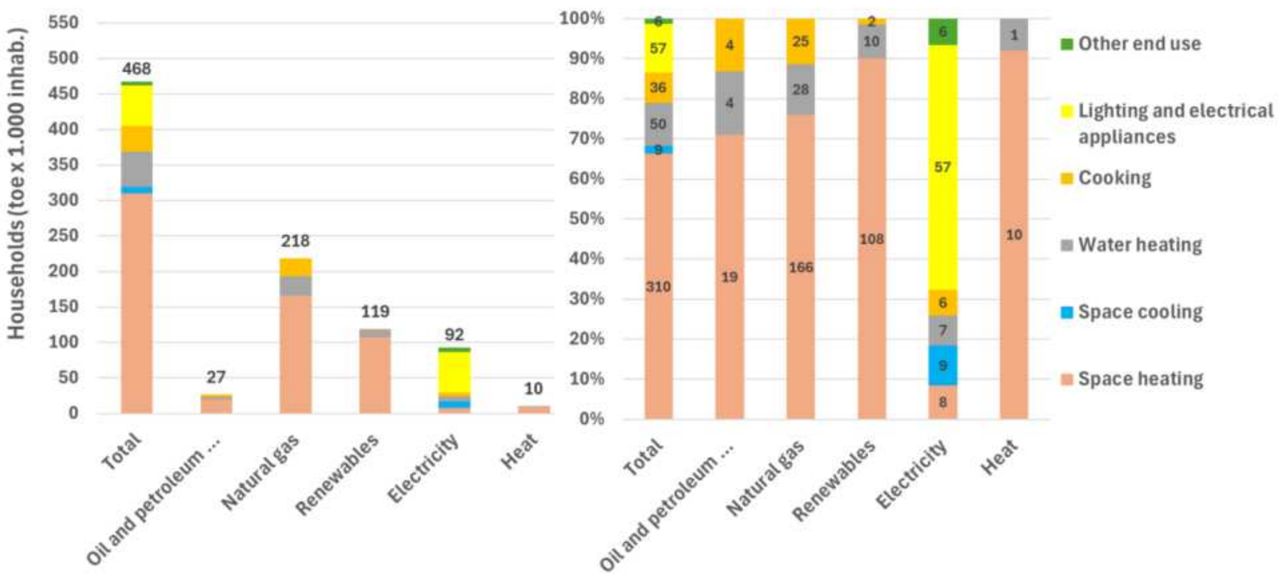
Figure 1.13 – Electrification of final energy consumption by subsector in manufacturing industry.



Some detail on households' final energy uses is provided in Figure 1.14. The energy consumption in 2023 is 468 toe per 1.000 inhabitants, -20% below 2005 level and 1.7% over 1990 level. As already seen the natural gas is the main source of energy (46.7%), while electricity and heat account for 19.8% and 2.2% respectively. Renewable sources supply the 25.5% of final demand. Oil and petroleum products supply only 5.8% of energy, while solid fuels are not used in households. The renewable energy is represented by 84.4% of primary solid biofuels, while heat pumps represent 11.7% and solar thermal 3.1%.

Space heating is the main purpose of energy consumption (66.3%), pursued with natural gas for 53.5% and renewables for 34.7%. Natural gas is the main fuel also for water heating (the fuel covers 55.4% of use energy demand) and cooking (69.1%), which together account for 18.3% of final consumption of the sector. The electricity carrier covers totally lighting & electrical appliances and space cooling, which take respectively 12.1% and 2% of final consumption, while plays only a marginal role in space heating (2.5%). Electricity supplies 13.9% of water heating consumption and 16.4% of cooking. Heat supplies only space heating and water heating with marginal share, respectively 3.1% and 1.6%, compared to the other energy sources.

Figure 1.14 – Disaggregated final energy consumption in households by energy carrier and use. The labels on the bars of left-hand graph are the energy consumption per 1.000 inhabitants by energy carrier. The labels on the right-hand graph are the energy consumption per 1.000 inhabitants by energy carrier and use.



1.1.2 Greenhouse gas emissions

Data of national greenhouse gas emissions (GHGs) are reported in more detail in the National Inventory of greenhouse gas emissions that ISPRA submits annually to the competent authorities at national and international level (ISPRA, 2025a). GHGs are expressed in CO_2eq. Starting from the 2023 submission under the UNFCCC (*United Nations Framework Convention on Climate Change*), the GWP in use for the GHGs is established by the IPCC V *Assessment Report* (2013). For CH_4 the GWP is 28, while for N_2O is 265.

The methodology to esteem GHGs and emission factors for each sector and its sources are detailed in the National Inventory. The emissions examined in this report follow the same sectoral nomenclature used internationally for the reporting of emission estimates. Tables are organized according to the Common Reporting Table (CRT) for energy and process emissions. Here the data submitted to UNFCCC on 15 April 2025 are considered, although the comprehensive review carried out by European Commission determined technical corrections for GHG emissions by enteric fermentation (about 2.8 MtCO_2eq upward per year from 2021 to 2023), by IPPU (about 1.0 MtCO_2eq downward per year from

2021 to 2023), and by LULUCF with more cumulated GHG absorption compared to the submitted values (-14.9 $MtCO_2eq$ from 2016 to 2018 and -13.9 $MtCO_2eq$ from 2021 to 2023).

Energy emissions of GHGs are due to the fuel combustion. In addition, fugitive emissions, i.e., emissions that occur along the fossil fuels chain, from production to final use, and methane emissions from geothermal sources are included in the energy emissions. Process emissions occur because of oxidation reactions other than combustion: other redox reactions, such as fermentation. Most methane emissions are due to the latter type of reactions.

Table 1.6 – GHG emissions by CRT source ($MtCO_2eq$.). Δ% is the percentage change in 2023 wrt 1990.

Source	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	*2024[*]*	*2025[x]*	Δ%
Energy industries	137.7	140.7	145.0	159.9	137.5	106.1	81.6	86.4	94.9	75.5	*64.2*	*67.0*	-45.1%
Fugitive emissions	14.2	13.4	12.1	10.6	9.7	8.7	6.2	5.7	5.1	4.5	*4.1*	*4.3*	-68.1%
Manuf. industries and constructions	92.2	90.2	96.2	92.3	70.0	55.6	45.8	54.6	54.7	50.5	*50.1*	*50.0*	-45.2%
Transport[1]	102.2	114.2	124.0	128.4	115.9	106.7	86.5	102.9	109.0	109.0	*110.6*	*111.6*	6.7%
Services	57.8	55.0	56.2	62.9	59.4	51.7	47.5	52.0	45.3	39.9	*40.3*	*40.3*	-31.0%
Households	12.0	14.2	17.4	23.8	28.7	23.2	23.9	22.1	19.7	21.4	*21.6*	*21.6*	78.1%
Agriculture (fuel combustion)	9.1	9.5	8.8	9.2	8.0	7.6	7.8	8.2	7.9	7.6	*7.7*	*7.8*	-15.9%
Other fuel combustion[2]	1.1	1.6	0.9	1.3	0.7	0.5	0.6	0.3	0.5	0.4	*0.3*	*0.6*	-67.2%
Ind. processes and product use (IPPU)	37.9	36.3	38.2	47.1	36.6	29.5	24.7	25.7	23.9	22.6	*20.4*	*22.4*	-40.5%
Agriculture	38.2	38.6	37.7	35.3	32.9	32.7	33.8	33.1	31.0	32.3	*31.7*	*32.3*	-15.6%
Waste	19.0	22.0	24.1	24.1	22.5	20.4	20.6	20.4	20.2	20.2	*19.8*	*20.2*	6.5%
LULUCF	-3.6	-23.4	-20.2	-33.7	-39.7	-41.8	-39.8	-38.1	-39.2	-53.6	*-52.1*	*-53.6*	1375%
Indirect CO_2	1.4	1.3	1.2	1.2	1.0	0.8	0.9	0.9	0.8	0.9	*0.9*	*0.9*	-38.6%
Total w/o LULUCF	**522.8**	**537.0**	**561.8**	**596.1**	**522.9**	**443.4**	**380.0**	**412.2**	**412.9**	**384.7**	***370.8***	***378.8***	**-26.4%**
Total with LULUCF	**519.1**	**513.6**	**541.6**	**562.4**	**483.2**	**401.6**	**340.2**	**374.1**	**373.7**	**331.2**	***318.7***	***325.2***	**-36.2%**

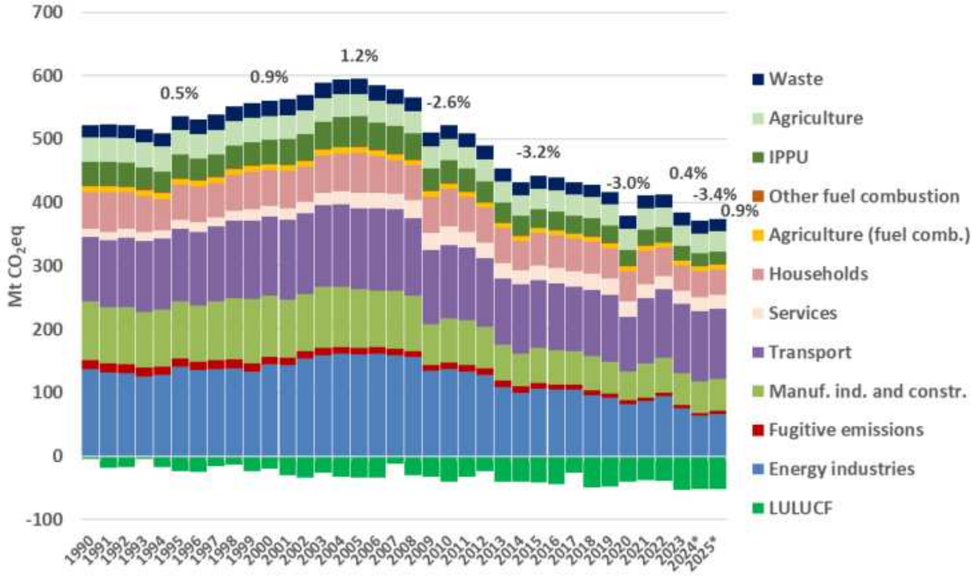
[1] without international aviation; [2] GHGs from military mobile activities; * Preliminary data; [x] early extrapolation from data available up to the end of August 2025.

Total GHGs show an increasing trend until 2005, followed by a decline accelerating in the aftermath of the economic crisis from 2008 to 2014. In 2020 GHGs (380 Mt CO_2eq w/o LULUCF) were heavily affected by lockdown measures to contain SARS-CoV-2 pandemic. GHGs without LULUCF fell by 27.3% in 2020 compared to 1990 and by 36.3% compared to 2005. All sectors reduced the emissions since 2005, albeit at different rates. In 2021 and 2022 the GHGs rebounded, although to level below the 2019 level (417.4 Mt CO_2eq w/o LULUCF). In 2023 GHGs without LULUCF fell by 26.4% compared to 1990 and by 35.5% compared to 2005. Preliminary data for 2024 confirm the downward trend of total GHGs w/o LULUCF (about -3.4% year over year), while a new increase is estimated in 2025 (around +1% year over year).

Emissions from manufacturing and construction decreased by 45.3% from 2005 to 2023. The transport sector shows steady growth with a reversal of the trend only after 2007 and the sharp decrease in 2020; GHGs in 2023 are 15.1% lower than 2005, but still over 1990 level (+6.7%). Households reduced the emissions by 31% compared to 1990, while the sector of services increased of 78.1%.

As for emissions from processes, GHGs from IPPU decreased by 52.1% from 2005 to 2023. GHGs from waste are 15.9% lower than 2005, although still over 1990 level (+6.5%). The GHGs from agriculture decreased by 15.6% from 1990 and 8.6% from 2005.

Figure 1.15 – GHGs trend by source. Labels are the average annual rate every 5 years since 1990, in 2023 wrt 2020, and the provisional change in 2024 and 2025 on year over year basis.



* Preliminary data for 2024; early extrapolation from data available up to the end of August 2025.

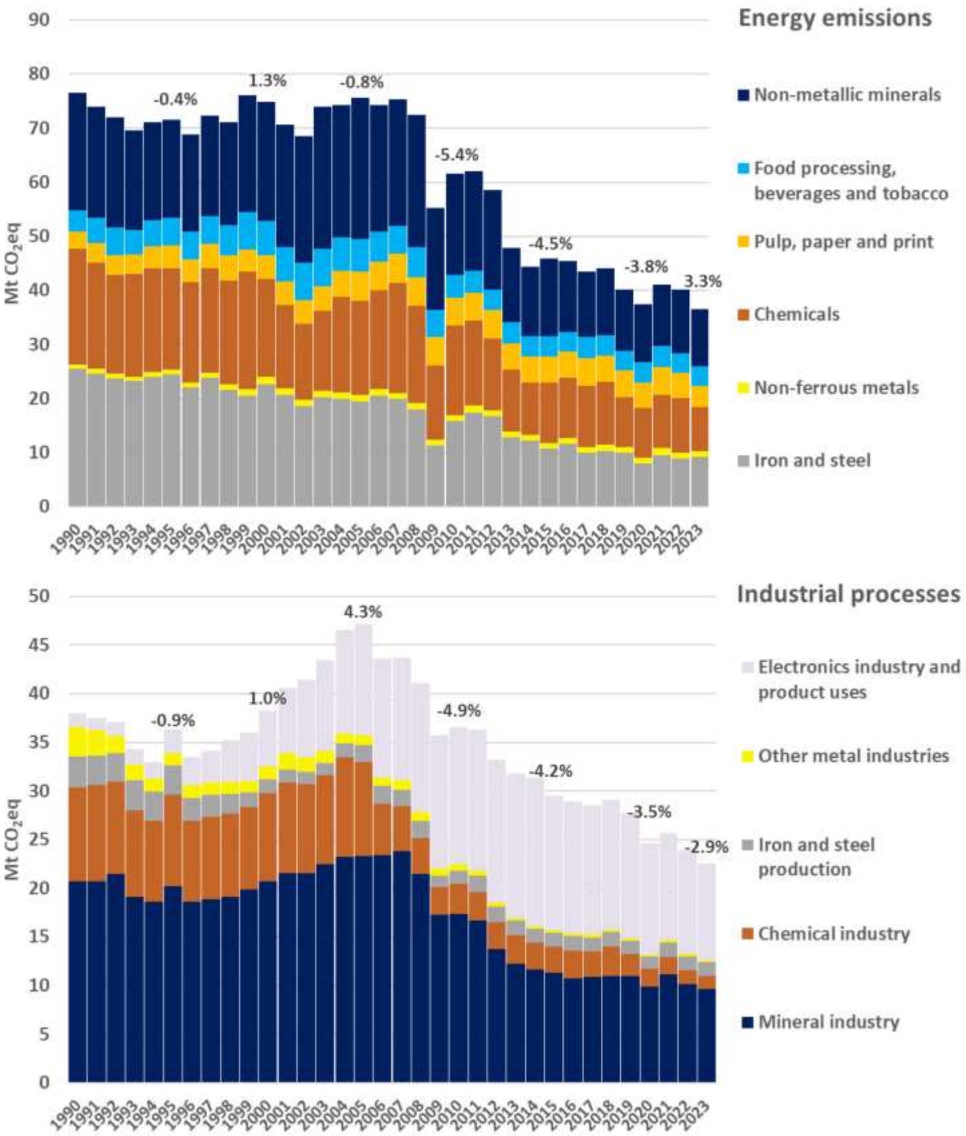
In 2023 energy industries, together with fugitive emissions, have 20.8% of the GHGs share, followed by transport with 28.3%, households and services, that together account for 15.9%. The sectors mentioned, together with all other energy sectors, such as manufacturing and construction industries, combustion from agriculture and fisheries, account for 80.3% of total GHGs.

Figure 1.16 shows how each sector changed since 2005. All sectors reduced the emissions, but it is worth noting that some sectors, such as agriculture (processes emissions) or transport (energy emissions) appear harder to abate than other sectors, as energy industries or manufacture industries.

Figure 1.16 – GHGs by source in 1990, 2005, and 2023.

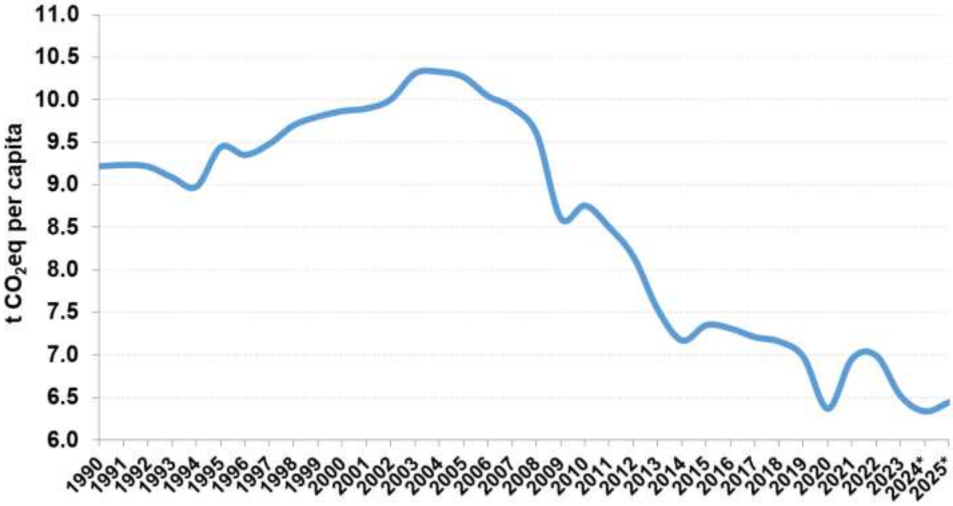
Further details are provided for industry, concerning the energy GHGs by source from manufacturing industries and construction, as well as for GHGs from processes (IPPU; Figure 1.15). All industry subsectors recorded decreasing trends since 2005. As for energy emissions the range goes from -59.1% for non-metallic minerals to -7.7% for non-ferrous metals. Energy GHGs from iron and steel decreased by 52.9%, from chemicals by 53.2%, paper industry by 27.7%, and food industry by 41.1%. As for GHGs from processes the most relevant decrease since 2005 occurred for chemical industry (-85.8%) and other metal industries, although the latter source accounts for less than 1% of GHGs from IPPU. Mineral industry reduced GHGs by 58.6%; iron and steel production reduced GHGs by 21.6%. Electronics industry and product uses decreased only by 11.6%, mainly due to the constant increase of F-gases up to 2014.

Figure 1.17 – GHGs trend by source from energy and processes in industry. Labels are the average annual rate every 5 years since 1990 and in 2023 wrt 2020.



GHGs per capita increased from 9.2 t CO_{2eq} in 1990 to 10.3 t CO_{2eq} in 2004, in the following years there was a rapid decline up to 6.4 t CO_{2eq} in 2020, followed by a rebound in the next years. In 2023 the GHGs per capita came back to 6.5 t CO_{2eq}. The GHGs per capita decreased from 2005 to 2023 with an average annual rate of -2.5% (-1% since 1990).

Figure 1.18 – Trend of per capita GHGs.



* Preliminary data.

1.1.2.1 GHGs from ETS and ESR

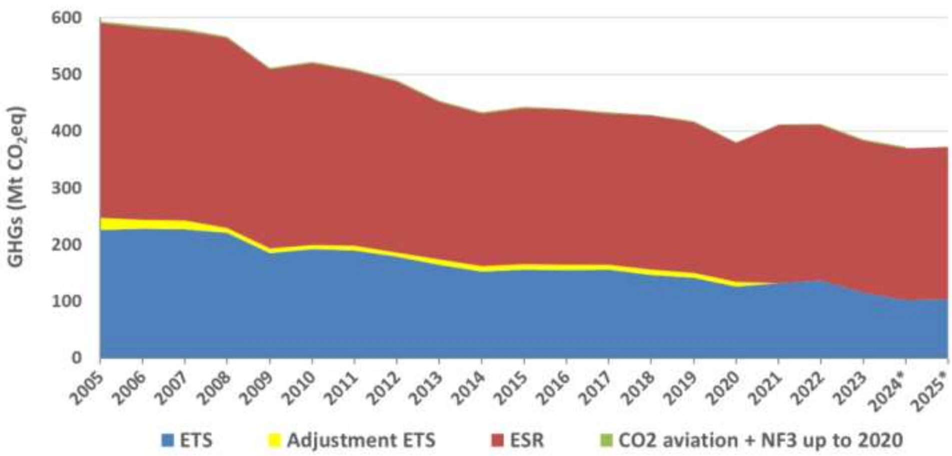
To monitor the achievement of GHGs reduction targets the GHGs must be allocated in the two compartments: ETS (EU Emissions Trading System, EU ETS) and ESR (Effort Sharing Regulation), defined according to the European legislation. EU ETS is one of the European Union's main policies to curb climate change and is an essential tool for cost-effective reductions in GHGs. It covers the emissions from power plants, big manufacturing industry and aviation within Europe. The Effort Sharing legislation covers GHGs from domestic transport (excluding CO_2 emissions from aviation), buildings, agriculture, small industry, and waste. The Effort Sharing legislation sets binding national targets to reduce emissions compared to 2005 levels, under the Effort Sharing Decision (ESD) for the period 2013-2020 and under the Effort Sharing Regulation (ESR) for the period 2021-2030. The analysis of the target's achievement has been carried by ISPRA (2025b) and goes beyond the purpose of this paper. Here only the emissions by sector will be focused for ETS and ESR compartments.

The EU ETS works on the 'cap and trade' principle. The cap, established at European level, is reduced annually in line with the EU's climate target and within cap each company trades on the market of carbon allowances. If an installation reduces the emissions, it can either keep the spare allowances to use in the future or sell them. The ETS emissions are regulated by market mechanisms, and each operator is responsible of its own emissions. On the other hand, emissions not subject to the ETS fall within the scope of Regulation (EU) 2023/857 (Effort Sharing Regulation, ESR), on binding annual greenhouse gas emission reductions by Member States over the period 2021-2030 and which set an emissions reduction target for Italy by 2030 by 43.7% compared to 2005 levels. This target will have to be achieved on a reduction trajectory that will result in annual emission allowances (AEAs) for each year.

The recent revision of the legislation relating to the Fit for 55 set the emission reduction at European level for ETS from -42% to -62% and for no ETS emissions from -30% to -40%, both targets compared to 2005. The new ETS target covers an expanded scope: emissions from power generation, energy-intensive industries and aviation as previously legislated; adding carbon dioxide emissions from maritime transport from 2024, further extended to methane and nitrous oxide as of 2026. With the revision of the EU ETS Directive (Directive (EU) 2023/959), a new emissions trading system will be established (ETS-2), for buildings, road transport and additional sectors, e.g. fuel combustion by industry not covered by the existing EU ETS. Separate from the existing EU ETS, the ETS-2 is an upstream system regulating fuel suppliers rather than households and car users. It will come into operation in 2027, while the monitoring and reporting of emissions will start in 2025. The cap is set to achieve an emission reduction of 42% by 2030 compared to 2005 levels. Emissions from sectors covered by the ETS-2 remain covered by Member States' emission reduction targets under the Effort Sharing Regulation (ESR). This means that the ETS-2 will complement national efforts to bring down emissions in the ESR sectors. It is estimated that by 2030, half of the ESR emissions will be covered under the ETS-2. The ETS-2 does not cover non-CO_2 emissions which are mainly from agriculture and waste management. (EEA, 2023).

ETS covers 29.8% of national GHGs in 2023. The share of such emissions steeply decreased from 2005, when it was 41.5%. The ESR scope remains substantially unchanged compared to the previous period up to 2020, but since 2021 only CO_2 from domestic aviation is not included in the ESR sector, no longer NF3, as until 2020. ESR accounts for 69.6% of national GHGs in 2023 with an increasing share since 2005, when it was 58%. As shown in Figure 1.19, the ETS emissions, including the adjusted share to consider the current scope, decreased by 53.6% from 2005 to 2023, while the ESR emissions decreased by 22.6%. The last figure should be compared with the national target of emissions reduction of -43.7% in 2030 compared to 2005. Moreover, the ESR target of must accomplish annual thresholds and data since 2021 show that such thresholds have been overcame: 5.5 $MtCO_2eq$ in 2021, 5.4 $MtCO_2eq$ in 2022, 8.2 $MtCO_2eq$ in 2023 (ISPRA, 2025a, b). The mentioned technical corrections carried by the EC determine an increase of such figures of about 1.8 $MtCO_2eq$ per year. The preliminary data in 2024 show a gap of about 19 $MtCO_2eq$, with some uncertainty, while the early extrapolation in 2025 shows a gap of about 30 $MtCO_2eq$ with higher uncertainty than 2024 data (Figure 1.20). According to the policy scenario in the National Energy and Climate Plan (MASE, 2024) the ESR emissions should decrease by 40.6% in 2030, not achieving the mandatory target, while the ETS emissions should decrease by 66% (Figure 1.22).

Figure 1.19 – Trends of GHGs from ETS and ESR (Mt CO_2eq). It is also shown the ETS adjustment for 2030 targets, as well the CO_2 emissions from domestic aviation and NF3. Since 2021 NF3 are included in ESR.

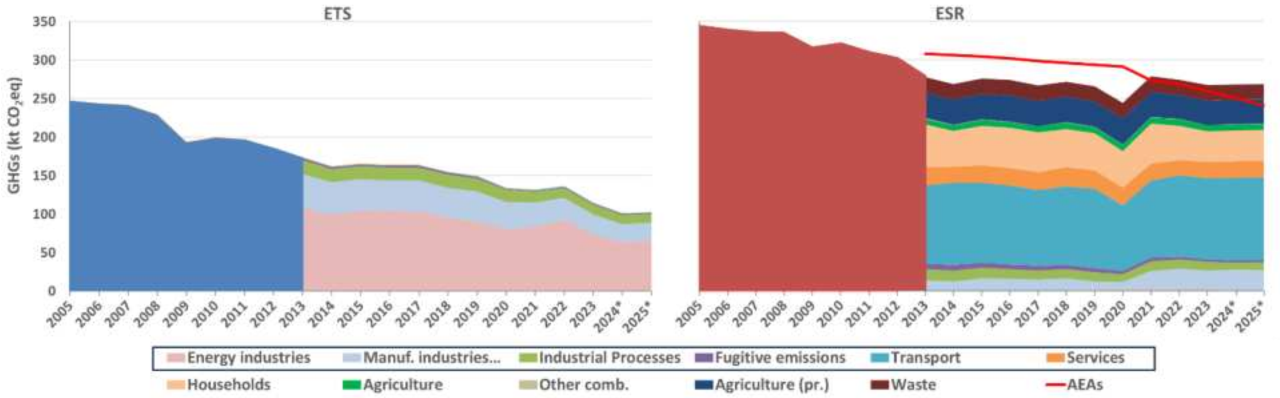


* Preliminary data for 2024 and early extrapolation from data available up to the end of August 2025.

Since 2013, the European Commission has required the reporting of ETS emissions allocated in the CRT sectors according with the implementing Regulation (EU) 749/2014 (art. 10, annex V pursuant to Regulation (EU) 525/2013) up to 2020, and according with the implementing regulation 2020/1208 (art. 14, annex XII pursuant to Regulation (EU) 2018/842) since 2021. By subtracting ETS emissions from the national emissions of the CRT sectors, ESR emissions by sector can be processed, without CO_2 from aviation in the transport. The adjusted ETS emissions are distributed in manufacturing industries & construction and industrial processes according to the weight of emissions recorded in the two sectors becouse the extension of ETS scope occurred in 2013 has only involved industrial installations, in particular manufacturing industries.

Figure 1.20 shows the trends of GHGs by CRF's sector since 2013 for ETS and ESR. Both compartments show long run downward trends, even though with a double rate in ETS than in ESR. Moreover, in the last years, particularly since 2021, GHGs show a rebound in ESR (+9.9% in 2023 compared to 2020), while in ETS a decrease is recorded (+14.6%). Preliminary data for 2024 show, as already reported, further increase of ESR emissions and decrease of ETS emissions.

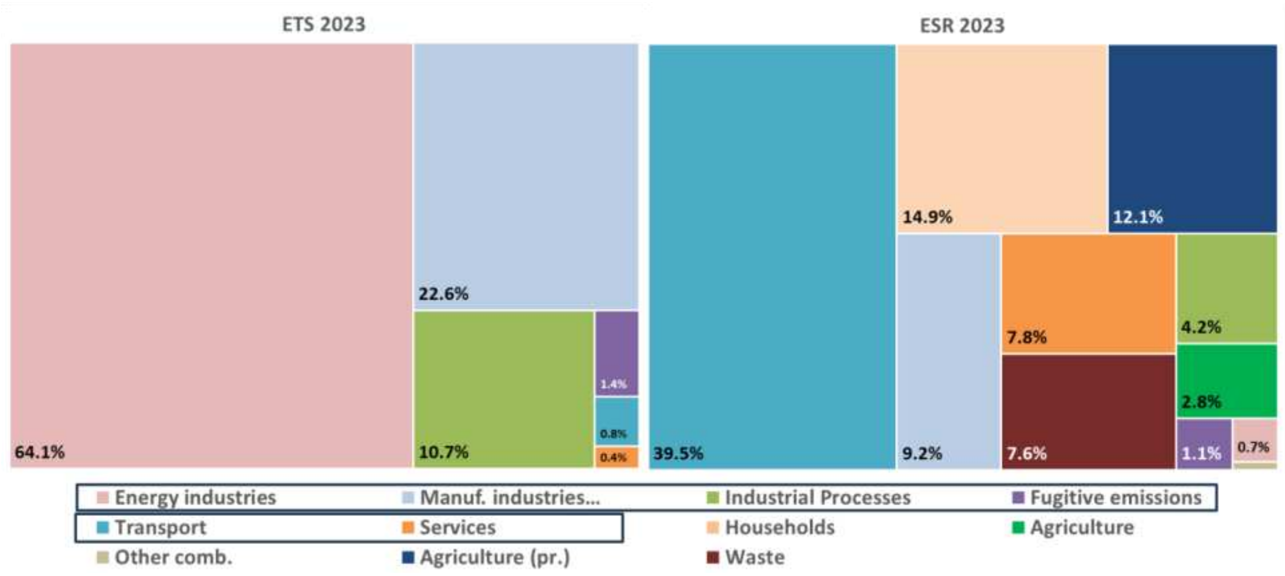
Figure 1.20 – Trends of GHGs from ETS and ESR by sector since 2013 (Mt CO_2eq). The sectors in the square are in ETS and ESR, while the other sectors are only in ESR. Annual emissions allowances (AEAs) are reported.



* Preliminary data for 2024 and early extrapolations from data available up to the end of August 2025.

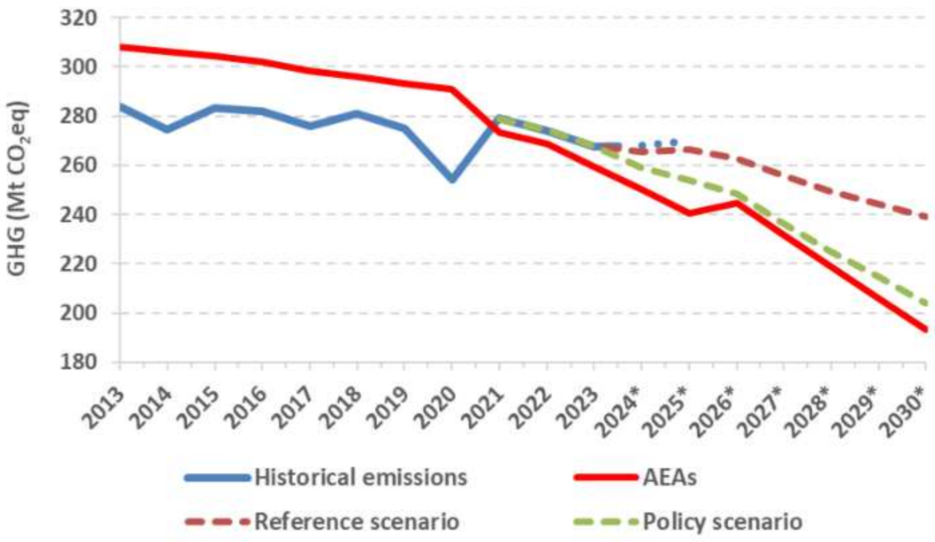
On the ETS side the dominant role is played by energy industries (64.1% of ETS GHGs in 2023) whose emissions are almost totally included in ETS, only a marginal share is in ESR. In the latter compartment the dominant role is played by transport with 39.5% of GHGs in 2023, the tiny share in ETS for such sector is utterly due to pipeline transport. GHGs from manufacturing industries and construction, together with industrial processess, account for 33.3% in ETS and 13.4% in ESR. The fugitive emissions in ETS concern only CO_2 from flaring in refineries, while all other sources and GHGs are in ESR. GHGs from services are almost totally in ESR and represent 7.8% of compartment's GHGs. GHGs from households (14.9% of ESR), agriculture (both combustion and processes; 14.9% of ESR), and waste (7.6% of ESR) are totally in ESR. Moreover, it should be considered that GHGs from agriculture processes and waste are mostly methane, that is utterly accounted in ESR. A focus on methane emissions is carried out in the next paragraph.

Figure 1.21 – Share of GHGs by sector from ETS and ESR in 2023 (Mt CO_2eq). The sectors in the square are both in ETS and ESR, while the other sectors are only in ESR.



Such quick glance is aimed to provide the current weight of each sector's emissions in ESR. Sectors with higher share of GHGs should be the priority targets for policies and measures directed to achieve the GHGs reduction goal. Figure 1.22 shows the projections of ESR emissions elaborated by ISPRA and reported in the NECP (MASE, 2024). The annual emissions allowances (AEAs) from 2026 to 2030 will be provided by specific legal act to be adopted at European level in 2025. The current estimation was based on the criteria set out in Regulation (EU) 2023/857 on binding annual GHGs reductions by Member States from 2021 to 2030. The actual emissions since 2021 up to 2023 are higher than the assigned annual allowances, as already stated. The emission projections show GHGs always higher than the annual allowances, both for reference and policy scenario and the preliminary data for 2024 and early extrapolations for 2025 show that the actual emissions are aligned to the trend of the NECP reference scenario.

Figure 1.22 – GHGs in the Effort Sharing sectors (Mt CO_2eq) since 2013. Actual emissions up to 2023 and preliminary esteem for 2024 and 2025 are shown, as well as projections up to 2030 as reported in the NECP. The red line shows the annual emissions allowances.



* Preliminary data in 2024 and early extrapolations in 2025 from data available up to the end of August 2025 (dotted blu line). Projections from 2026 to 2030 (dashed lines).

According to the trend shown in Figure 1.22, and considering also the technical corrections carried out by the EC the gap cumulated between the actual emissions and the annual allowances from 2021 up to the early extrapolation for 2025 will be around 74 Mt CO_2eq. To compensate such gap Italy would need to acquire the lacking allowances. During the previous compliance period (2013-2020), AEAs prices were determined bilaterally between Member States and were generally low. For the current period, the trading prices is expected to be higher due to stricter emission targets and the projected supply shortage in the European carbon market, although political arrangement among countries may set the final prices. Considering a wide range of carbon prices, from € 45 to € 260 per allowance, Transport & Environment (2024) estimated that Italy might need to disburse from € 5.7 to € 31.1 billion to comply with its targets set by the Effort Sharing Regulation. Adopting the carbon prices recorded up to 2024 for EU ETS and the forecast up to 2030 issued by BloombergNEF (2024), with an average price of about € 72 from 2021 to 2025 and € 118 from 2026 to 2030, the Italian emissions gap could value around € 22-25 billion if the actual emissions should resume the reference trajectory since 2026, and around € 9 billion if the actual emissions should align to the policy scenario trajectory since 2026.

It must be noted that the final accounting of ESR emissions will consider the flexibility mechanisms envisaged in the Effort Sharing regulation: provided that the LULUCF target for 2030 is achieved it is allowed the use a limited amount of LULUCF credits to contribute to the achievement of national Effort Sharing target (the so-called LULUCF flexibility). For Italy such amount is equal to 11.5 MtCO_2 eq., for the entire period 2021-2030 (divided into 5.75 MtCO_2 eq. for each five-year period 2021-2025 and 2026-2030). Moreover, the Member States can buy allocations from other Member States for offsetting emissions in the effort sharing sectors. The Regulation also has a safety reserve of a maximum of 105 million tonnes; member States struggling to meet their national targets may obtain, through the safety reserve, access to a limited number of additional allocations to cover their emissions. Finally, the Effort

Sharing regulation provides that, despite using all the flexibilities, the annual target is exceeded, a penalty is applied: the exciding emissions multiplied by a factor of 1.08 is added to the GHGs emissions of the following year. All considered, the mentioned figures can change significantly and, standing the current trajectory, the monetary value of the Italian gap may be very relevant.

1.1.2.2 Methane emissions

Methane is a powerful greenhouse gas, second only to carbon dioxide in terms of contribution to global warming (IPCC, 2021). According to the methodology of National GHGs Inventory the Global Warming Potential (GWP) for methane over a period of 100 years is 28 times that of CO_2, however the GWP over a period of 20 years is about 85 times that of CO_2. CO_2 has an atmospheric lifetime of thousands of years, while methane disappears in about 10-15 years. The rapid decay of methane and its high impact on atmospheric temperature make it a primary objective to curb in a timely and effective way the climate change.

According to the recent reports of the International Energy Agency (IEA, 2025) and IPCC (2022), reducing anthropogenic methane emissions is one of the most effective strategies, including in economic terms, to rapidly reduce the rate of warming and contribute significantly to limit the increasing global temperature.

1.1.2.2.1 National methane emissions

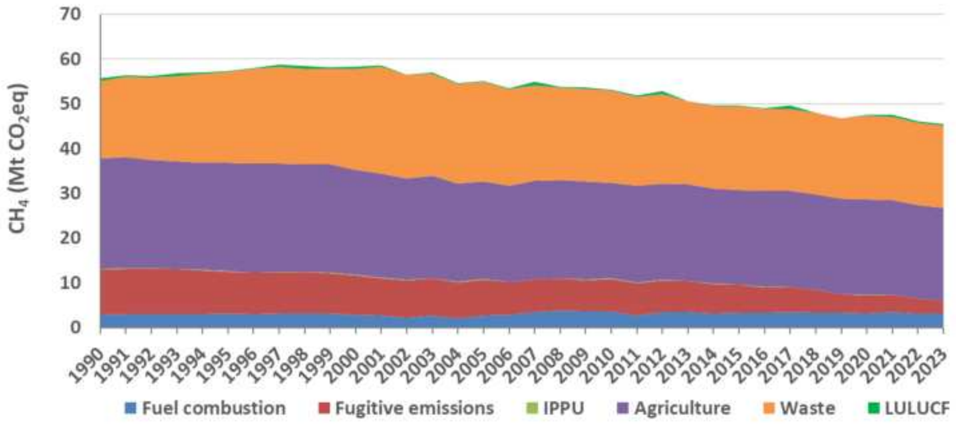
National methane emissions, without the contribution of natural sources, represent on average 10.6%±0.8% of total emissions from 1990 to 2023. Methane emissions without LULUCF decreased from 55 to 45.2 Mt CO_2eq, -17.9%. The reduction of methane is lower than the reduction of total GHGs (-26.9%). Moreover, GHGs other than methane reduced by 27.4% from 1990. These rates show the need to achieve methane emissions reduction from the main sources.

Table 1.7 – Methane emissions by source (Mt CO_2eq).

Source	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Combustion	2.8	3.1	2.8	2.6	3.5	3.4	3.1	3.4	3.2	3.1
Fugitive	10.1	9.4	8.8	8.0	7.3	6.1	4.1	3.8	3.2	2.8
IPPU	0.1	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Agriculture	24.6	24.1	23.5	21.8	21.5	21.2	21.4	21.2	20.8	20.8
Waste	17.3	20.4	22.5	22.3	20.6	18.7	18.8	18.6	18.4	18.5
Total	**55.0**	**57.1**	**57.8**	**54.9**	**52.9**	**49.4**	**47.4**	**47.0**	**45.7**	**45.2**

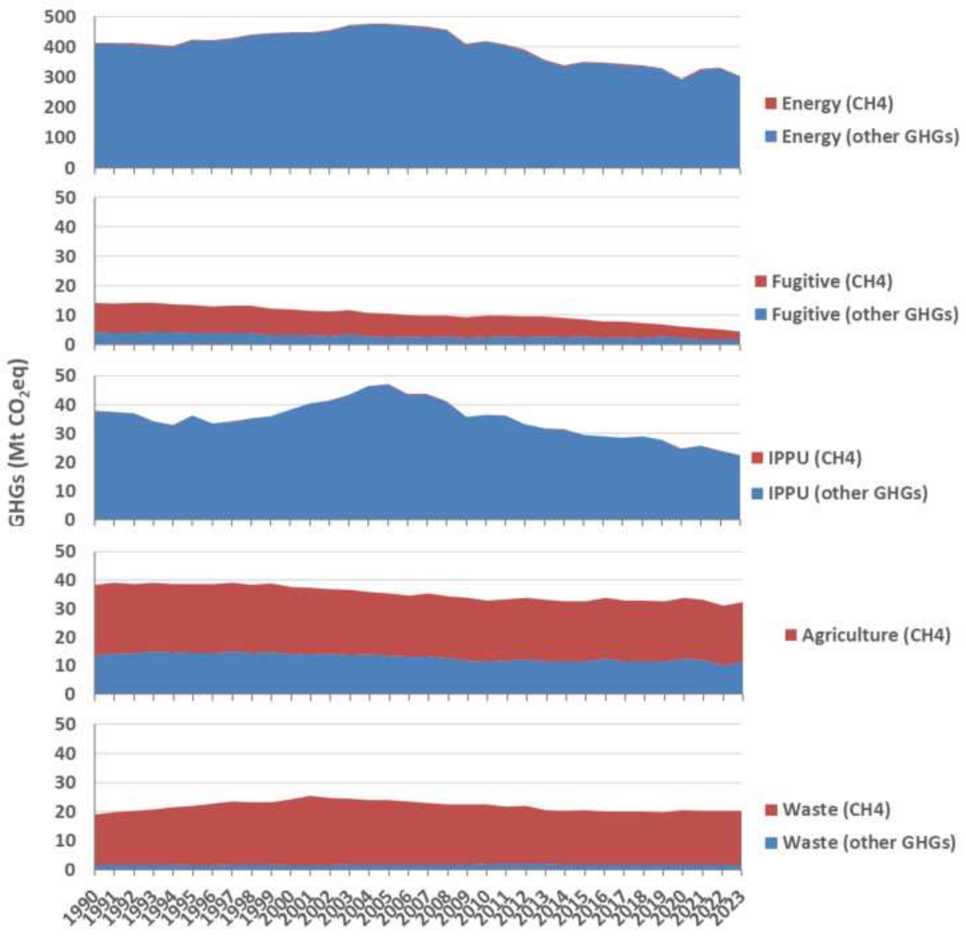
Figure 1.23 shows the decreasing trends of methane emissions by source and the dominant role of agriculture and waste sources. Moreover, among the main sources agriculture has the lowest average rate of emissions reduction per year since 2005, with -0.3% per year *vs* -1% per year for waste, -5.7% per year for fugitive emissions. The unburned methane in the energy sector is the only source with increasing emissions since 2005 (+0.9% per year).

Figure 1.23 – Trends of methane emissions by source (Mt CO_2eq).



The sources contribute differently to methane emissions. Some sector, as IPPU, emits a very marginal share of methane, while the GHGs by waste are almost entirely methane.

Figure 1.24 – Trends of methane and other GHGs by source (Mt CO_2eq).



Among the main sources, emissions by wastes in 2023 were higher than 1990 levels (+6.8%), although the trend is clearly descending from 2005 (-17.1%). Since 1990 agriculture decreased by 15.6% and fugitive emissions by 72.6%. Agriculture contributes with 46.1% of methane emissions in 2023, while wastes account for 40.9%. Fugitive emissions make up 6.2%, and unburned methane in the energy sector accounts for 6.8%.

By far the most important source of the agricultural sector is represented by enteric fermentation, or the digestive processes of farm animals, with 69.3% of methane emissions from the sector in 2023, followed by manure management with 23.3% and rice cultivation with 7.3%. Emissions due to the combustion of agricultural residues in the open field represent a marginal share of 0.06%.

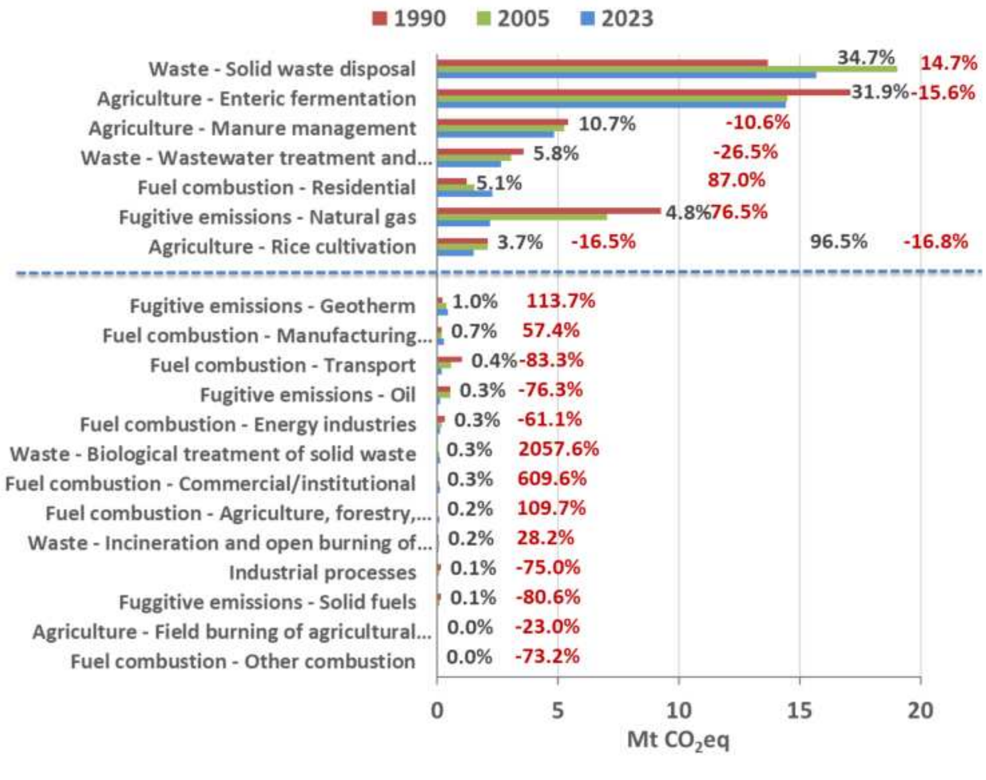
In the waste sector, the dominant source of methane emissions is represented by the disposal of solid waste, with 84.8% of sector's methane emissions, the next source is represented by wastewater treatment, with a share of 14.2%. The remaining two sources, biological treatment of solid waste and incineration and open field burning, account for a marginal share, lower than 1%.

Most of the fugitive methane emissions are due to the natural gas supply chain (production, transport, and distribution) which in 2023 accounts for 78% of total fugitive methane emissions with a share that has decreased significantly since 1990, when it was 91.2%. Oil and natural gas supply chains reduced methane emissions of 76.5% since 1990.

Unburned methane emissions in energy sectors are mainly due to the source of the civil sectors (mainly by households) with 81% of methane emissions of the energy sector, followed by manufacturing and construction industries with 9.6%, transport with 5.5% and energy industries with 3.8%.

Arranging in descending order the methane emissions recorded in 2023 from all sources it can be noted that 96.5% of methane emissions come from seven key sources that emit 43.6 Mt CO_2eq (Figure 1.25). Emissions from key sources decreased by 16.8% since 1990. Minor sources, cumulatively responsible for 3.5% of emissions, are 39.9% lower than 1990 level. The disposal of municipal solid waste is the first key source with 34.7% of total methane emissions, followed by enteric fermentation with 31.9%. The first two sources are responsible for two-thirds of methane emissions.

Figure 1.25 – Methane emissions by source in 1990, 2005 and 2023. Data in descending order of 2023 values. The black labels next to the bars are the 2023 share of emissions by source, the red labels are the percentage change from 1990 to 2023. The values for the seven key sources are reported on the dotted line.



The waste sector has two key sources (Solid waste disposal and disposal and wastewater treatment) with 40.5% of total methane emissions, while the agriculture has three sources (enteric fermentation, manure management and rice cultivation) with 46% of total methane emissions. The energy sector has one source for fugitive emissions (natural gas supply chain) and one for combustion (residential sector) which contribute 4.8% and 5.1% of total methane emissions respectively.

1.1.2.2.2 Agriculture

The sector accounts for 46.1% of total methane and the three main sources of agriculture represent almost 100% of methane emissions from the sector in 2023.

Table 1.8 – Methane emissions from the agriculture sources (Mt CO_2eq).

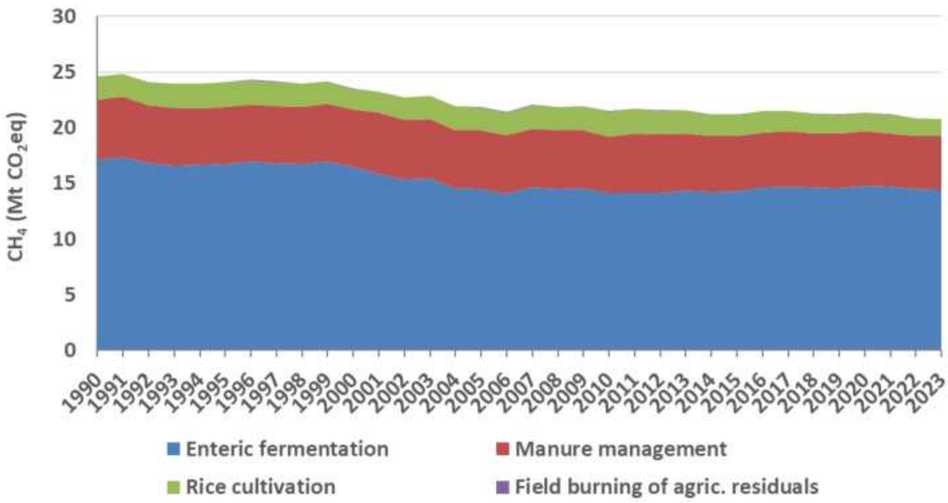
Source	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Enteric fermentation	17.1	16.7	16.5	14.5	14.1	14.3	14.8	14.7	14.5	14.4
Manure management	5.4	5.2	5.1	5.2	5.1	5.0	4.9	4.8	4.8	4.8
Rice cultivation	2.1	2.2	1.9	2.1	2.3	1.9	1.7	1.7	1.5	1.5
Field burning of agric. residuals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**24.6**	**24.1**	**23.5**	**21.8**	**21.5**	**21.2**	**21.4**	**21.2**	**20.8**	**20.8**

The top source of methane is the enteric fermentation of livestock, which in 2023 accounts for 69.3% of methane emissions from agriculture. Number and mass of livestock are the main activity data for estimating emissions. Moreover, other parameters are considered for the main animal categories, as the milk production, the fat content in the milk, the percentage of grazing animals, the daily weight gain, the share of females that give birth, the quantity and quality of the diet and the coefficient of conversion into methane of the diet. More details on animal categories and methodology for this and following sources are in ISPRA, 2025a.

Manure management is the second largest source of methane emissions in the agriculture, with 23.3% of the sector's emissions. Such emissions are generated by the decomposition of organic matter under anaerobic conditions, during treatment and storage, and on pasture. The most relevant factors of the emissions are the amount of manure produced, which depends on the number of animals and the rate of manure production per animal, and the share of anaerobic treatment, which depends on the adopted manure management. The storage of non-palatable manure (liquid waste), which takes place in environments essentially devoid of oxygen, generates a significant amount of methane compared to the management of solid manure. The temperature and duration of storage also affect methane production. In the estimation of methane emissions from manure management, fugitive methane losses of plants are also considered, which are equal to 1% of total biogas production. This percentage is calculated on all the biogas produced which derives not only from livestock waste, but also from all the other organic components that feed the digester. The amount of fugitive methane losses in 2023 are 395.7 kt CO_2eq.

Rice cultivation is the third source of methane emissions in the agriculture with 7.3% of sector’s emissions. Emissions are generated by the decomposition of organic material by methanogenic microorganisms in rice fields submerged by the water. Emissions depend on the extent of the crops, the length of the growing period, the irrigation regimes and usage of organic and inorganic soil improvers. Soil type, temperature and cultivated variety also affect methane emissions. In 2023 the source emitted 54.3 kt CH_4, with a reduction of 27.7% compared to 1990.

Figure 1.26 – Methane emissions trend from agriculture.



1.1.2.2.3 Waste

Waste sources emit 40.9% of total methane emissions. The disposal of solid waste is the dominant source, responsible in 2023 for 84.8% of the sector's methane emissions, the next source is represented by wastewater treatment and management with 14.2%.

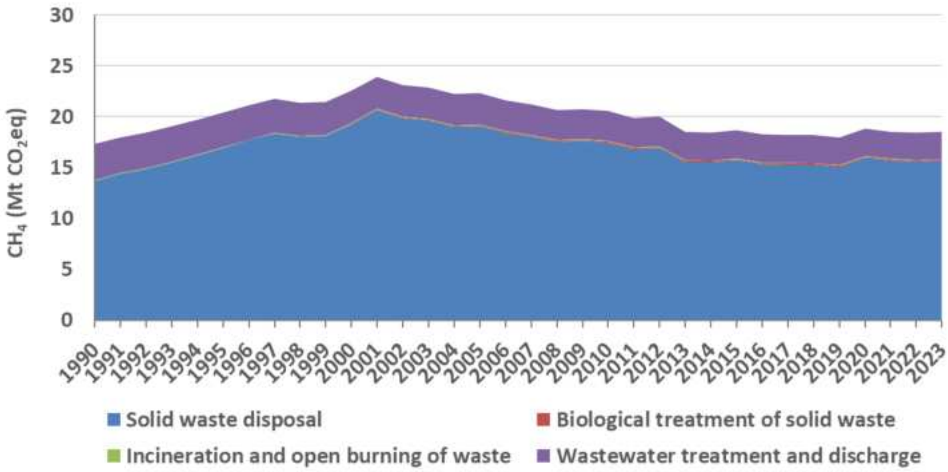
Table 1.9 – Methane emissions from the waste sources (Mt CO_2eq).

Source	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Solid waste disposal	13.7	16.9	19.3	19.0	17.4	15.7	16.0	15.7	15.6	15.7
Biological treatment of solid waste	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Incineration and open burning of waste	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Wastewater treatment and discharge	3.6	3.4	3.2	3.1	2.9	2.7	2.7	2.7	2.7	2.6
Total	**17.3**	**20.4**	**22.5**	**22.3**	**20.6**	**18.7**	**18.8**	**18.6**	**18.4**	**18.5**

Solid waste disposal is a key category for methane. The main parameters that affect the estimation of landfill emissions are, in addition to the quantity of waste disposed in landfills, the waste composition, the methane ratio in the biogas and the quantity collected and recovered. These parameters are strictly dependent on the waste management policies that start from the production and transport of waste, separate collection, treatment for volume reduction, stabilization, recycling, and energy recovery up to the deposition of the final residues in landfills. The disposal of solid waste in landfills contributes for more than a third of total methane emissions in 2023 (34.7%). Methane emissions from this source in 2023 are 14.7% higher than 1990 level. The emissions increase from 1990 to 2001 (+51.1%), then decrease up to 2023 (-24.1%), reflecting the downward trend of annual waste disposal in landfills.

As for wastewater management, the sewage sludge and the organic substance contained in the sewage can undergo anaerobic degradation if dispersed in the environment. Methane emissions are strictly connected to the characteristics of the wastewater and therefore to the quantity of organic substance present in the sewage, to the management techniques, as well as to the temperature. Methane emissions from wastewater management decrease constantly from 1990 to 2023 (-26.5%).

Figure 1.27 – Methane emissions trend from waste.



1.1.2.2.4 Energy: fugitive emissions

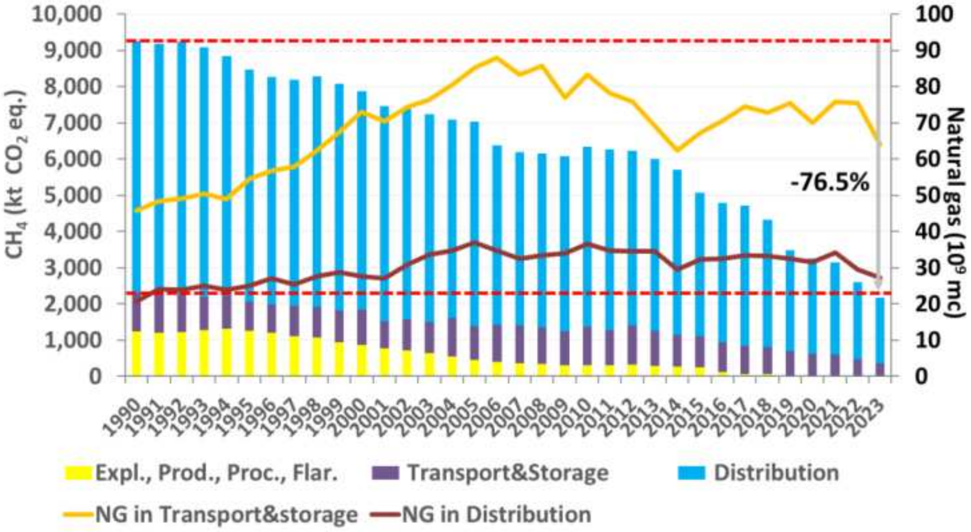
Fugitive emissions are 6.2% of national methane emissions. The natural gas supply chain accounts for 4.8% of total methane emissions and 78% of fugitive emissions in 2023. A significant reduction in emissions has been recorded since 1990, when the source represented 16.8% of total methane emissions and 91.2% of fugitive emissions.

Table 1.10 – Methane emissions from the fugitive sources (Mt CO_2eq).

Source	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Solid fuels	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Oil	0.5	0.6	0.5	0.5	0.4	0.4	0.2	0.2	0.1	0.1
Natural gas	9.3	8.5	7.9	7.0	6.3	5.1	3.3	3.1	2.6	2.2
Geothermal	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.5	0.5	0.5
Total	**10.1**	**9.4**	**8.8**	**8.0**	**7.3**	**6.1**	**4.1**	**3.8**	**3.2**	**2.8**

Transport, storage, and distribution of natural gas are the main sources of fugitive emissions with distribution in the dominant role. Fugitive emissions from the supply chain have been significantly reduced since 1990 because of many measures to improve the transport and distribution network performances. Since the 90s there has been the replacement in the distribution network from material characterized by high emissions factor (grey cast iron with hemp and lead joints) to materials characterized by fewer joints and lower emissions factor. In addition, the steel pipelines with cathodic protection for the corrosion prevention is increasingly extensive. Such improvements led to the methane emissions reduction of 76.5% from 1990 to 2023 compared to the increase of gas transported (+40.2%) and distributed (+32.4%) in the same period. Distributed natural gas meets the demand of users in the civil sector and small industry, while large industrial users are directly served by the transport network.

Figure 1.28 – Trend of methane emissions by source from the natural gas supply chain (left axis) and amount of natural gas transported and distributed (right axis). The dotted lines are the emission levels of 1990 and 2023.



The main sources transport-storage and distribution recorded emission reductions from 1990 to 2023 of 65.8% and 74.1%, respectively. Transport-storage source includes losses due to the transport, storage, and regasification of liquefied natural gas. The emissions factor shows a continuous decrease, because of the performance improvement of transport and distribution network. The emissions factor per gas volume in the transport-storage source recorded a reduction of 75.6% from 1990 to 2023, while emissions factor in distribution decreased by 80.5%. The emissions factor in the transport-storage source is about an order of magnitude lower than the emissions factor in the distribution (5.6 g CO_2eq/mc *vs* 66 g CO_2eq/mc) and shows that the grid set-up for the satisfaction of natural gas demand is a crucial factor for the reduction of fugitive emissions in the natural gas supply chain. In addition, the relevance of emissions from distribution, 83% of methane emissions from natural gas supply chain, makes this source the main objective to furtherly reduce fugitive emissions.

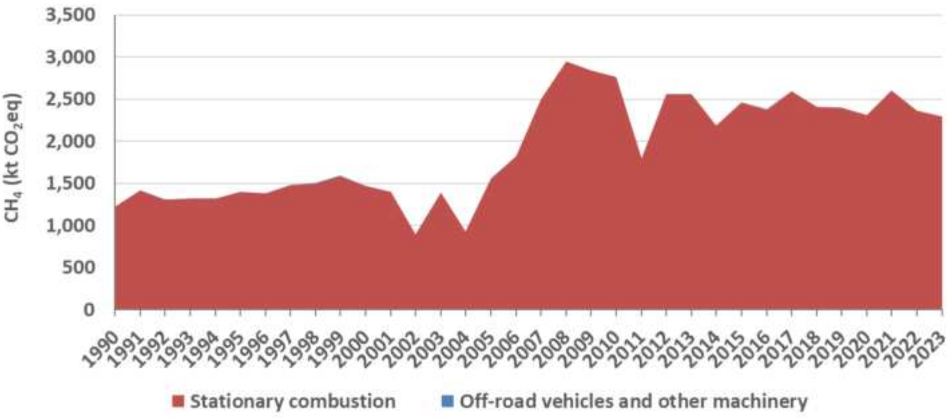
1.1.2.2.5 Energy: Combustion

Energy sector emits 6.8% of total methane emissions. The residential sector is the main source with a growing share from 1990, when it contributed to 44.1% of methane emissions by energy sectors, to 2023 with 75.1%. GHGs in the residential sector originate from the energy used directly in buildings, mainly for heating.

Table 1.11 – Methane emissions from the energy sources (Mt CO_2eq).

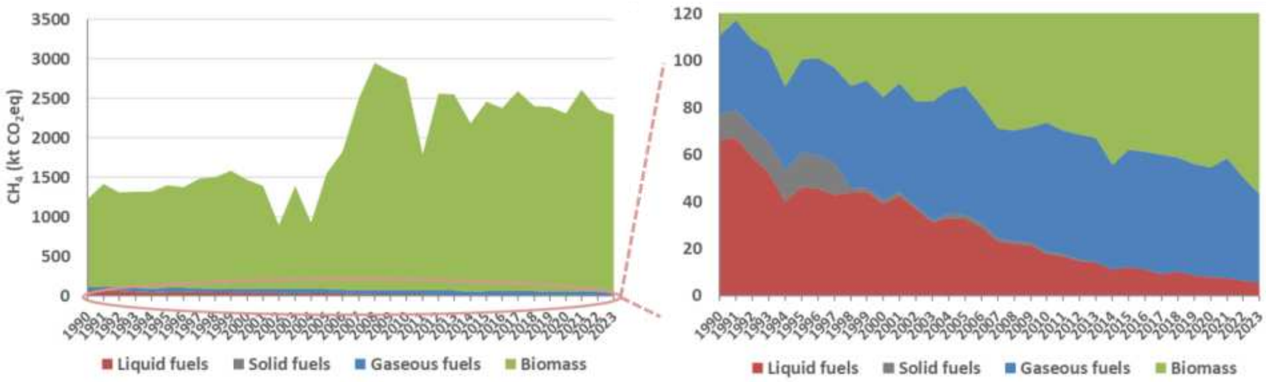
Source	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Energy industries	0.3	0.3	0.3	0.2	0.1	0.2	0.1	0.1	0.1	0.1
Manuf. industries and construction	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3
Transport	1.0	1.1	0.9	0.6	0.3	0.2	0.2	0.2	0.2	0.2
Other: Commercial / institutional	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Other: Residential	1.2	1.4	1.5	1.6	2.8	2.5	2.3	2.6	2.4	2.3
Other: Agriculture / forestry / fishing	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1
Other combustion	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**2.8**	**3.1**	**2.8**	**2.6**	**3.5**	**3.4**	**3.1**	**3.4**	**3.2**	**3.1**

Figure 1.29 – Methane emissions trend from residential sector.



Methane emissions in the residential source increased from 1990 to 2023 by 87% compared to reduction in total GHGs in the sector by 31 %. The decoupling is due to the increasing share of energy from biomass compared to other fuels. The sector's energy consumption swings around its average without a particular trend, while the share of energy consumption from biomass has increased, going from an average of 14.2% in the 90s to an average of 26.6% in the last five years. Biomass essentially refers to the consumption of wood for heating.

Figure 1.30 – Methane emissions trend from residential sector by fuel.

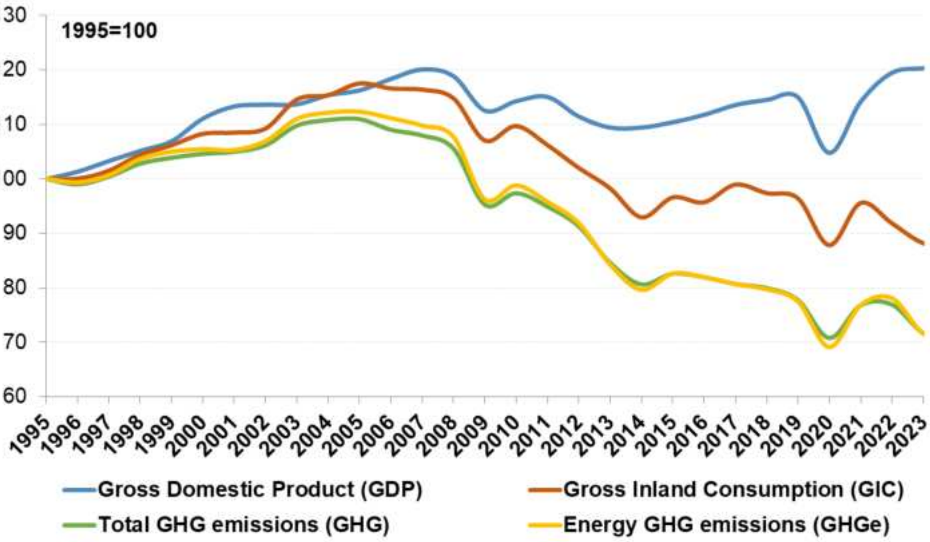


The share of methane emissions from biomass has always been prevalent but increased from 91% in 1990 to 98.1% in 2023. Other fuels contribute with fewer and fewer shares. The emission factors of methane and nitrous oxide from biomass for the entire time series examined are respectively 320 and 14 kg/TJ, much higher than those recorded for fossil fuels. However, the emission factors of biomass, expressed in CO_2eq, thus also considering the zero emissions of CO_2, are lower than those of fossil fuels.

1.2 Energy intensity and decarbonization indicators

To assess the relationship between energy consumption, economy and GHGs the trends of gross inland energy consumption (GIC), gross domestic product (GDP; chain linked volumes, reference year 2020) and GHGs are analysed. GDP and GIC had parallel trends up to 2005. Then the two parameters begun to diverge showing an increasingly decoupling. GHG emissions growth was slower than that of GDP until 2005, highlighting a relative decoupling. After 2005, the divergence between the two parameters became wider showing even absolute decoupling when the GDP increased and GHGs decreased (2015-2019).

Figure 1.31 – Indexed trend of gross inland energy consumption, GDP and GHGs.



Decoupling is also evident from the downward trend in the ratio of GIC to GDP since 2005. The decreasing trend in energy GHGs per primary energy consumption is mainly due to the replacement of higher carbon fuels with natural gas, mostly in power sector and industry, and to the increase of renewable share. The same decreasing trends are confirmed for final energy consumption (net of non-energy uses) per GDP and for GHGs per final energy consumed.

In the period 1995-2023 the GIC per GDP decreased from 101.1 toe/M€ to 74 toe/M€ (-26.8%). Over the same period, GHGs per GDP fell by 40.5%, from 336.7 t CO_2eq / M€ to 200.3 t CO_2eq/M€, while energy emissions per primary energy goes from 2.81 t CO_2eq/toe to 2.21 t CO_2eq/toe, with a reduction of 21.3%. All declining trends of the considered indicators are statistically significant to Mann-Kendall test ($p<0.001$). The preliminary data for 2024 show further decrease of energy intensity and decarbonization indicators by GDP compared to the previous year, while the early extrapolations for 2025 show an upward trend for some indicators.

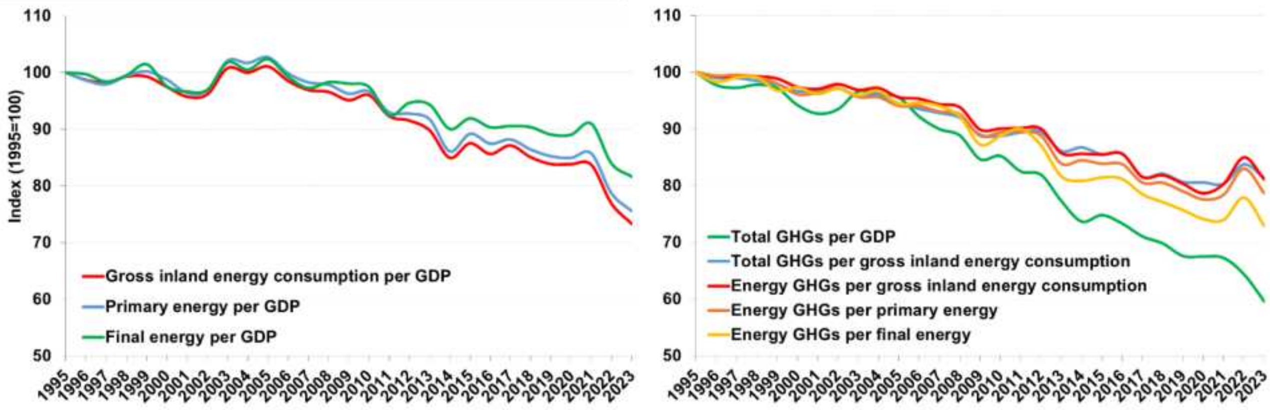
Table 1.12 – Energy intensity by economy and decarbonization indicators. GDP; chain linked volumes, reference year 2020.

	Indicators	1995	2000	2005	2010	2015	2020	2021	2022	2023	*2024**	*2025ˣ*
Energy intensity	GIC per GDP (toe/M€)	101.1	98.6	102.3	97.1	88.5	84.8	84.7	77.6	74.0	*72.9*	*71.9*
	Primary energy per GDP (toe/M€)	95.0	93.8	97.6	91.9	84.8	80.7	81.5	74.7	71.7	*70.1*	*68.7*
	Final energy per GDP (toe/M€)	69.3	67.6	71.0	67.6	63.7	61.7	63.1	58.1	56.2	*56.1*	*56.2*
Decarbonization	Total GHGs per GDP (t CO_2eq/M€)	336.9	317.3	321.7	287.2	252.0	227.5	226.6	216.5	200.3	*192.1*	*192.9*
	Energy GHGs per GDP (t CO_2eq/M€)	266.9	253.3	257.9	230.8	199.7	176.0	179.5	174.1	158.4	*152.4*	*153.4*
	Total GHGs per GIC (t CO_2eq/toe)	3.33	3.22	3.15	2.96	2.85	2.68	2.68	2.79	2.71	*2.64*	*2.68*
	Primary energy emissions (t CO_2eq /toe)	2.81	2.70	2.64	2.51	2.36	2.18	2.20	2.33	2.21	*2.17*	*2.23*
	Final energy emissions (t CO_2eq/toe)	3.85	3.75	3.63	3.41	3.13	2.85	2.85	3.00	2.82	*2.72*	*2.73*

* Preliminary estimates. ˣ early extrapolation from data available up to the end of August 2025.

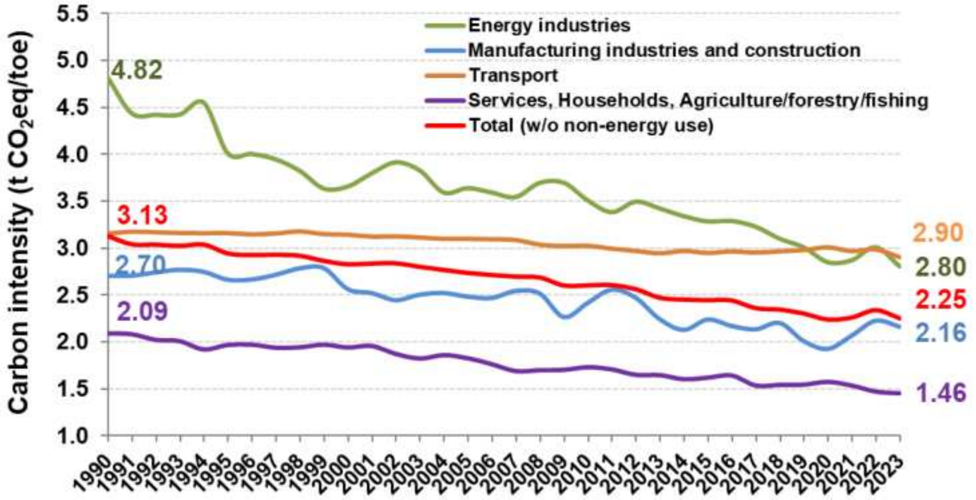
Since 2005 there has been an acceleration in the energy intensity decrease and decarbonization of the national economy up to 2019/2020, once again highlighting the growing decoupling of economy, energy and GHGs. The decoupling between energy consumption and GDP leads to a decreasing energy intensity of the national economic system. The causes can be manifold and among the main ones is the contraction of industrial activities, which are more energetic intensive as compared to services characterized by lower energy intensity and higher value added. GHGs per energy consumed (primary and final) decreased rapidly since 2005 mainly because of the increasing share of renewable energy since 2007. After 2020 the indicators show an upward trend due to the increase of share oil fuels (2021 and 2022) and solid fuels (2022), while in 2023 the indicators get back the downward trend.

Figure 1.32 – Indexed trends of energy intensity and decarbonization indicators.



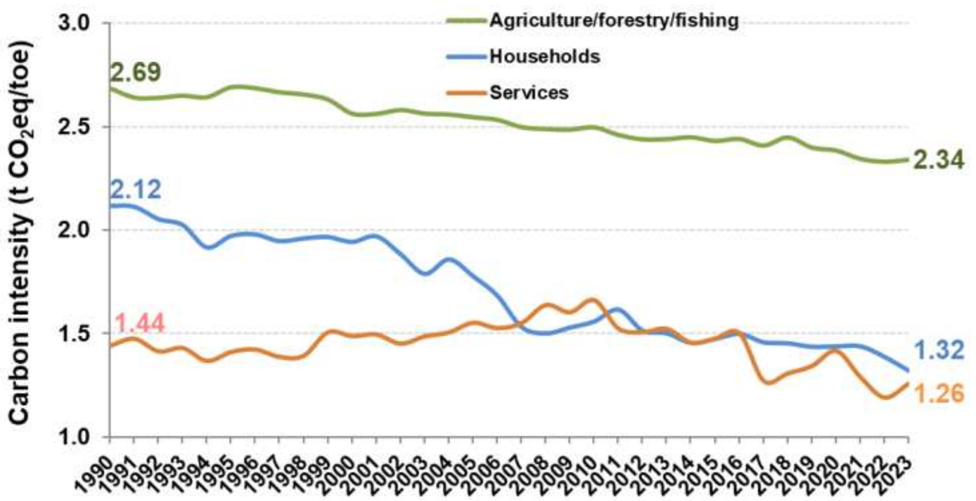
Decarbonization at sectoral level can be assessed by energy emissions and energy consumption by sector. The carbon intensity by energy is the ratio between GHGs and energy consumption. The average carbon intensity by sector is notable different among sectors, depending upon the different deployment of renewable sources and electrification of final energy consumption. The carbon intensity of energy industries decreases by 41.8% in 2023 compared to 1990, from 4.82 t CO_2eq/toe to 2.8 t CO_2eq/toe. The carbon intensity of manufacturing industry in 2023 is 2.16 t CO_2eq/toe, decreasing by 20.2% compared to 1990 level. The transport carbon intensity is 2.9 t CO_2eq/toe (-8.2% compared to 1990) and shows the highest value in the last years with the slowest decreasing slope since 1990 among sectors. The carbon intensity in the civil sector is 1.47 t CO_2eq/toe, 29.5% down compared to 1990 value. All declining trends of these indicators are statistically significant to Mann-Kendall test ($p<0.001$). Overall, the carbon intensity for the energy consumption considered, accounting by 93.6%±1.2% of gross energy inland consumption from 1990 to 2023, is 2.25 tCO_2eq/toe in 2023 (-28.1% compared to 1990 level).

Figure 1.33 – Carbon intensity by sector for energy GHGs.



Splitting the other sector into its subsectors it emerges how services have the lowest intensity because of the high electrification of final consumption and the structural low energy demand of the sector. The households show the highest reduction from 1990 to 2023 (-37.7%), followed by agriculture, forestry, and fishing (-12.9%) and services (-12.6%). Moreover, it is noteworthy how households catch up services from 1990 to 2008, mainly because of the steep decrease of high carbon content fuels and parallel increase of renewable energy in the households' sub-sector, as seen in Figure 1.9.

Figure 1.34 – Carbon intensity in the other energy subsectors.



Delving into the industry subsectors according to the source categories in CRT it can be seen the different decarbonization rate in the subsectors. The carbon intensity recorded in the last three years in the iron and steel subsector is 43.9% lower than the average recorded in the first half of '90. On the other end the carbon intensity for non-ferrous metals increased by 45.2%. The decarbonization rates for the other subsector are shown in Table 1.13.

Figure 1.35 – Carbon intensity in the industry subsectors for energy GHGs.

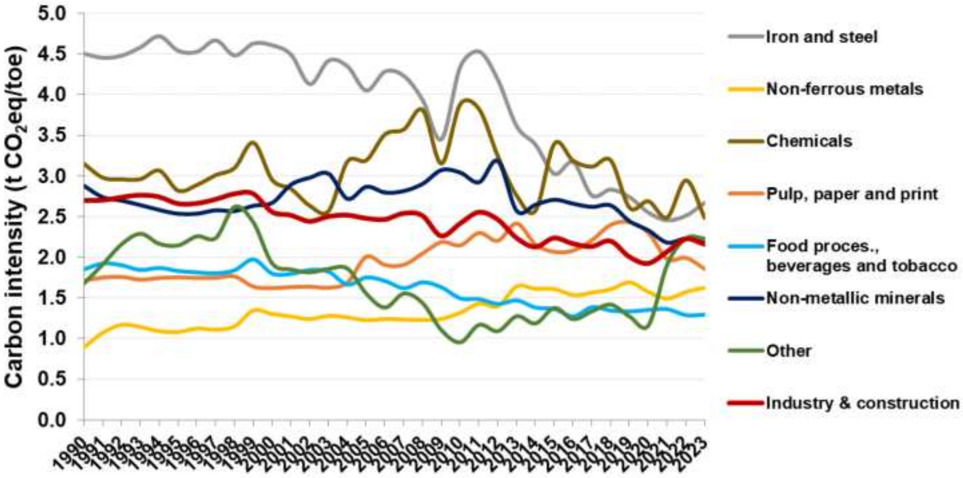


Table 1.13 – Carbon intensity in the industry subsectors for energy GHGs (t CO_2eq/toe). Δ% is the percentage change of average intensity in the period 2021-2023 compared to the average in the period 1990-1995.

Subsectors	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	Δ%
Iron and steel	4.50	4.54	4.61	4.05	4.35	3.03	2.55	2.46	2.52	2.67	-43.9%
Non-ferrous metals	0.89	1.08	1.30	1.23	1.32	1.61	1.57	1.49	1.57	1.62	45.2%
Chemicals	3.15	2.82	2.95	3.20	3.89	3.40	2.69	2.49	2.95	2.48	-11.7%
Pulp, paper and print	1.71	1.75	1.62	2.01	2.15	2.06	2.30	1.98	1.99	1.85	11.6%
Food processing, beverages and tobacco	1.86	1.84	1.80	1.76	1.50	1.37	1.36	1.37	1.29	1.30	-29.7%
Non-metallic minerals	2.88	2.54	2.67	2.87	3.04	2.71	2.33	2.18	2.23	2.18	-18.0%
Other	1.68	2.15	1.92	1.55	0.95	1.38	1.16	1.91	2.23	2.23	3.2%
Industry & construction	**2.70**	**2.66**	**2.56**	**2.48**	**2.41**	**2.24**	**1.92**	**2.06**	**2.22**	**2.16**	**-21.0%**

1.2.1 Energy and carbon intensities by economy

The carbon and energy intensity indicators by sector are calculated matching the GHGs by sector with respective value added or GDP for households and transports. Both value added and GDP are expressed in chain linked volumes, reference year 2020. Emissions by sector include only direct emissions and emissions from electricity self-production in industry. Indirect emissions due to electricity consumption from the grid are not considered, since they are allocated in the energy industries.

The indicators for services are to be read considering that in such sector are allocated the GHGs by fossil waste burnt in incinerators with energy recovery, as stated in the National Inventory Report (ISPRA, 2025a): "*Emissions from these plants are allocated in the commercial/institutional category because of the final use of heat and electricity production which is mainly used for district heating of commercial buildings or is auto consumed in the plant.*" According to such approach GHGs from services and the sector's final energy consumption in energy balance are not directly related, because the energy balance considers only energy consumption by end users, while incineration is accounted in the transformation.

For agriculture, which includes fisheries and forestry, it is possible to establish a direct correspondence between GHGs, final energy consumption, and value added produced by the sector. For the services, value added was considered without the transport item, to compare sector's GHGs and value added. For industry, the items of value added from manufacture of coke and oil-petroleum products, electricity and water services are excluded to make comparable the industry value added with the GHGs of manufacturing and construction industries and relative energy consumption. For agriculture and industry both combustion and process emissions are considered.

Overall, emissions from the three sectors (agriculture, industry, services) fell by 28.9% in 2023 compared to 1995. Combustion and process emissions reduced by 30.2% and 26.8%, respectively. GHGs from the three sectors represent on average 34.5±0.8% of total GHGs in the period 1990-2023.Figure 1.36 shows the indexed trends of GHG emissions, final energy consumption and value added for each sector compared to 1995 level. The figures show how the decoupling among the three parameters is working in the sectors. The decoupling is quite clear in industry which requires less and less energy with even lower GHG emissions compared to the value added of the sector. While the decoupling between energy and emissions starts from 2012, the decoupling with value added starts since 2005. An opposite behaviour is shown by services, whose emissions are higher compared to the value added, also due to the accounting of GHGs from incinerators, as previously reported. In the last years GHGs and value added are approaching each other. GHGs from agriculture show a constant decrease compared to 1995 with some early decoupling, even not growing, between emissions, final energy and value added. The aggregate trend is mainly driven by industry.

Figure 1.36 – Indexed trend of GHGs, final energy, and value added by sectors and whole economy area.

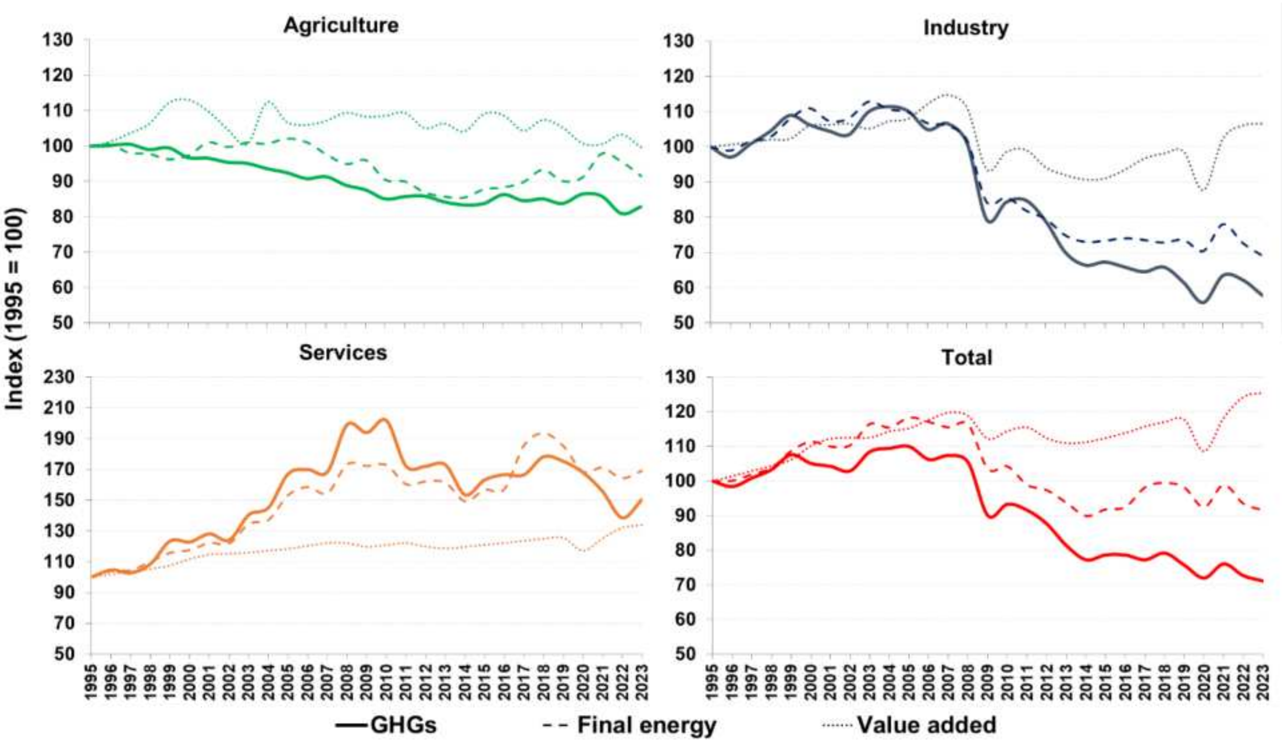
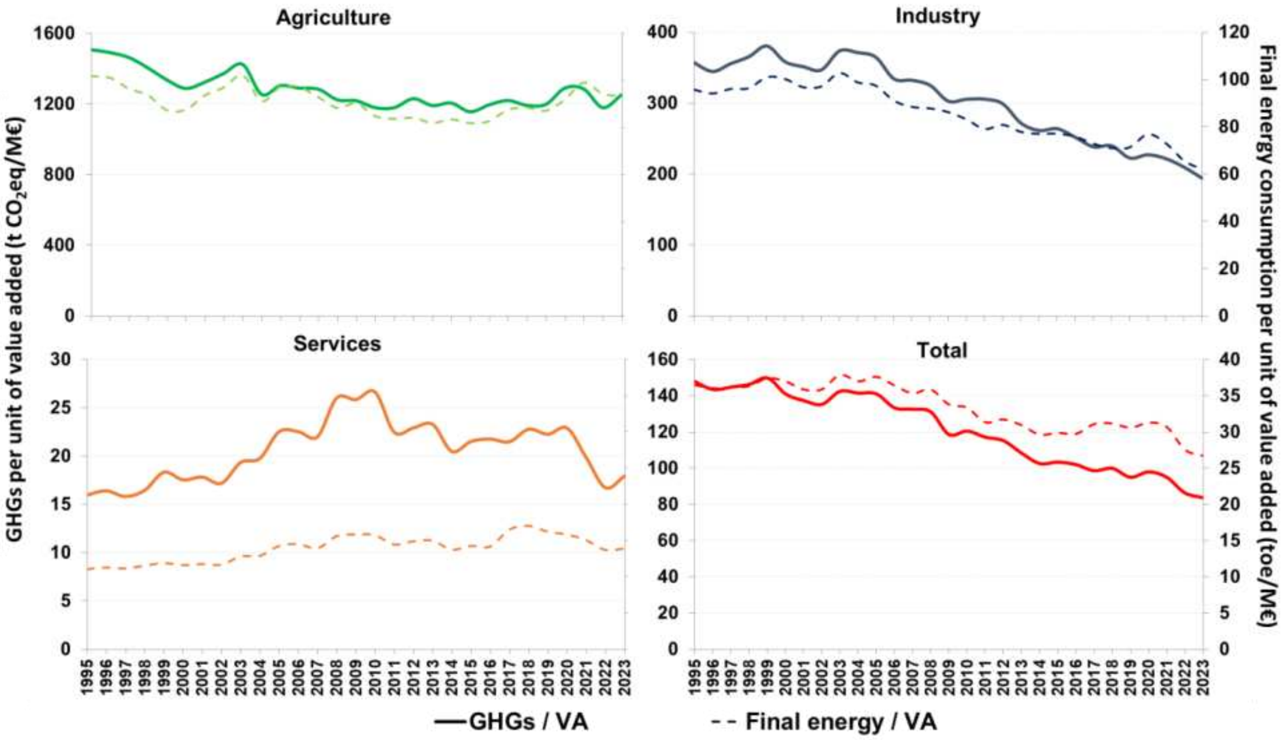


Figure 1.37 shows both carbon intensity and final energy intensity by sector per unit of value added. In 2023 the energy intensity (toe/M€) of industry is well below the 1995 level (-34.9%), while services are higher (+26.3%), although in the last years the sector intensity decreased significantly. As for agriculture, after a downward trend from 2003 to 2015, the intensity shows increasing trend even though 2023 level is -8.2% below the 1995 level. Aggregate energy intensity for the three sectors decreased by 26.7% over the period 1995-2023.

The ratio between GHGs and value added, carbon intensity, decreased because of the increasing share of renewable energy and fuels with lower carbon content, as natural gas. The carbon intensities per value added are very different among sectors. Agriculture has the highest values, while services recorded the lowest ones. In 2023 the agriculture intensity is 16.8% below the 1995 level, while services' one is 12.3% over. In the latter sector the indicator increased until 2010, then followed by a decarbonization, particularly steep in 2021 and 2022. Industry shows a robust and quite constant downward trend (-45.8% in 2023 compared to 1995). Such sector drives the aggregate trend which records -43.3% in 2023 compared to 1995.

Figure 1.37 – Carbon intensity (left axes) and final energy intensity (right axes) by value added.



A more detailed analysis can be carried out for industry subsectors both for carbon intensity and final energy intensity. The value added by manufacturing subsectors in 2023 is provisional, estimated according to the value added by manufacturing industry and the share of subsector's value added in the previous year. The disaggregation of subsectors concerning carbon intensity has been performed according to CRT categories. The disaggregated subsectors cumulatively demand more than 73% of final energy of industry and construction in 2023. All other subsectors of manufacturing industry have been aggregated in the item "other".

As for carbon intensity (Figure 1.38), the subsector of the paper industry, among the main subsectors, is the only one with higher values nowadays compared to the '90s. The carbon intensity recorded in the last three years is 13.3% higher than the average recorded in the second half of '90s, although the biggest increase occurred from 1995 to 2009, followed by a weak decreasing trend.

The subsector of chemical & petrochemical experienced the most robust and continuous decrease in carbon intensity (-64.7%; average in 2021-2023 compared to average in 1995-2000), followed by food, beverages and tobacco (-50%) and iron and steel & non-ferrous metals (-40.1%). The trend in the food industry increased from 1995 up to 2003, then decreased rapidly up to 2012 and with a slower slope in the next years. Carbon intensity of metallurgy industry shows a slow decrease from 1995 up to 2011, followed by a sharp fall up to 2017 and an increasing trend in the last years, although with wide variability. Non-metallic mineral products decreased the carbon intensity by 38.1% since the end of '90s, although the trend assumed a negative slope only after 2003. The heterogeneous group of other subsectors has the lowest levels of carbon intensity with a decreasing trend from 1999 to 2010. The values remained quite stable up to 2020 but in the last years a surge of carbon intensity was recorded (Table 1.14).

Figure 1.38 – Carbon and final energy intensity by value added in industry subsectors.

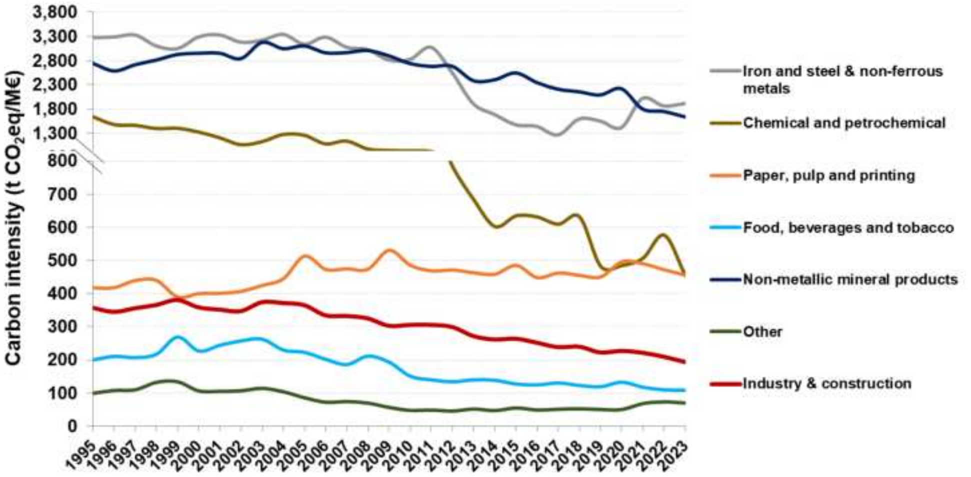


Table 1.14 – Carbon intensity in the industry subsectors per unit of value added (t CO_2eq/M€). Δ% is the percentage change of average intensity in the period 2021-2023 compared to the average in the period 1995-2000.

Subsectors	1995	2000	2005	2010	2015	2020	2021	2022	2023	Δ%
Iron and steel & non-ferrous metals	3279.3	3294.2	3143.0	2827.1	1474.5	1417.1	2020.3	1865.5	1913.2	-40.1%
Chemical and petrochemical	1644.1	1328.8	1261.7	940.0	635.4	485.7	508.1	577.2	455.7	-64.7%
Paper, pulp and printing	416.4	399.3	513.4	485.4	485.1	496.0	490.0	471.6	455.4	13.3%
Food, beverages and tobacco	199.7	226.8	222.7	150.2	126.6	132.1	116.7	108.8	107.3	-50.0%
Non-metallic mineral products	2745.0	2956.9	3108.7	2744.7	2547.9	2221.5	1800.5	1749.0	1637.6	-38.1%
Other	99.4	106.6	85.8	47.4	54.7	50.1	68.3	73.2	69.8	-38.9%
Industry & construction	**356.8**	**358.1**	**364.6**	**305.3**	**263.7**	**226.9**	**221.3**	**209.3**	**193.5**	**-42.2%**

The final energy intensity, as well as the carbon intensity, changed with different rates in the subsectors. Chemical & petrochemical show a continuous decrease from 1995 to 2015, then followed by stable values. The final energy intensity of non-metallic mineral products decreased constantly from 2008. The food industry decreased its intensity since 2003, with higher slope up to 2011, followed by the slowdown in the next years. The subsector of paper, pulp and printing shows wide oscillations with the current values like those recorded up to 2002. Metallurgy industry shows a peculiar trend with an upward tendency since 2017 which the long run decrease from 2009. The intensity of the last three years is 1.2% over the average recorded in the period 1995-2000 (Table 1.15).

Figure 1.39 – Final energy intensity by value added in industry subsectors.

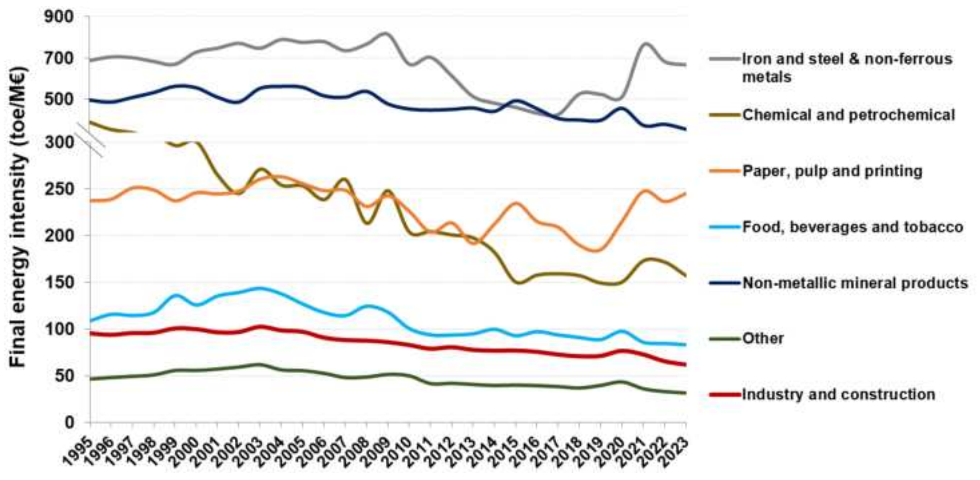


Table 1.15 – Final energy intensity in the industry subsectors per unit of value added (toe/M€). Δ% is the percentage change of average intensity in the period 2021-2023 compared to the average in the period 1995-2000.

Subsectors	1995	2000	2005	2010	2015	2020	2021	2022	2023	Δ%
Iron and steel & non-ferrous metals	686.7	726.9	774.5	669.4	460.4	512.3	762.3	681.2	666.1	1.2%
Chemical and petrochemical	388.6	300.5	253.3	203.6	150.0	150.3	173.0	171.5	161.9	-49.1%
Paper, pulp and printing	237.7	246.5	256.0	226.2	235.0	215.8	247.9	236.8	245.5	-0.1%
Food, beverages and tobacco	108.7	125.7	126.8	100.2	92.5	97.3	85.4	84.2	82.7	-29.8%
Non-metallic mineral products	496.5	557.7	559.5	452.8	492.8	455.6	371.6	377.3	352.5	-30.0%
Other	46.3	55.5	55.3	49.7	39.8	43.1	35.8	32.8	31.3	-34.6%
Industry & construction	**95.6**	**100.1**	**97.3**	**83.1**	**77.0**	**76.8**	**72.9**	**65.5**	**62.2**	**-31.2%**

1.2.1.1 Transport and households

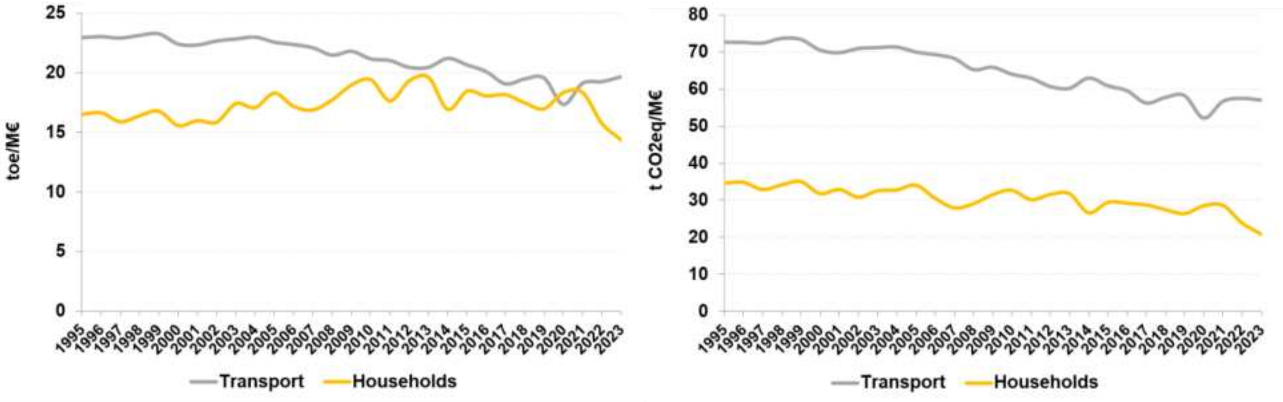
GHGs in transport and households cannot be uniquely linked to a specific economic parameter, such as the value added for the sectors seen before. Energy and carbon intensities by economy for such sectors are calculated considering the GDP. Moreover, GHGs per capita (in transport) could provide useful insights about the sector's performance concerning carbon intensity. Furthermore, to consider the transport performance for unit of transported item, without the effect of increasing population and integrating the technology change of vehicles over time, the GHGs are compared to passenger-km (p-km) or tonne-km (t-km) for freight transport. One passenger-km represents the transport of one passenger over one kilometre, while one tonne-km represents the transport of one tonne of goods over one kilometre. So, the carbon intensities per p-km or t-km are the GHGs emitted to move one passenger or one tonne of goods over one kilometre. Passenger-km and tonne-km data are issued by Ministry of infrastructures and transport. For freight transport extrapolated data are considered because such source includes also transport below 50 km. For such metric the GHGs from heavy and light duty trucks are considered together. The sources of transport data (number of vehicles, p-km, and t-km) are Eurostat database, Ministry of infrastructures and transport (CNIT), ACI.

The GHGs from transport and households together show an increasing share, from 30.6% to 38.7% of total GHGs in the period 1990-2023. The increase is due to transport (from 19.5% to 28.3%), while the share of households does not show any specific tendency but fluctuates within the range 10%-12%.

Figure 1.40 shows the trend of energy and carbon intensities by GDP for the two sectors. The household's energy intensity swings around an average without a clear tendency downward or upward (17.3±1.3 toe/M€ in the period 1995-2023), even though in the last years could be observed a decrease never recorded before. The carbon intensity shows a downward trend since 1995 (from 34.5 t CO_2eq/M€ in 1995 to 20.8 t CO_2eq/M€ in 2023; -39.8%). The trend of GHGs emissions by GDP witnesses the sector's change of energy mix in the final consumption, with increasing contribution of biomass leading to lower carbon intensity but not reducing energy intensity.

As for transport the energy intensity decreased by 15.9%, from 23 toe/M€ to 19.3 toe/M€ from 1995 to 2023. A quite parallel decreasing trend was observed for carbon intensity with a reduction by 21.6%, from 72.6 t CO_2eq/M€ to 56.9 t CO_2eq/M€ from 1995 to 2023, showing some decarbonization also in this sector.

Figure 1.40 – Energy and carbon intensities by GDP for transport and households.



The GHGs per capita (Figure 1.41) show a decreasing trend since 2005 for the two sectors (-17% transport, -37.6% households). It is noteworthy that the relevant fall of emissions per capita recorded in 2020 for transport because of the pandemic and the rebound in the next year with emissions per capita even higher than the pre-pandemic values.

Figure 1.42 shows the decoupling among the considered indicators in the two sectors since 2005. As for transport there is no real decoupling between energy and carbon intensities, while GHGs per capita, as well as energy consumption per 1000 inhabitants show only small decoupling, even though in the last years all the indicators are very close.

As for households, the two intensities by GDP show some decoupling since 2005, due to the decrease of GHGs compared to energy consumption. Even more distant from energy intensity are GHGs per capita. The relative closeness between energy intensity by GDP and energy consumption per 1000 inhabitants, confirms that it was the fuel mix the driving factor leading to less GHGs, followed by efficiency of energy final consumption in the dwellings. As already seen, the GHGs per capita decreased by 37.6%, whereas the energy per capita consumption decreased by 20% since 2005.

Figure 1.41 – GHGs per capita for transport and households.

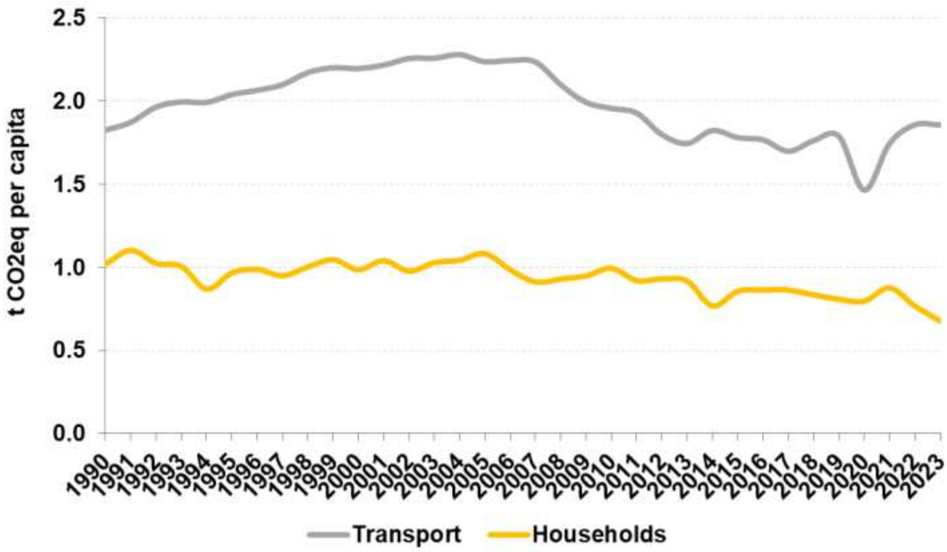
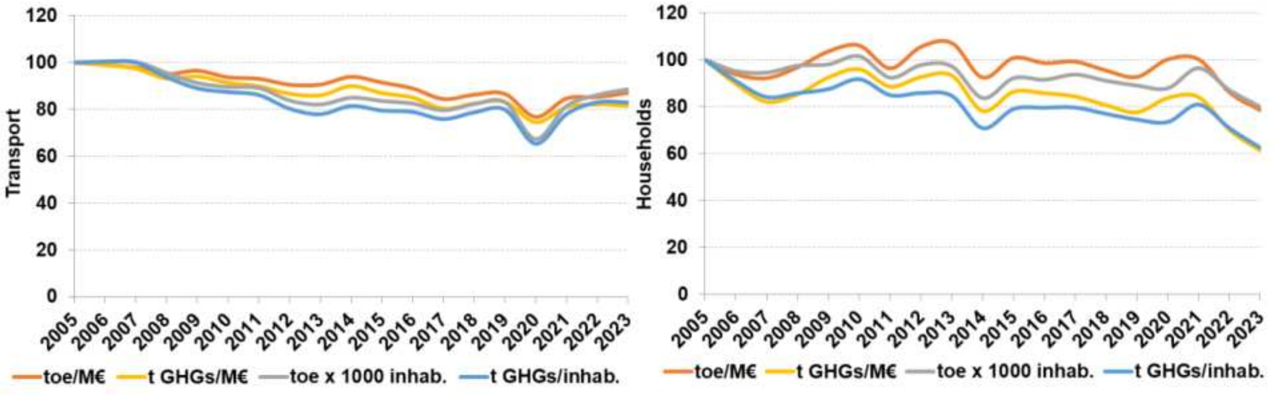


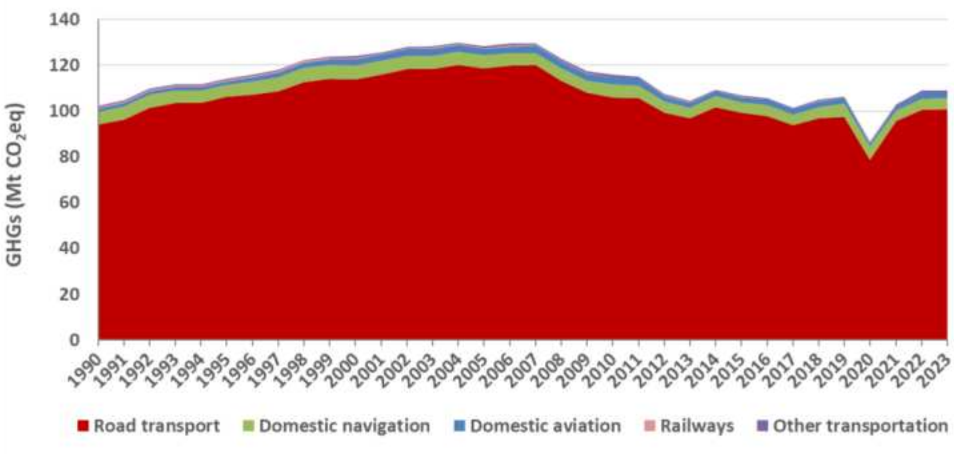
Figure 1.42 – Change since 2005 of energy and carbon intensities, and GHGs per capita for transport and households.



The relevance and complexity of transport sector deserve considering GHGs by different mobility segments, mainly for road transport. The passengers and freights mobility respond to very different driving factors. If the former segment, although not independent by country's wealth, satisfies the mobility demand without a direct link to economy, the freights transport is directly driven by economy. So, GHGs per capita indicator from freights' transport provides only limited information about the performance of segment, better described by the GDP driver. Considering the multiple sources of transport, it will be useful a focus on GHGs from such sector.

As shown in Figure 1.43, the GHGs from road transport represent almost the totality of the sector's GHGs (the average share since 1990 is 92.3%), followed by domestic navigation (4.8%), and domestic aviation (2%). The carbon intensity has been calculated only for the main source. Since 2005, when the peak of transport GHGs was reached, the road transport reduced the emissions by 15.1% even though the 2023 level is still over the 1990 level (+6.7%) and 2.5% over the pre-pandemic level of 2019.

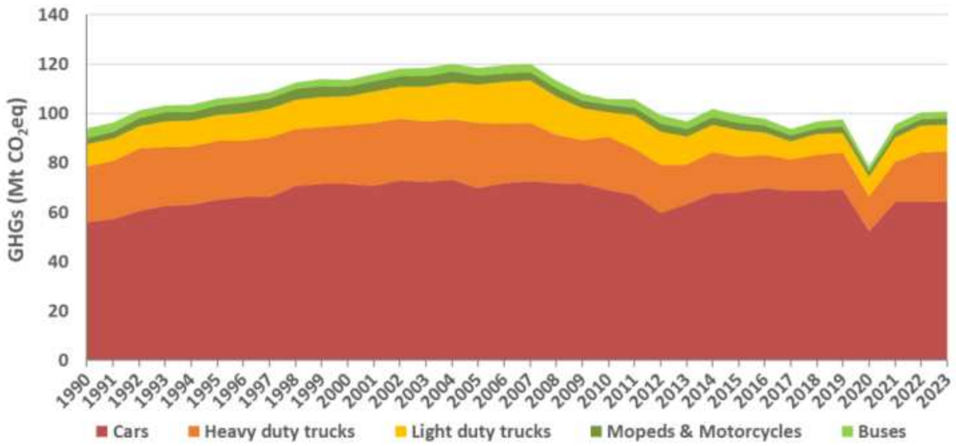
Figure 1.43 – GHGs from transport.



The road transport can be split into its components, according to the type of transport and vehicles. The mobility on cars produces about 64% of GHGs from road transport, heavy duty trucks around 20%, light duty trucks 11%, and mopeds & motorcycles (L-category) 3%, as well as buses. All categories reduced the GHGs since 2005, even though cars and light duty trucks are still over 1990 levels, respectively +15.1% and +18.7%. GHGs from cars decreased by 7.8% since 2005. Light duty trucks' emissions decreased by 30%, while heavy duty trucks decreased by 23.2%. GHGs from mopeds & motorcycles decreased by 29.5%. GHGs from buses decreased by 11.3%. The comparison between the emissions before and after 2020 shows that the 2023 levels for cars, buses, and L-category vehicles are respectively 6.8%, 4.2%, and 1%

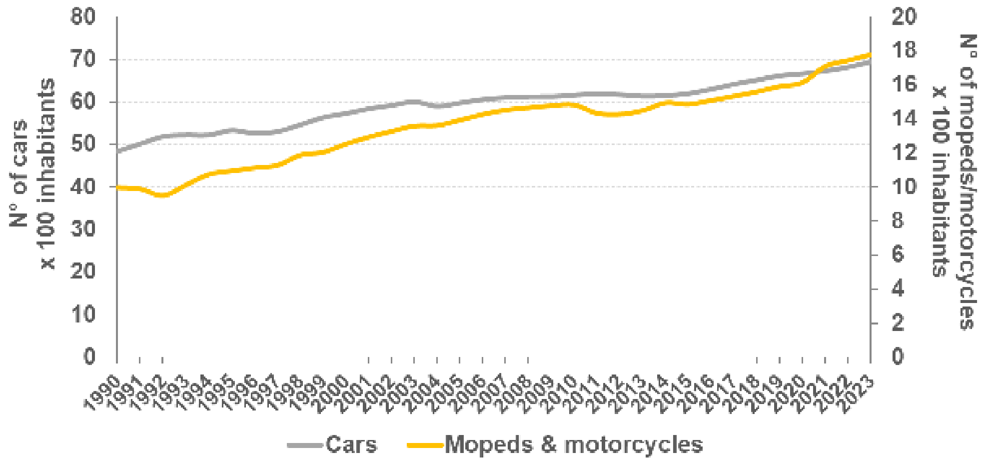
below the 2019 levels, while commercial vehicles are over the 2019 levels (light duty trucks, +35%; heavy duty trucks, +36%).

Figure 1.44 – GHGs from road transport.



The number of cars per 100 inhabitants increased by 43.4% since 1990 (+16.1% since 2005), while L-category vehicles increased by 78.2% since 1990 (+27.6% since 2005).

Figure 1.45 – Number of vehicles per 100 inhabitants.



GHGs per capita by cars are about 20 times higher than those by L-category vehicles. The emissions per capita by L-category vehicles decreased by 5.8% since 1990 and 30.6% since 2005. The trend is significantly decreasing since 1990 only for L-category vehicles, while for the other vehicles the emissions per capita decreased significantly only since 2005, even though the observed increase in the last years for buses weaken the significance of Mann-Kendall test.

Figure 1.46 – GHGs per capita for cars, buses, and mopeds & motorcycles.

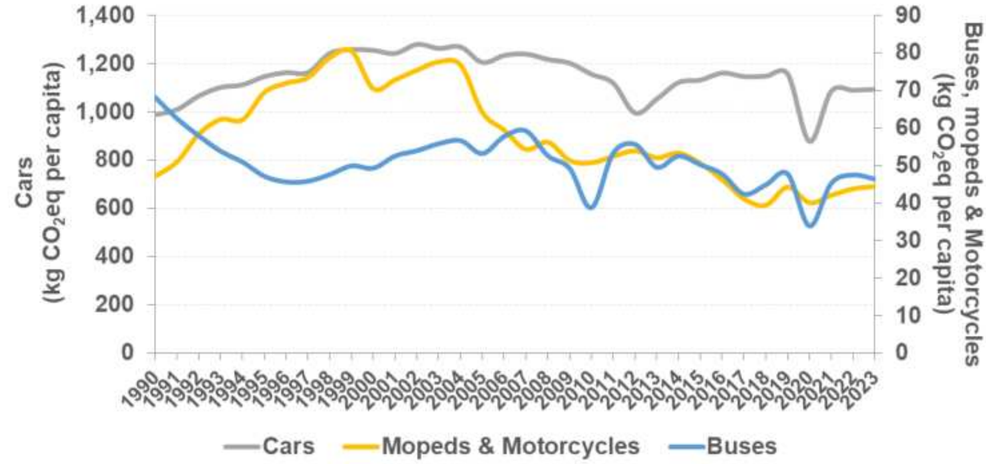
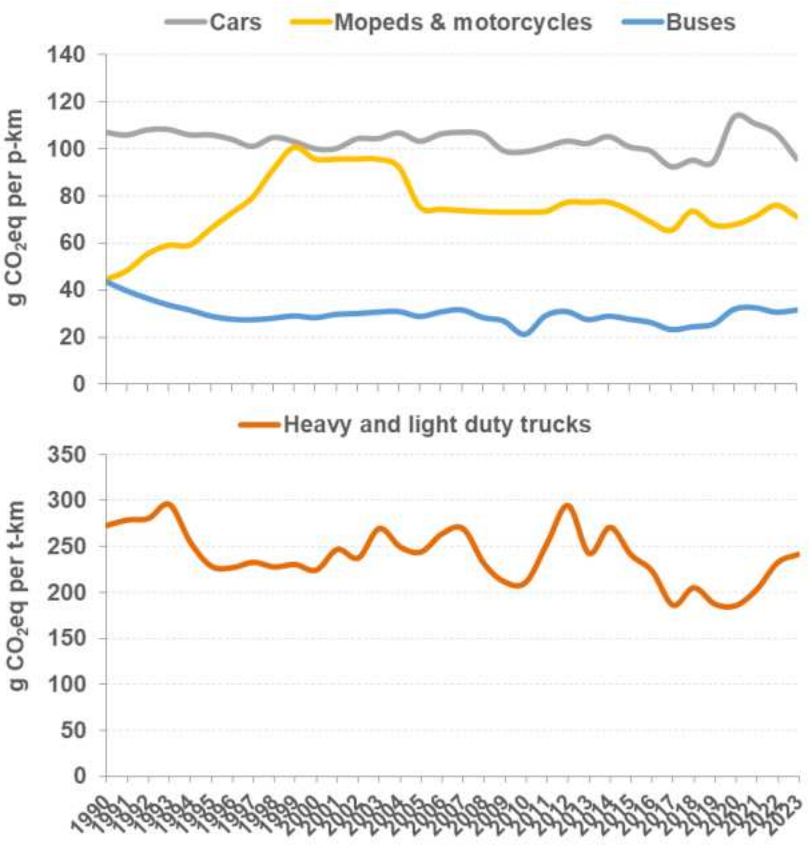


Figure 1.47 shows that the carbon intensity of mobility with cars or L-category vehicles are much higher than mobility with buses; cars have the highest intensity. GHGs per p-km of cars in 2023 is 10.7% below the 1990 level and 7.4% below 2005 level. The GHGs per p-km for mopeds & motorcycles show wide change from 1990 to 2005, followed by swinging values around the average, as well as for buses.

As concerns freight transport, up to 2012 the GHGs per t-km fluctuate around the average, while after 2012 there is a downward trend with wide oscillations. Since 2020 an upward trend is observed and the 2023 level is 11.5% below the 1990 level and 1.1% below the 2005 level.

Figure 1.47 – GHGs per passenger-km and per t-km.



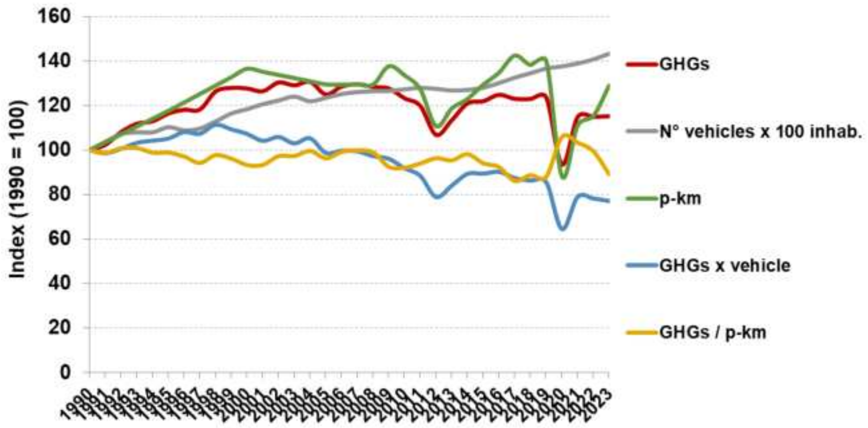
Just to complete the picture of the transport sector, also GHGs per passenger-km for the other transport items have been elaborated. As shown in Table 1.16 navigation is the more carbon intensive transport, whereas mobility on railways is the lowest one.

Table 1.16 – GHGs per passenger-km (g CO_2eq/p-km); transport items in decreasing order of 2023 data.

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	Δ% 1990-2023
Domestic navigation	1920.0	1963.4	1566.6	1529.1	1412.5	1252.5	2004.1	1495.0	1343.0	1271.1	-33.8%
Domestic aviation	234.6	225.3	263.8	223.4	189.6	122.7	200.9	187.9	134.2	127.4	-45.7%
Cars	107.1	106.0	100.0	103.3	98.8	100.9	113.6	110.7	106.6	95.6	-10.7%
Mopeds & motorcycles	44.5	66.0	95.6	75.2	73.1	73.9	67.8	71.2	76.0	71.2	59.7%
Buses	43.8	29.0	28.3	28.8	21.2	27.7	31.9	32.6	30.7	31.6	-27.8%
Railways	14.2	14.2	9.6	6.7	4.6	1.5	6.6	4.6	0.8	0.9	-93.7%

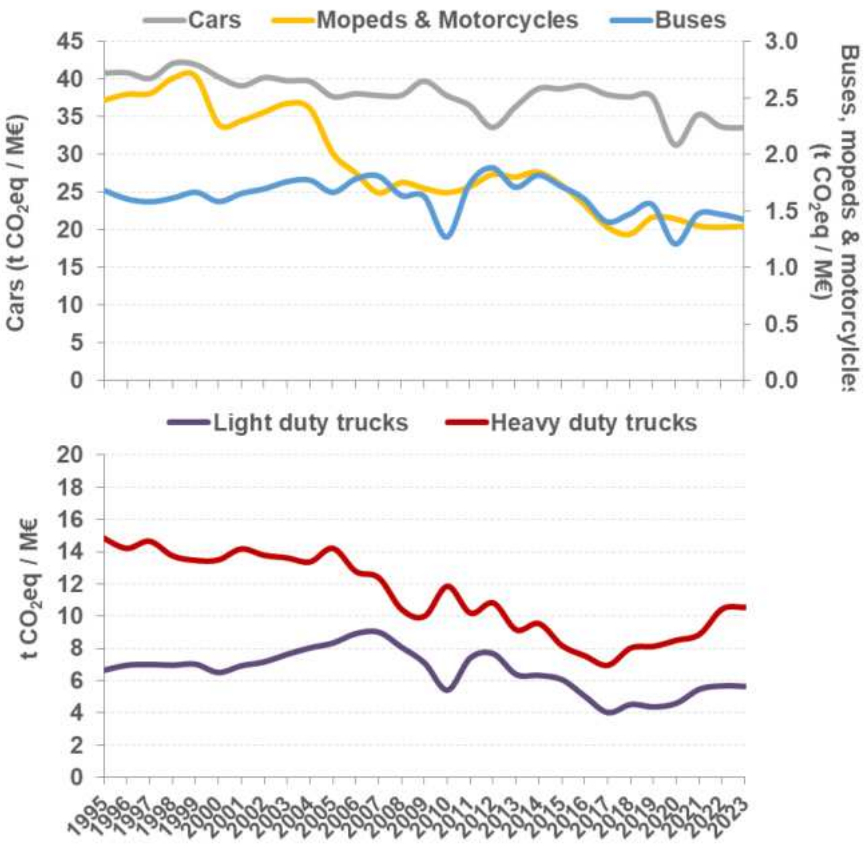
A summary for cars is provided in Figure 1.48 with indexed indicators showing that the improvement in technology to reduce GHGs per vehicle is more than offset by the increasing number of vehicles. Moreover, GHGs follow the mobility demand (p-km) which reached the top in 2017 (+42.5% compared to 1990); after the shock of 2020 there was a recovery of mobility demand, which in 2023 is about 13% over the 1990 level. The vehicles which can drag downward GHGs, such as BEV and PHEV, still represent a marginal share of cars circulating, around 0.6% and 0.5% respectively in 2025.

Figure 1.48 – Indexed indicators for cars.



The responsiveness to GDP of GHGs for passenger and freight mobility is shown in Figure 1.49 for the road transport items. The carbon intensity by GDP recorded a downward trend for cars and L- category vehicles. Buses have reduced their intensity only since 2012. As for commercial vehicles, the light duty trucks have reduced intensity since 2007. Both light and heavy-duty trucks stopped the downward trend in 2017; since then, the intensities increased and in 2023 are +40.2% higher for light vehicles and +51.8% higher for heavy vehicles compared to 2017. The carbon intensity of cars in 2023 is 17.9% below the 1995 level, while for L-category vehicles it is 44.9% below. As for freights transport, the intensities of light and heavy-duty trucks in 2023 are below their 1995 levels by 15.2% and 29.1%, respectively. The carbon intensity of buses in 2023 is 15.2% below the 1995 level.

Figure 1.49 – GHGs per GDP by vehicle categories.



1.3 Kaya identity and decomposition analysis

Decomposition analysis is a technique for studying the variation of an indicator in each time interval in relation to the variation of its determinants. In other words, the variation of a parameter is decomposed in the variation of the driving parameters. The starting point of the analysis is the construction of an identity equation, where the variable whose change over time is to be studied is represented as the product of components considered as the causes of the observed variation. In the identity equation the examined variable is indicated as a product of the driving factors, expressed as ratios where the denominator of a factor is the numerator of the next one. This identity, called Kaya by the economist Yoichi Kaya, is defined as *a priori,* and must be realized according to a conceptual model consistent with the physical constraints of the studied variable, in addition to the considerations related to the availability of data and the objectives of the analysis.

GHG emissions are decomposed in six driving factors: 1) population; 2) economic growth per capita; 3) efficiency; 4) renewable energy deployment; 5) carbon intensity from fossil fuels; 6) final energy intensity.

The analysis of decomposition makes it possible to evaluate the contribution of each determining factor. Identity is expressed in logarithmic form:

$$ln\left(CO_{2eq}\right) = ln(POP)\ x\ ln\left(\frac{GDP}{POP}\right)\ x\ ln\left(\frac{GIC}{FEC}\right)\ x\ ln\left(\frac{FFC}{CIL}\right)\ x\ ln\left(\frac{CO_{2eq}}{FFC}\right)\ x\ ln\left(\frac{FEC}{GDP}\right)$$

where:

CO_2eq: GHG emissions;

POP: population;

GDP/POP: Gross domestic product per capita – economy;

GIC/FEC: ratio between gross inland energy consumption and final energy consumption (included non-energy uses) - efficiency;

FFC/GIC: ratio between fossil energy consumption and gross inland energy consumption – renewable;

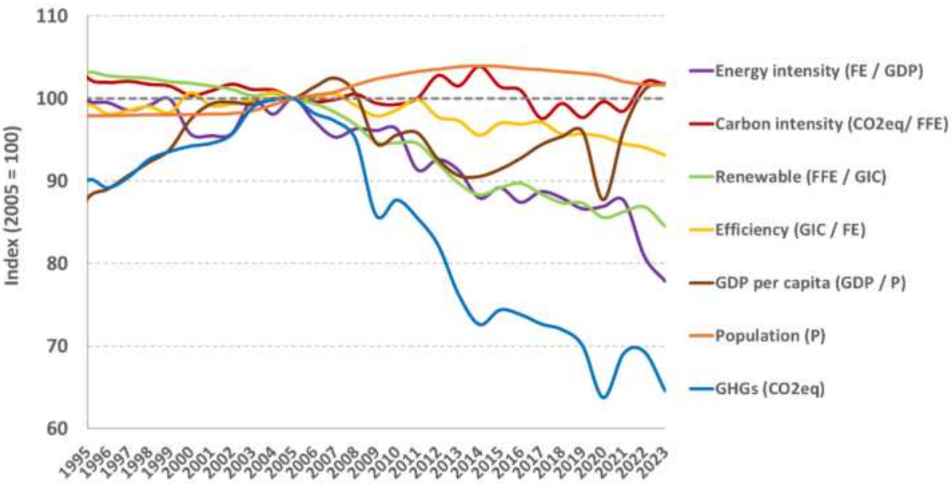
CO_2eq/FFC: ratio between CO_2eq emissions and fossil energy consumption – fossil fuel carbon intensity;

FEC/GDP: ratio between final energy consumption and gross inland consumption – final energy intensity.

The equation therefore allows to assess the effect of population, economic growth, efficiency, renewables, fossil fuel carbon intensity and energy intensity. As for carbon intensity by fossil energy consumption, it must be noted that a stricter definition should account for only GHGs by energy, however also no energy emissions are included to consider the full carbon print of the national economy.

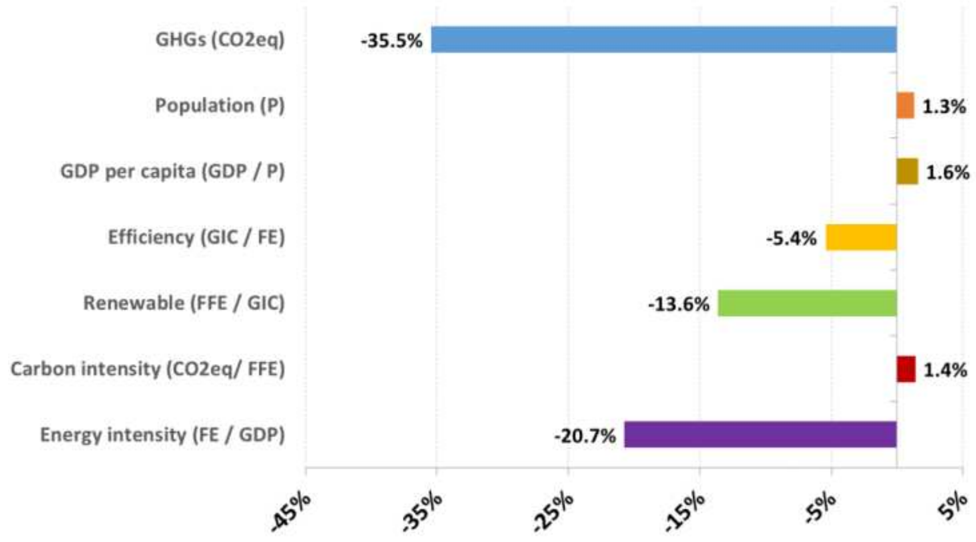
The trend of the Kaya Identity parameters in the period 1995-2023 is shown in Figure 1.50, with normalized values to 2005. The reduction of emissions since 2005 is determined by factors such as energy intensity, renewable sources, GDP per capita, efficiency. Carbon intensity, population, and GDP per capita drive an increase in emissions in 2023 compared to 2005. GHGs reduction in 2020 has been mainly driven by economy contraction.

Figure 1.50 – Performance of the national parameters of the Kaya Identity. Normalised values for 2005.



The outcomes of decomposition analysis of GHGs change, carried out according to *Logarithmic mean Divisia index* (Ang, 2005), shows that the effect of the factors that led to a reduction of emissions in the period 2005-2023 overcome the effect of the factors that led to an increase of emissions. The three factors which led to the growth of emissions contributed collectively with +4.3% (Figure 1.51). The remaining factors have led to a reduction of GHGs. The final energy intensity (final energy consumption / GDP) played the main role (-20.7%) followed by the share of renewable energy (fossil energy consumption / gross inland energy consumption; -13.6%) and the efficiency factor (gross inland consumption / final energy consumption; -5.4%). The overall contribution of each factor leads to -35.5% of GHGs over the period 2005-2023.

Figure 1.51 – Decomposition of the change in GHGs emissions from 2005 to 2023.



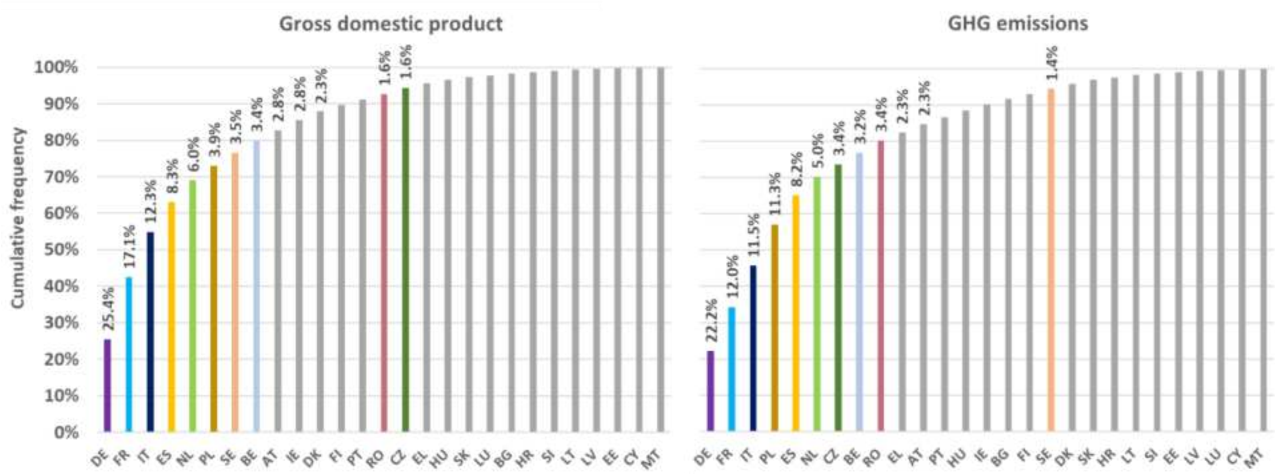
2 ITALY AND THE BIGGEST EUROPEAN COUNTRIES

This chapter will examine the trends of efficiency and decarbonization indicators in the biggest European Member States. The indicators are elaborated using data of energy balances from the Eurostat database (https://ec.europa.eu/eurostat/data/database, last update 02 May 2025). The renewable share by sector are from SHARES 2023, SHort Assessment of Renewable Energy Sources by Eurostat (https://ec.europa.eu/eurostat/web/energy/database/additional-data, last update 07 March 2025). GHG emissions submitted by EU countries to UNFCCC on 15 April 2025 are available in the EEA greenhouse gases — data viewer (https://www.eea.europa.eu/en/analysis/maps-and-charts/greenhouse-gases-viewer-data-viewers), last update 16 April 2025. Preliminary data on electricity production by source in 2024 are available in the Eurostat database (last update 25 June 2025).

2.1 Efficiency and decarbonization indicators

Comparison of decarbonization and efficiency indicators is carried out among Italy and the EU Member States with more than 3% of EU27 GHGs or more than 3% of EU27 GDP in 2020. The Member States examined (Germany, France, Italy, Spain, Poland, the Netherlands, Belgium, Romania, Czechia, and Sweden) in 2020 accounted for 81.6% of the population in EU27, 81.6% of GHGs, 83.2% of GDP, and 82.5% of the gross inland energy consumption in EU27.

Figure 2.1 – Cumulative frequencies for gross domestic product and GHGs in the EU27 countries (data 2020). Labels of selected countries or higher than 2% are reported.



2.1.1 Energy consumption and gross domestic product

Since 1990, European environmental policies have led to a significant change of the energy mix in the Member States. The nuclear energy represents 12.2% of EU27 gross inland consumption in 2023, with a slight increase compared to the previous year, mainly due to the increase recorded in France. The nuclear phase out of Germany goes on and in 2023 the share is 0.7%. Fossil fuels have been grouped in macro categories (solids, oil & petroleum products, etc.; see Table 2.1). Solid fuels energy faces significant contraction in EU27 since 1990. In 2023 the share reaches the lowest level ever recorded (9.9%), to be compared with 26.9% in 1990. All countries reduced sensibly the energy by solid fuels, even though there are still significant shares in Germany (16.6% in 2023), Poland (34.7%), and Czechia (27.9%). Oil and petroleum products show a very modest reduction at European level (from 37.6% in 1990 to 35.8% in 2023) with different trends among the States. Natural gas energy consumption shows a considerable increase in almost all States and at EU27 level ranges from 17.1% in 1990 to 21% in 2023, quite lower than the share recorded in 2021 and 2020 (23.9% and 24.4%, respectively).

The share of fossil fuels decreased since 1990, from 82% to 67.7% in 2023, while renewable energy increased significantly, from 4.9% to 20.1%.

Figure 2.2 – Trend of fuel energy share in gross inland consumption for EU27 and Italy.

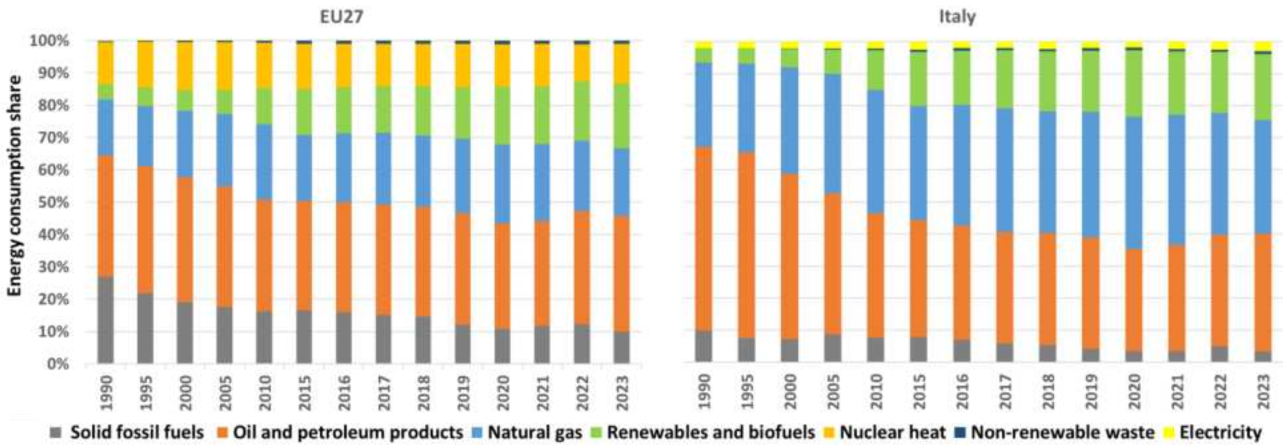
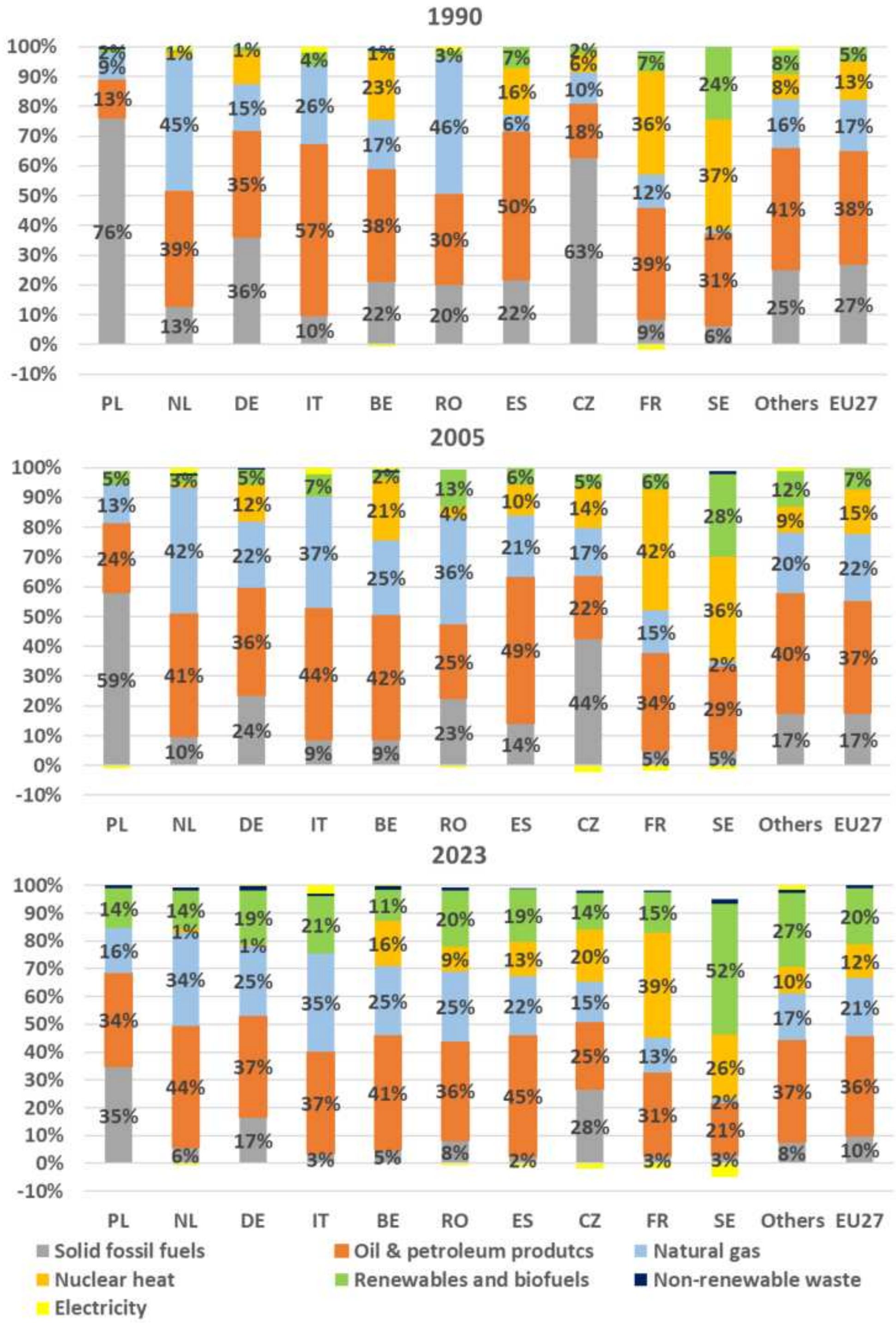


Figure 2.3 shows the fuel energy share in gross inland consumption for each country in 1990, 2005, and 2023. There is a great heterogeneity in the European countries' energy mix and a common shift toward renewable sources and fuels with lower carbon content, as natural gas.

The Italian share of solid fuels, mainly bituminous coal, decreased from 9.9% in 1990 to 3.4% in 2023, resuming the downward trend interrupted in 2022 because of the contraction of natural gas in the aftermath of the Russia's invasion of Ukraine. The share of natural gas in the period 1990-2023 grew from 26.3% to 35.4%, with a downward trend since 2020 (41.2%), while the share of oil and petroleum products decreased from 57.3% to 36.4%, well above the 2021 level (33.1%). Renewable share grew from 4.4% to 20.5% from 1990 to 2023, reached after the contraction recorded in 2021 and 2022. The contraction of renewables after 2020 concerned almost all European countries even though Italy recorded an extremely important fall of hydropower in 2022 which led to further reduction of renewable share. Italy's renewable share in gross inland consumption in 2023 is one of the highest among the biggest countries, only Sweden has a share higher than Italy (Figure 2.3; Figure 2.5). However, the European renewable target in 2030 concerns the gross final consumption and, as shown in Figure 2.16, Italy's overall share is below the European average in 2023 (19.6% vs 24.6%) and behind countries as France, Germany, and Spain. However, it is worthy to underline that the 2030 target for Italy is lower than the European average target (38.7% *vs* 42.5%).

The share of fossil fuels decreased significantly in almost all European countries. The EU27 average decreased from 82% in 1990 to 67.7% in 2023. Among the examined countries, the Netherlands and Poland shares are still higher than 85%, respectively 85.1% and 85.3%.

Figure 2.3 – Fuel energy share in gross inland consumption for EU27 and biggest countries in 1990, 2005, and 2023. Countries in decreasing order of 2023 fossil share (solid, liquid, and gaseous fuels).



The countries' trends on the path of decarbonization of the energy mix can be summarized by the following graph showing the change of renewable and fossil shares from 1990 to 2023. The picture makes clear the widening area of renewable energy opposed to the shrinking area of fossil energy since 1990. The rates of renewable increase and fossil decrease are very different among countries, as shown in Figure 2.5.

Figure 2.4 – Share of renewable and fossil energy in gross inland energy consumption. The labels show the percentage points range between the share in 2023 and 1990.

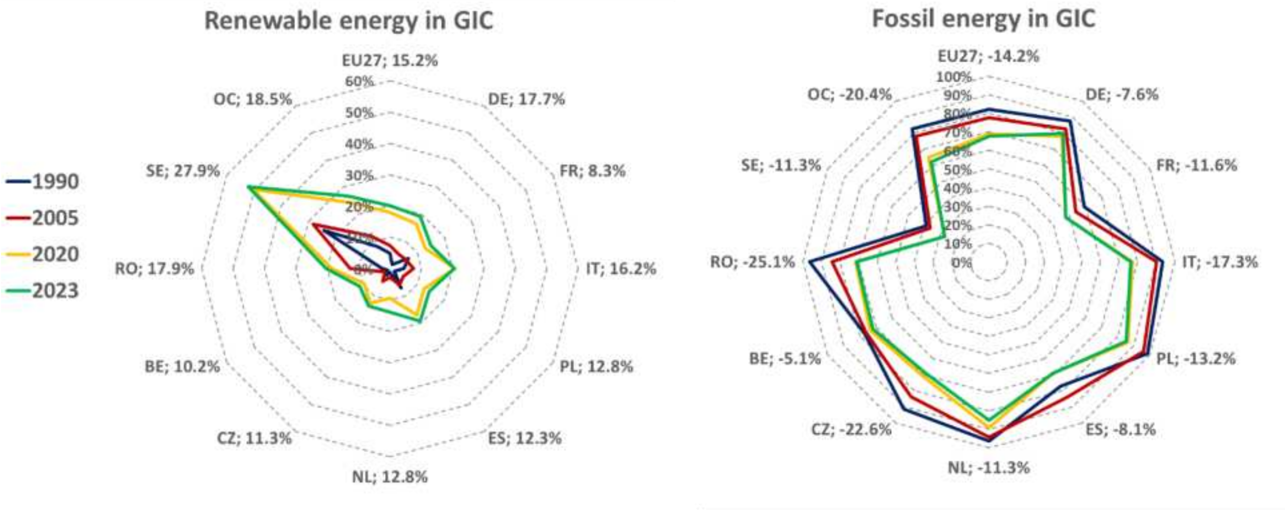
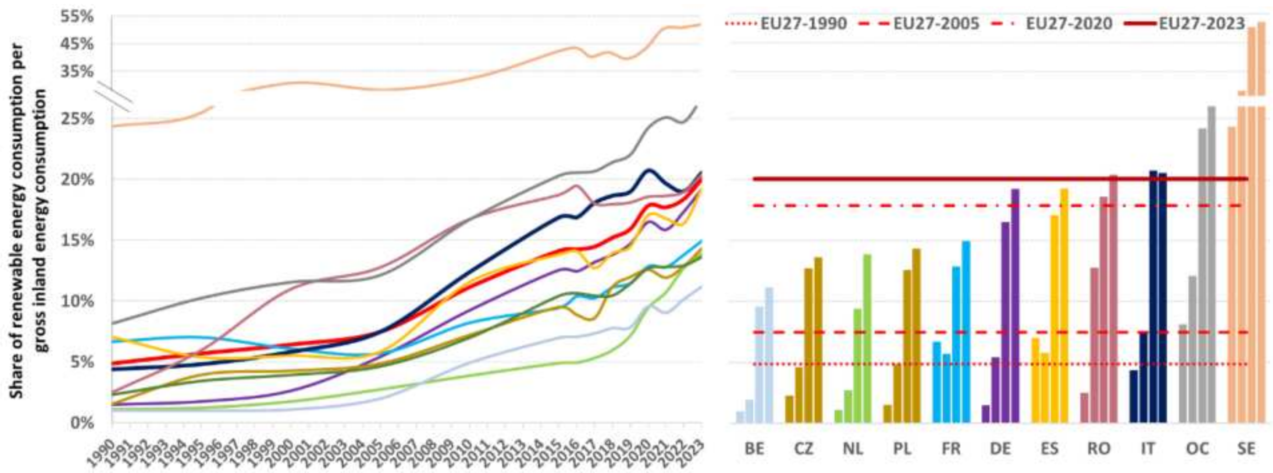


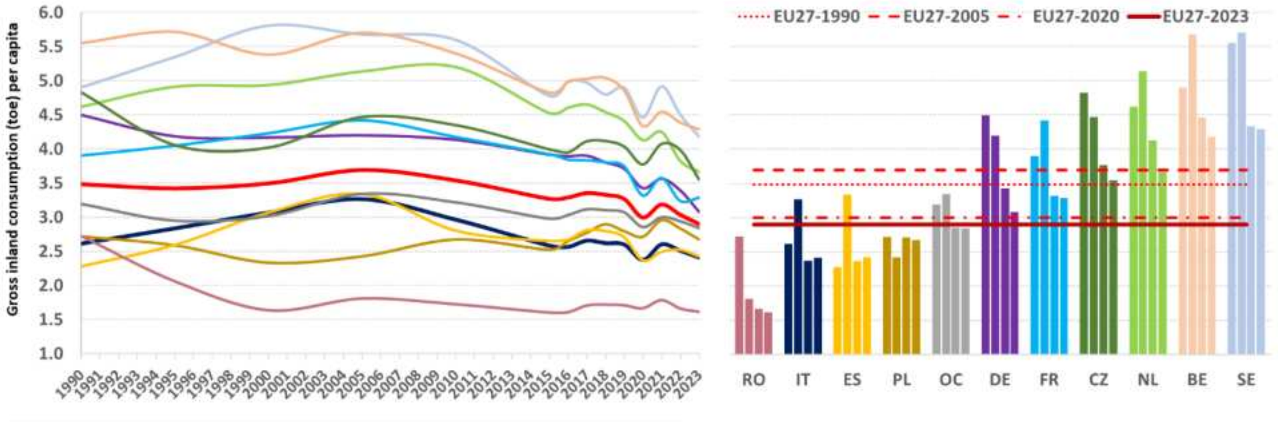
Figure 2.5 – Share of renewable energy in gross inland energy consumption. For each country the bars on the right graph refer to 1990, 2005, 2020, and 2023. Data in ascending order of 2023 value. OC – Other countries.



The European countries show a wide range of gross inland energy consumption per capita. Italy is well below the European average (2.41 *vs* 2.9 toe per capita). The consume per capita in Italy increased from 2.61 toe in 1990 to 3.26 toe in 2005. After 2005 the consumption falls to 2.41 toe per capita in 2023, while in EU27 the consumption per capita was 3.48 in 1990, 3.69 in 2005, and 2.9 in 2023. In 2023 Italy has one of the lowest consumptions per capita among the countries examined, only Romania registered lower level: 1.61 toe per capita. Germany, France, Czechia, the Netherlands, Belgium, and Sweden have higher figures than EU27 averages. The countries' energy consumption decreased everywhere since 2005 with relevant fluctuations in the last years. In 2020 data was heavily affected by measures adopted by all countries to contain SARS-CoV-2 pandemic.

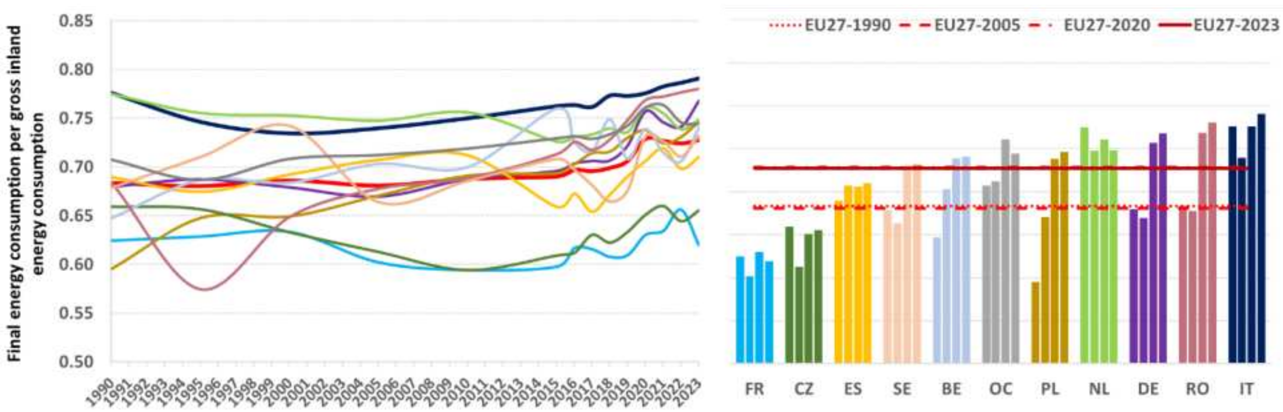
The Netherlands show the highest rates of reduction from 2005 to 2025 (-28.6%), followed by Spain (-27.5%). The other biggest countries show a range from -26.7% in Germany to -10.7% in Belgium. Italy reduced the energy consumption per capita by 26.2%. Poland is the only exception to the downward trends, with +10.2% increase from 2005 to 2023.

Figure 2.6 – Gross inland energy consumption per capita. For each country the bars on the right graph refer to 1990, 2005, 2020, and 2023. Data in ascending order of 2023 value. OC – Other countries.



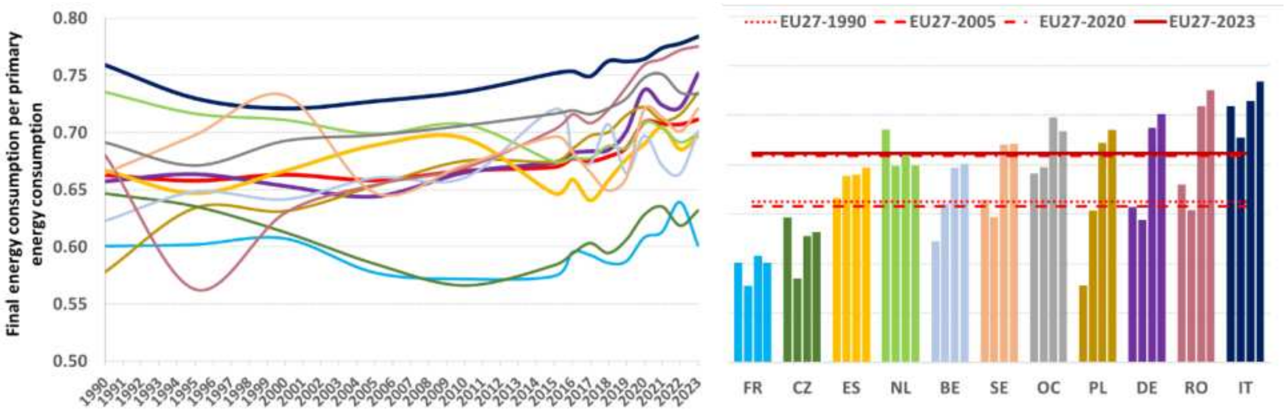
The ratio between the final energy consumption (including non-energy uses) and gross inland consumption is an indicator of energy efficiency (Figure 2.7). Since 1990 this indicator has always been higher for Italy than for the European average and shows values which, among the biggest countries, are comparable only with those of the Netherlands up to 2010. In the next years the Netherlands efficiency shows wide fluctuations with a sensible decrease compared to their past, while the Italian efficiency increased constantly. As concerns the other States, the efficiency fluctuates around the European average since 2005, except France and Czechia which have the lowest values. The lowest values for France and Czechia are also due to the low electrical conversion efficiency of nuclear power plants and the significant weight that such source has in the energy balance of these States (39.3% and 19.7% of gross inland consumption in 2023, respectively in France and Czechia). However, this is not the only factor because Sweden and Belgium, with respectively 25.7% and 16.1% of gross inland consumption by nuclear energy, have final energy efficiency much higher than France and Czechia. A sharp increase in efficiency made Poland reach and overcome the European average in recent years. It should be noted that, beyond the already mentioned countries, also Spain and Romania have significant shares of nuclear heat in their energy consumption in 2023 (12.7% in Spain and 9.3% in Romania).

Figure 2.7 – Ratio between final energy consumption (including non-energy uses) and gross inland energy consumption. For each country the bars on the right graph refer to 1990, 2005, 2020, and 2023. Data in ascending order of 2023 value. OC – Other countries.



To evaluate energy transformation efficiency, it is useful to consider energy consumption without non-energy uses. In other words, the ratio between final energy consumption and primary energy (Figure 2.8). The Italian energy transformation efficiency is higher than any other countries examined. The trend of this indicator is like that of the previous one, although it highlights some difference among Member States concerning the share of non-energy uses. This indicator reveals that the transformation efficiency of the Netherlands is well below the Italian ones. In the Netherlands, the average share of non-energy uses is more than 16% of gross inland consumption, while for Italy the average is below 5% with a downward trend. In 2023 the Netherlands' share of non-energy consumption is the highest among the biggest countries (16.4%), followed by Belgium (13.4%). The EU27 average is 5.6%, while Italy's share is 3.2%.

Figure 2.8 – Ratio between final energy (w/o non-energy uses) and primary energy consumption. For each country the bars on the right graph refer to 1990, 2005, 2020, and 2023. Data in ascending order of 2023 value. OC – Other countries.

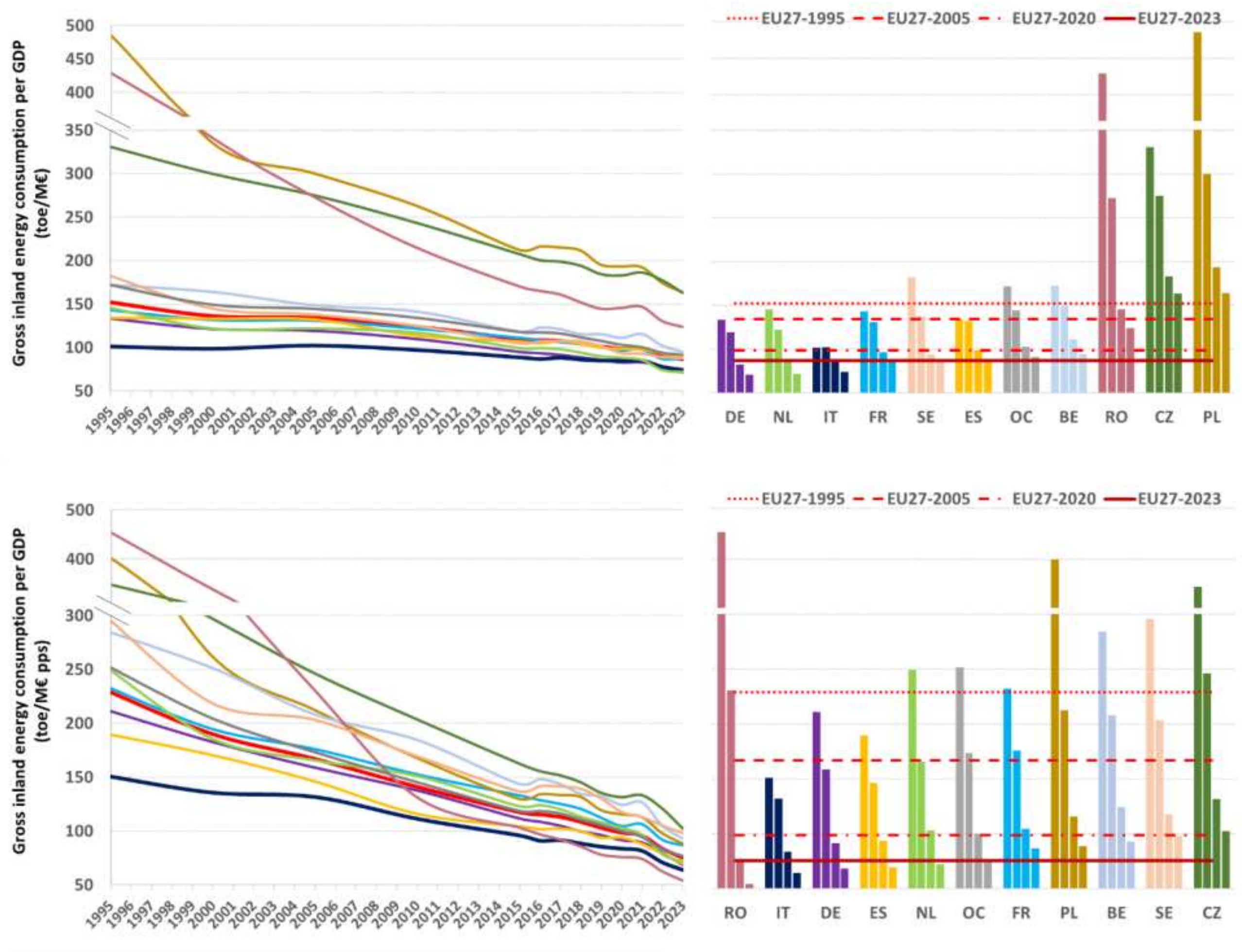


The gross inland energy consumption per gross domestic product (GDP - chain linked volumes, reference year 2020 and current prices, purchasing power standards) is an indicator of the country's economic and energy efficiency (energy intensity by economy; Figure 2.9). Such indicator is sensible to the country's energy mix and economy structure, in terms of industry and services share. An industry-based economy is more energy intensive than a service-based economy, even without considering the efficiency improvement. Moreover, the GDP is also determined by activities related to international bunkers, such as international maritime bunkers, whose energy consumption is not included in gross inland energy consumption. The role of international bunkers will be considered in the paragraph 2.1.2.1.

Italy was one of the European countries with lowest energy intensity since 1995, when it was second only to Denmark, then lost positions and in 2023 has the 7th lower values. Among the biggest EU27 countries, Italy continues having one of the lowest energy intensities, after Germany and the Netherlands. Considering the GDP at purchasing power standards, the position of countries changes reflecting the price levels of each economy.

GDP at purchasing power standards (PPS) and GDP at chain-linked volumes measure different economic dimensions, leading to systematic differences. The gap arises from their distinct purposes: PPS enables cross-country welfare comparisons, while chain-linked volumes track economic performance over time. GDP at PPS adjusts for price level differences across countries. A country with lower prices will see its GDP inflated when converted to PPS (e.g., €1 buys more in Italy than in Sweden). This adjustment reflects differences in price levels, not production volumes. On the other hands, GDP at chain linked volumes measures real GDP growth within a country over time by updating price weights annually. This eliminates substitution bias (e.g., consumers switching of commodities as prices change) but does not account for cross-country price disparities (World Bank, 2020; International Monetary Fund, 2016, 2025).

Figure 2.9 – Gross inland energy consumption per GDP (chain linked volumes, reference year 2020, upper graphs; current prices, purchasing power standards, lower graphs). For each country the bars on the right graph refer to 1995, 2005, 2020, and 2023 values. Data in ascending order of 2023 value. OC – Other countries.

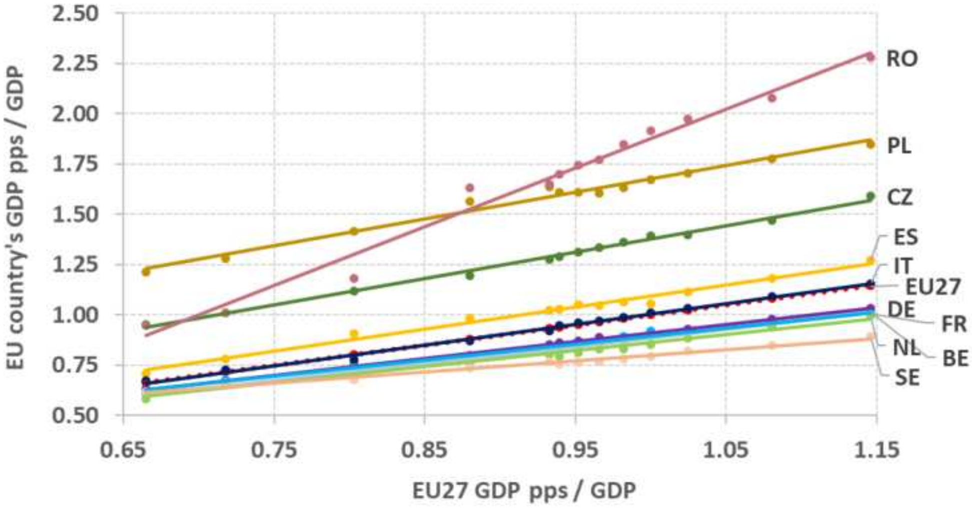


The different ranking between energy intensity calculated with GDP at PPS or at chain linked volumes can be explained by the ratio between the two GDP measures for each country and by the relationship among the country's ratio and the same ratio in EU27 (

Figure 2.10). The ratio between the two measures would highlight the relationship between a country's real economic output (adjusted for inflation) and its economic output adjusted for international price level differences. A higher ratio might indicate that the country has relatively lower domestic price levels compared to international standards, making its economy appear larger when adjusted for purchasing power. A lower ratio could suggest higher domestic prices relative to international levels.

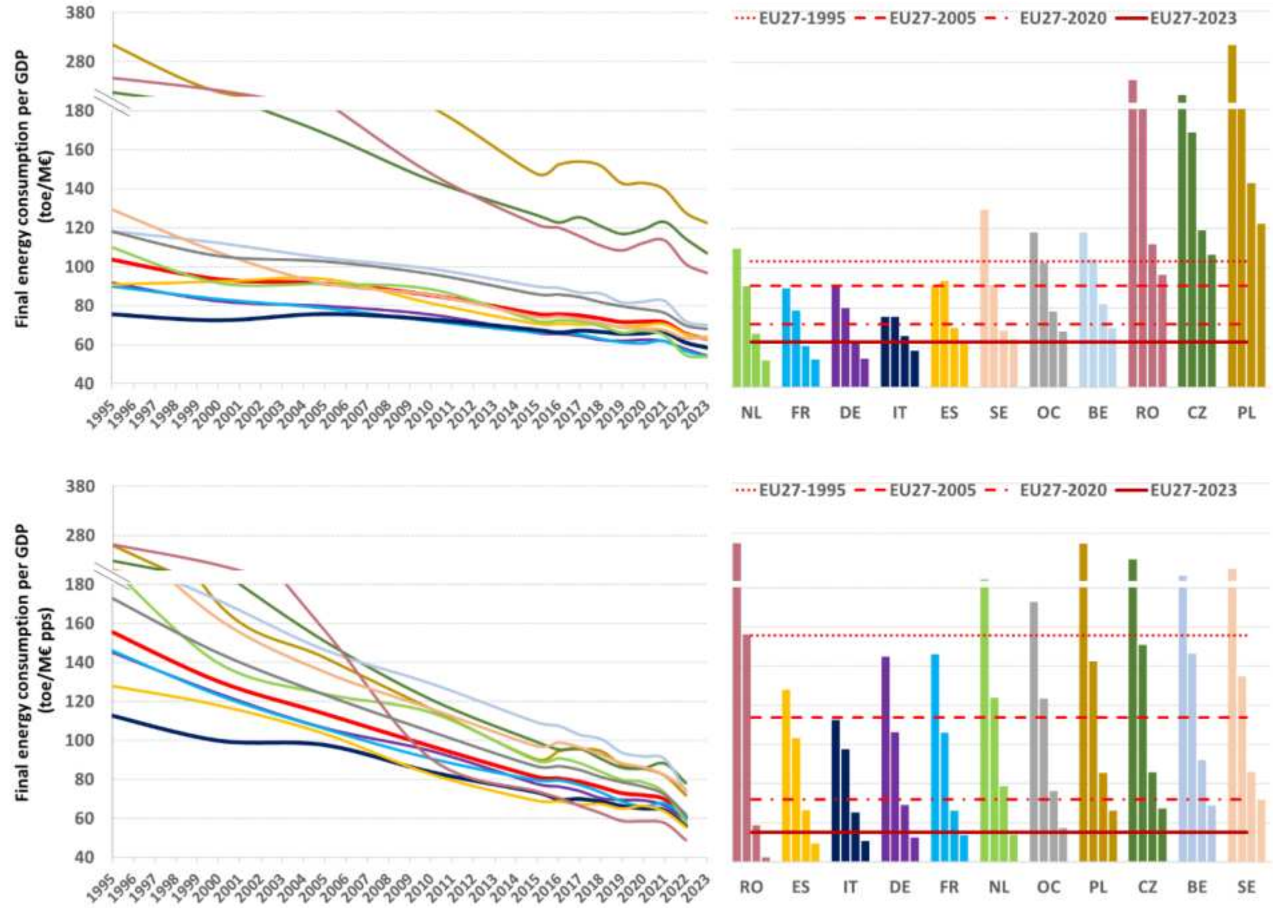
In the last years the GDP at PPS in Romania is more than 2 times its GDP at chain linked volumes, on the other end Sweden ratio is less than 1. The two countries show the range from lowest to highest prices, among the main EU countries. The ratio in Italy is 1.15 in 2023 and almost perfectly aligned with EU27 average. The ratios in Germany, France, the Netherlands, and Belgium are close to 1 in 2023 and overlapped along the time series. Such ratios determine the energy intensity ranking because countries with ratios much higher than 1, as Romania, see larger adjustments towards lower energy intensity with GDP at PPS, while the opposite occurs for countries with ratios lower than 1. In summary it is possible to say that the energy intensity with GDP at PPS of Romania, as well as Sweden, are much more influenced by country's price levels than the energy intensities of countries clustered among them and EU average. The complete overlap between ratios of Italy and EU27 allows to conclude that energy intensity with GDP at PPS of Italy is much lower than the EU27 average independently of price levels but because of effectively lesser use of energy in Italy to produce wealth.

Figure 2.10 – For each country the ratio between GDP at PPS and GDP at chain linked volumes (y-axes) has been compared to the ratio of EU27 (x-axes).



The final energy intensity (ratio between final energy consumption, including non-energy uses, and gross domestic product) follows similar trends of gross energy intensity with a sudden reduction in the European countries which, starting from higher levels than Italy, reached Italian figures and in some cases exceed them (Figure 2.11). Since 1995 Italy shows considerable energy and economic efficiency; the final energy intensity with GDP at chain linked volumes reduced by 22.4% from 1995 to 2023, by 54.9% considering GDP at PPS. Much higher reductions have occurred in the other European countries (EU27: -39.2% with GDP at chain linked volumes and -64.7% with GDP at PPS), whose "starting point" of energy intensity was much higher than the Italian one, around 37% over. The reasons of the observed reduction in energy intensity are manifold such as the increase in building efficiency, industrial efficiency improvement, electrification of final consumption, and shift of economy towards economic activities with high value added and low energy consumption as services to the detriment of industrial sectors. The last aspect is particularly relevant considering the long-term growth of GDP in the countries and the increasing share of the value added from services, which in EU27 represents 74.6% of the value added of all economic activities in 2023, while in1995 it represented 69.9%. On the other hand, the share of value added in industry (except construction), the most energy-intensive sector, was 27.8% in 1995 and 23.8% in 2023.

Figure 2.11 – Final energy consumption per unit of GDP (chain linked volumes, reference year 2020, upper graphs; current prices, purchasing power standards, lower graphs). For each country the bars on the right graph refer to 1995, 2005, 2020, and 2023 values. Data in ascending order of 2023 value. OC – Other countries.



European countries show a wide range of electrification of final energy consumption (energy uses only), ranging from 14.3% in Latvia to 39.2% in Malta in 2023. Italy is below the EU27 average with 22.2% *vs* 22.9%. Among the biggest countries, Sweden, France, and Spain have higher levels of electrification than Italy, respectively 33.2%, 26.6%, and 24.7%. At the lowest end there are Romania and Poland with 15.3% and 16.6% respectively.

Figure 2.12 – Share of final electricity consumption in total final energy consumption in EU27 countries (2023).

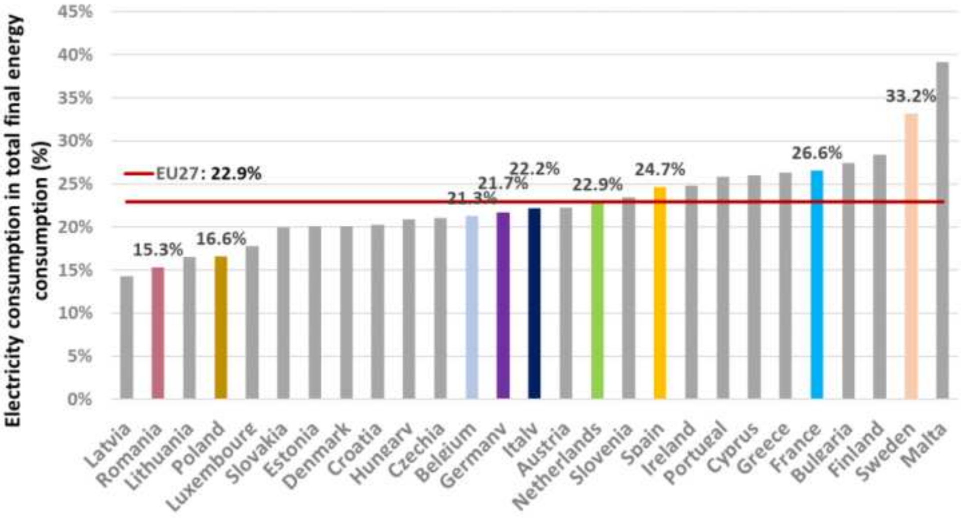
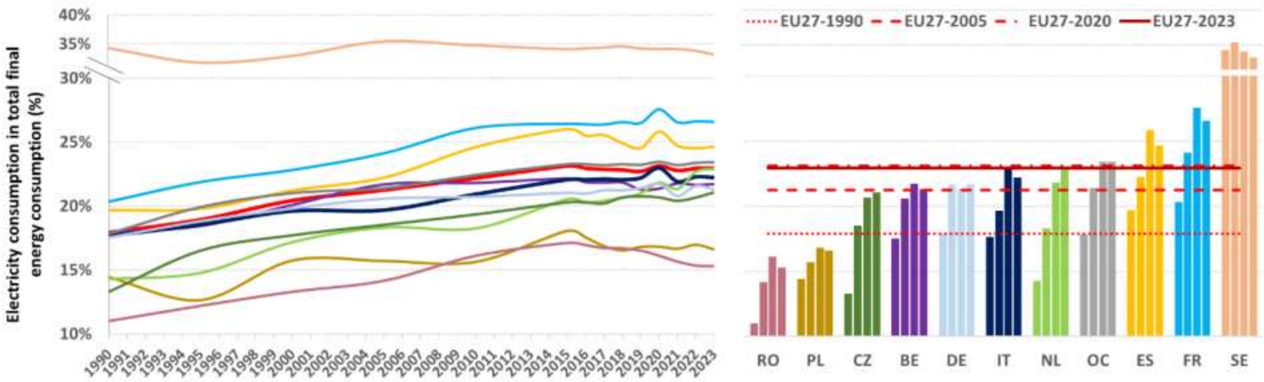


Figure 2.13 shows the increasing trends of electrification in almost all the European countries except Sweden whose highest level is quite constant and slightly downward in the last years.

Figure 2.13 – Trend of final electricity consumption share in total final energy consumption. For each country the bars on the right graph refer to 1990, 2005, 2020, and 2023. Data in ascending order of 2023 value. OC – Other countries.



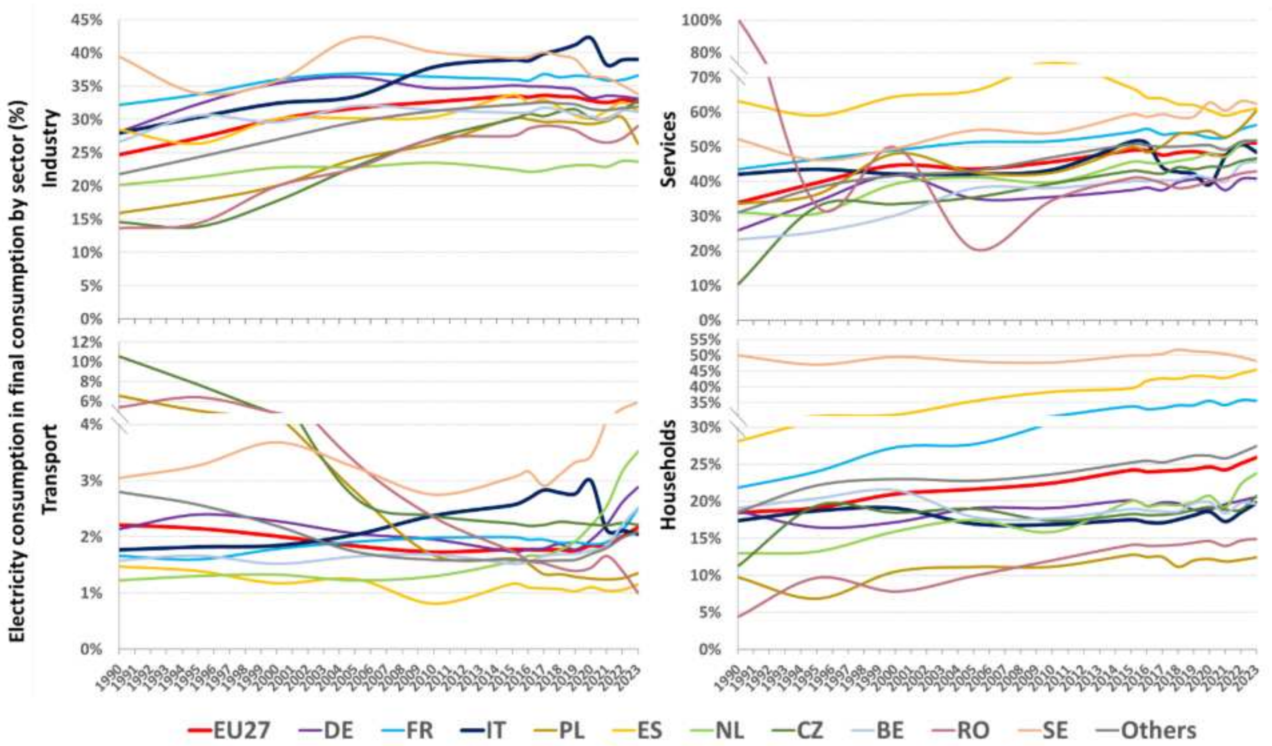
At sectoral level, the Member States' electrification shows different shares although with a common growing trend. The electrification of industry in Italy (39% in 2023) is the highest among the biggest countries and much higher than EU27 average (32.6%). The sharp boost of industry electrification recorded in Poland, Czechia, and Romania is particularly interesting. These countries are approaching the EU27 average. Equally notable is the reduction recorded in Germany from 36.4% in 2005 to 33.1% in 2023. The electrification of final consumption in the most carbon intensive sector, such as industry, is an important strategy to mitigate GHG emissions if pursued with renewable electricity production.

Services show the highest percentages of electrification among sectors. The Italian share in 2023 is 48.4%, lower than the EU27 average (51.2%). Among the largest countries, Sweden, Spain, and Poland have the highest electrification shares in services, higher than 60%, although in Spain there has been a sharp reduction since 2010, when the share of electricity consumption was 73.8%. The share in France is 56.3%. Germany and Romania are at the lower end with 40.8% and 43% respectively.

The electrification of Italian households is much lower than the EU27 (19.8% *vs* 25.9% in 2023). Among the largest countries, Sweden (48.2%), Spain (45.4%), and France (35.7%) have the highest electrification shares in households. At the lowest end there are Romania (14.9%) and Poland (12.5%).

The transport sector shows the lowest percentages of electrification. The EU27 average in 2023 is 2.2% and among the biggest countries the highest percentages are in Sweden (5.8%) and the Netherlands (3.5%). The Italian value is 2%. Electricity consumption in the mobility sector has been limited so far to public transport (train, tram, metro), while for private mobility the electricity still plays a marginal role. The decline in the electrification rate in Poland, Czechia and Romania is explained by the strong growth of final consumptions in this sector, especially due to road transport, and decreasing consumptions of electricity as consequence of decrease of public transport demand.

Figure 2.14 – Trend of final electricity consumption share in total final energy consumption by sector.



The share of electricity consumption by sector can provide insights on the emission mitigation performance of each sector reading the figures together with consumption of renewable energy by sector and above all with the role of renewable source for electricity production and consumption (Figure 2.15).

Figure 2.15 – Share of renewable electricity production in the EU27 countries (2023).

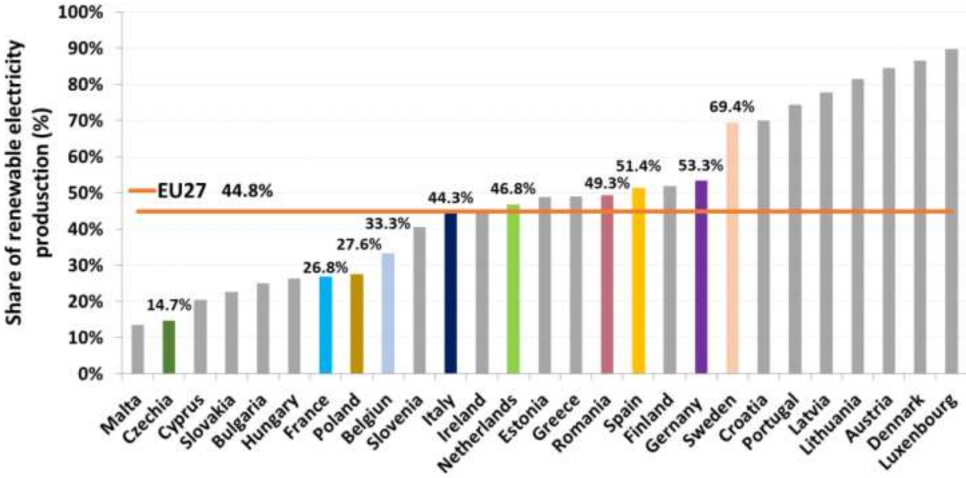
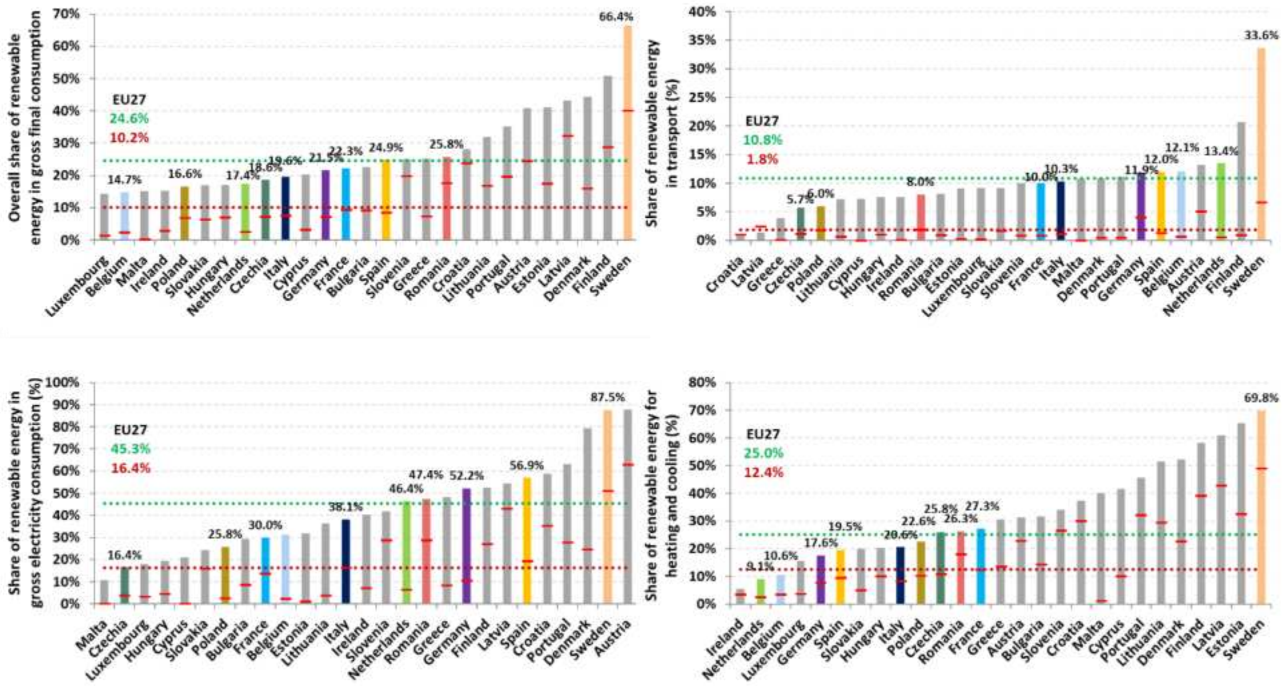


Figure 2.16 shows the overall and sectoral shares of renewable energy recorded in 2023 in the EU27 countries according to the Directive (EU) 2018/2001. The EU27 average share of renewable energy in gross final electricity consumption has more than doubled from 2005 to 2023 (16.4% *vs* 45.3%). Italy overall share is well below the European average (19.6% vs 24.6%). This indicator is crucial to follow the achievement of European target of renewable share in 2030.

Figure 2.16 – Share of renewable energy in the EU27 countries (2023) according to Directive (EU) 2018/2001. The red dash on the bars is the country's 2005 level. The red and green dotted lines are the EU27 average respectively in 2005 and 2023.



The main countries consume 78% of EU27 renewable gross final electricity in 2023. Such outcomes show that the electrification of the final consumption in the biggest countries, such as Germany, France, Italy, Spain, and Sweden, involve a significant contribution to the mitigation of GHGs in Europe. The mentioned countries collectively account 65% of EU27 renewable gross final electricity consumption.

2.1.2 GHGs and energy consumption

Italy's average GHGs per capita from 1990 to 2023 is 8.7±1.3 t CO_2eq (ISPRA, 2025a). In 2023 the GHGs per capita came back to 6.5 t CO_{2eq}. Italian GHGs per capita have always been below the European average (6.9 t CO_2eq in 2023).

Apart for Italy and Spain, the trend of GHGs reductions in the other countries began as early as 1990. GHGs per capita in Spain increased with higher rate than in Italy until 2005, when the GHGs per capita of the two countries reached the same level. After 2005 a downward trend is observed also for Italy and Spain. Sweden has the lowest GHGs per capita, while at the other end there is Poland: the range goes from 4.2 to 9.5 t CO_2eq per capita.

Figure 2.17 – GHGs per capita. For each country the bars on the right picture are 1990, 2005, 2020, and 2023 values. Data in ascending order of 2023 value. OC – Other countries.

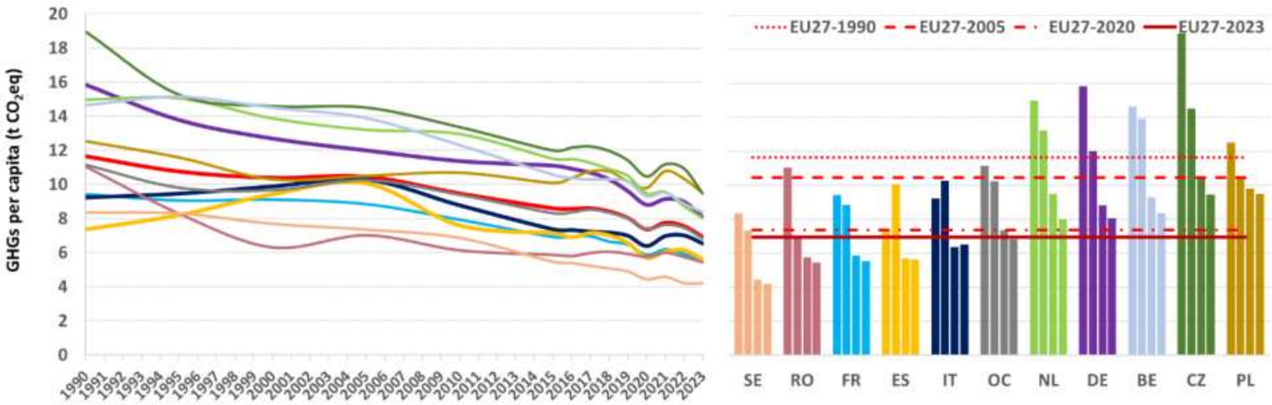
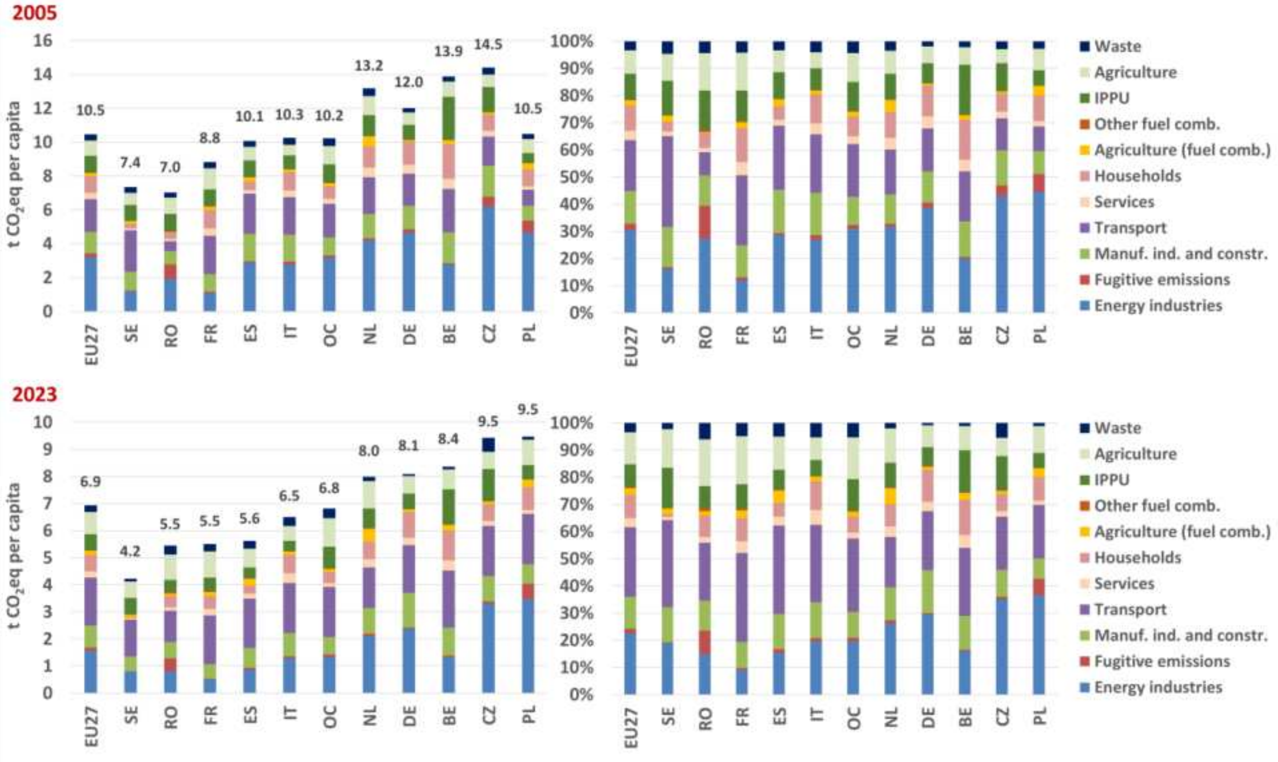


Figure 2.18 shows the GHGs per capita by sector in 2005 and 2023. The allocation by sector of countries' emissions is very heterogeneous depending upon the peculiarity of the energy system of each country, with its own ratio between energy consumed for transformation and final users. Energy industries and transport are the sectors with the highest shares in EU27 in 2023, 22.5% and 25.6% respectively. In 2005 the EU27 share of energy industries was 30.5%, while transport was 18.6%.

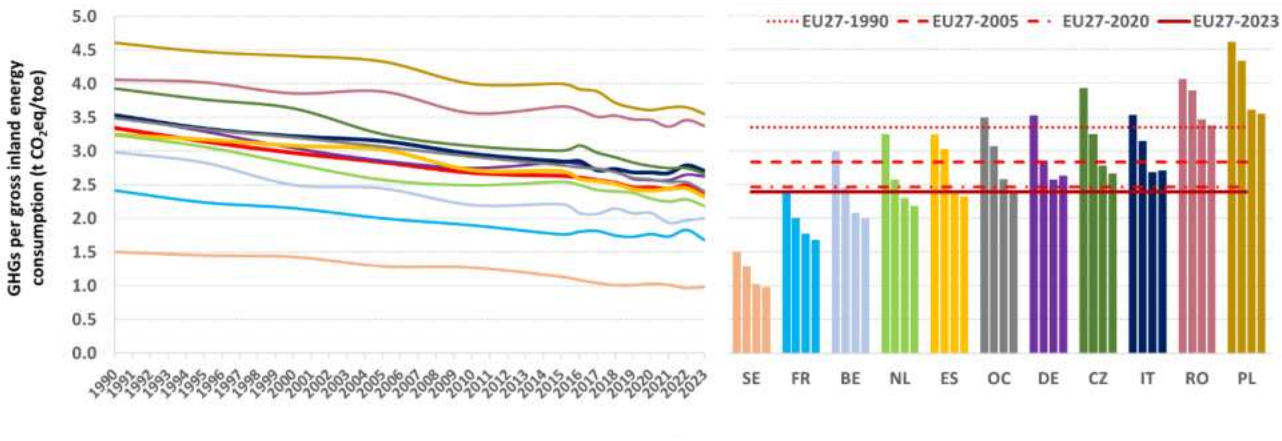
The range is very wide in the countries. In 2023 the share of GHGs per capita by energy industries goes from 9% in France to 36.6% in Poland, while transport goes from 18.6% in the Netherlands to 32.8% in France.

Figure 2.18 – GHGs per capita by sector in 2005 and 2023 (left), and share (right). Data of MSs in ascending order of GHGs per capita in 2023. OC – Other countries.



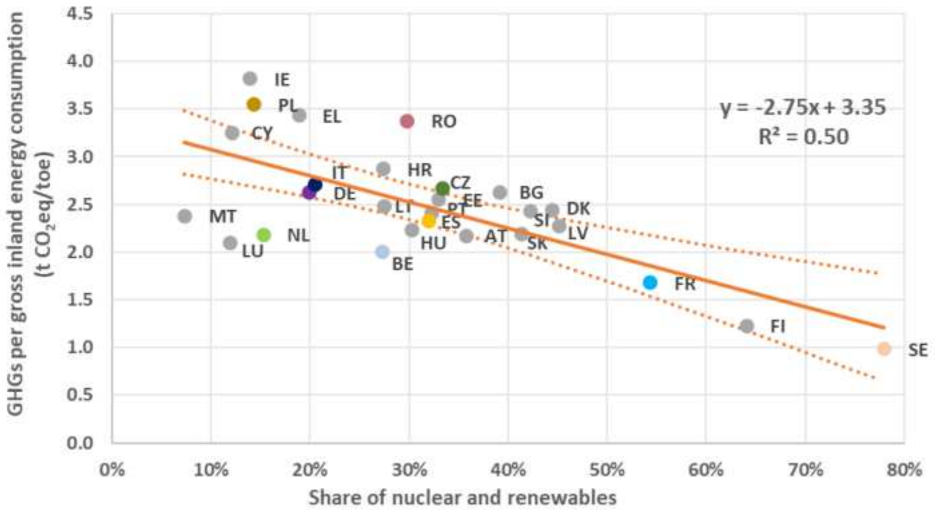
GHGs by energy consumption, carbon intensity, decreased in all countries since 1990. Such indicator is sensible to the country's energy mix. It should be considered that sources of energy, as renewables and nuclear heat, do not contribute to GHG emissions, so countries with higher share of such sources are more likely to have low carbon intensity. Moreover, the share of net imported electricity plays a positive role in reducing the indicator, because the emissions to generate such electricity are allocated to the countries which produce it. The country economy structure is another relevant factor to be considered to correctly read such indicator. The industry activities are more energy consuming than service activities. Carbon intensity of Italy is higher than the European average (2.71 t CO_2eq/toe *vs* 2.39 t CO_2eq/toe in 2023; Figure 2.19), also for the contribute of nuclear power in Europe. Unbundling nuclear power from gross inland consumption in the European countries, Italy's value is just below the EU27 average (2.71 t CO_2eq/toe *vs* 2.72 t CO_2eq/toe in 2023).

Figure 2.19 – GHGs per gross inland energy consumption. For each country the bars on the right picture are 1990, 2005, 2020, and 2023 values. Data in ascending order of 2023 value. OC – Other countries.



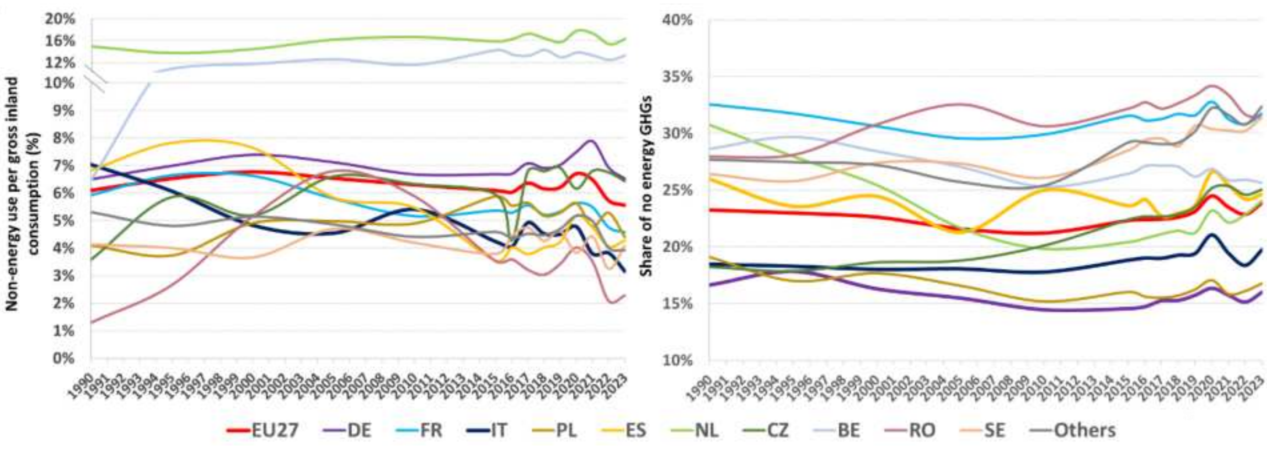
Countries with lower carbon intensity than Italy have higher share of renewable and nuclear energy with the only exception of the Netherlands, whose share for such sources is lower than the Italian one (15.3% of which 1.4% nuclear in the Netherlands vs 20.5% of renewables with no nuclear energy in Italy 2023). Carbon intensity is inversely correlated with energy sources without GHGs emission, even though other factors, as specific fossil fuel mix or the share of non-energy consumptions and emissions, explain the distance of some countries from the upper and lower 95% confidence intervals of the linear regression (Figure 2.20).

Figure 2.20 – Linear regression with upper and lower confidence interval (95%) between GHGs per gross inland energy consumption and share of nuclear and renewable energy.



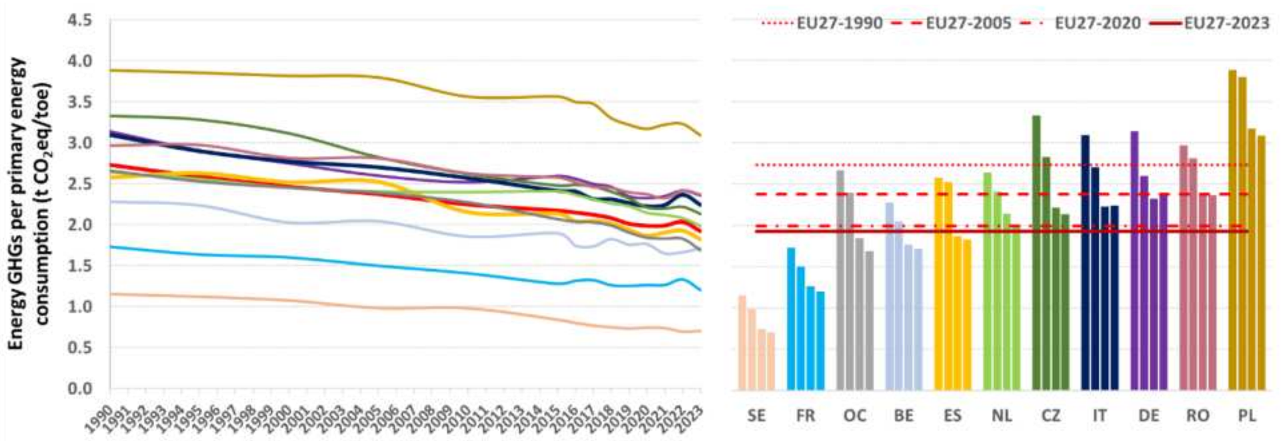
The carbon intensity indicator should be read considering the non-energy consumption in the energy mix, as well as the no energy GHG emissions (Figure 2.21). The share of non-energy consumption in the Netherlands or Belgium are significantly higher than in Italy, which is one of the lowest share. While primary energy consumption has a direct relationship with GHGs, the same is not true for non-energy uses. These consumptions include industrial processes in sectors such as the petrochemical, pharmaceutical, etc., where oil and its products are not used as fuels for combustion, but for transformation into other products. Moreover, the role of no energy GHGs must be considered along with large source of GHGs, as waste and agriculture, not related to energy consumption. The GHGs from no energy sectors show a wide range in the European countries with an average for EU27 of 23.9% in 2023. Among the countries here considered the range goes from 16% in Germany to 31.4% in Sweden and Romania; the Italian share is 19.7%.

Figure 2.21 – Shares of no energy use per gross inland energy consumption and no energy GHGs.



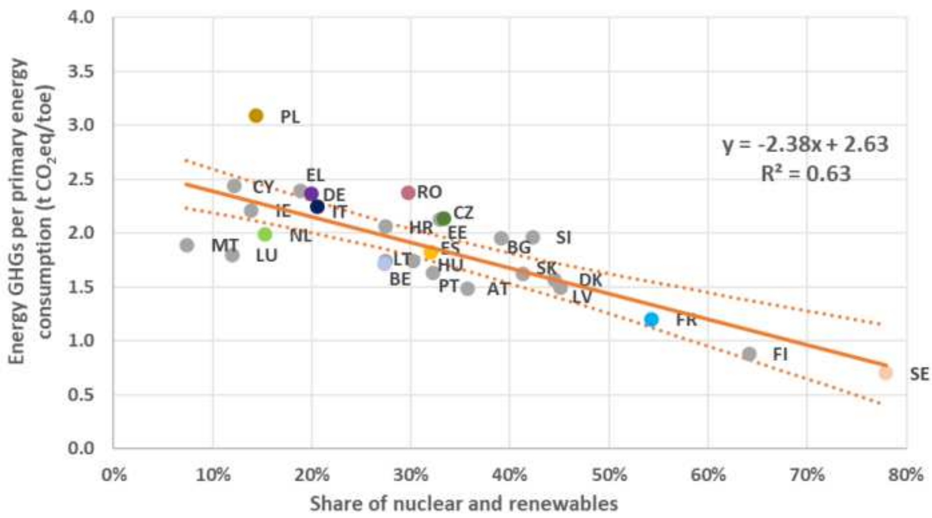
The comparison of decarbonization indicators among countries with significantly different shares of no energy uses and no energy GHGs can be corrected by considering the energy GHGs per unit of primary energy consumption: primary energy carbon intensity. This indicator highlights the decarbonization of a Country's energy sector. According to this indicator the intensities of the Netherlands and Italy are closer than what the carbon intensity for total energy consumption has shown. The primary energy carbon intensity of Germany is higher than the Italian one also because of the lower share of no energy GHGs in Germany (16%) than in Italy (19.7%).

Figure 2.22 – Energy GHGs per primary energy consumption. For each country the bars on the right picture are 1990, 2005, 2020, and 2023 values. Data in ascending order of 2023 value. OC – Other countries.



The linear regression between energy GHGs per primary energy consumption (Figure 2.23) is stronger than the previous one shown in Figure 2.20, with countries nearer to the upper and lower 95% confidence intervals, as such distance is fully explained by the energy mix of fuels used for combustion.

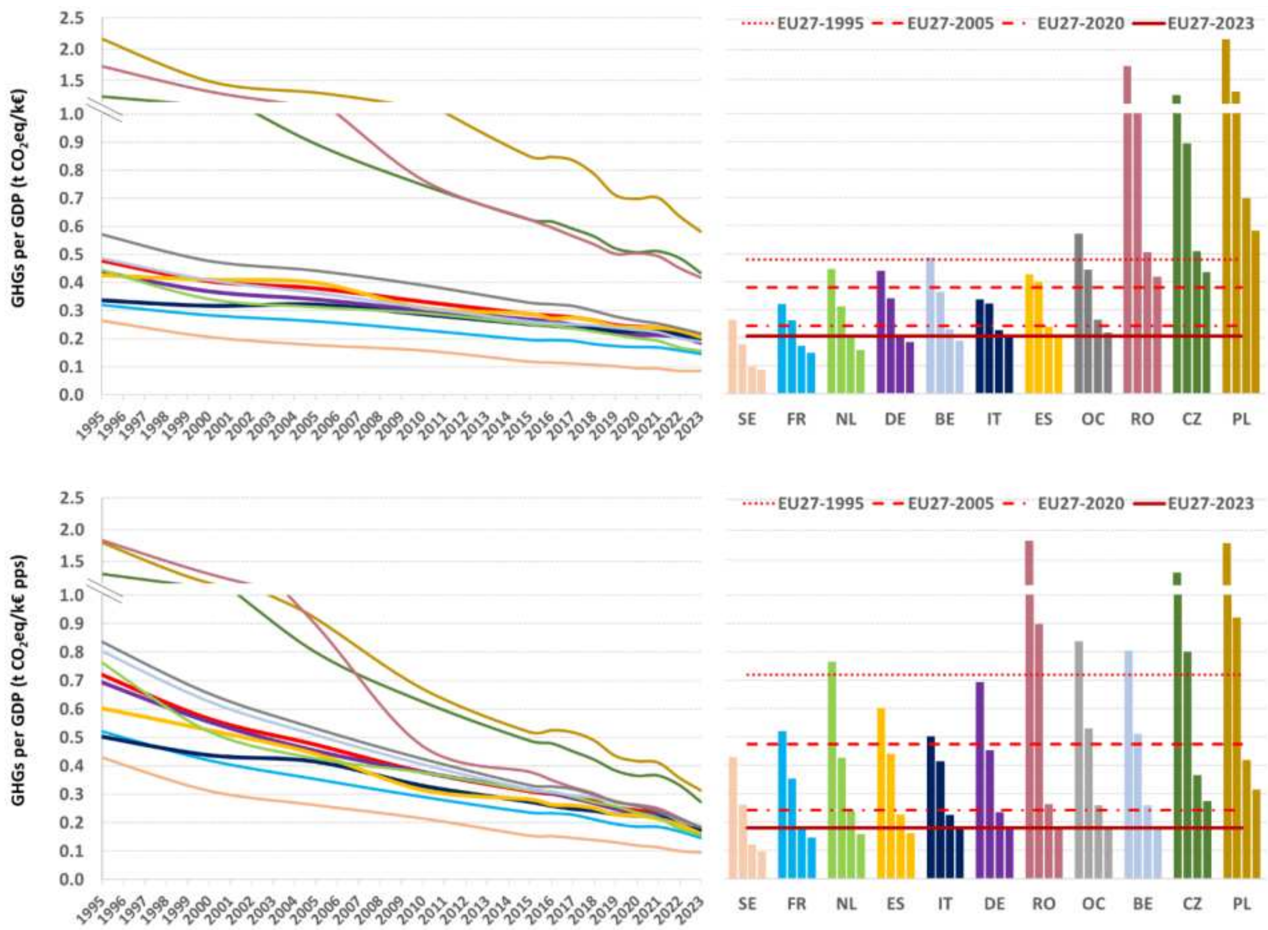
Figure 2.23 – Linear regression with upper and lower confidence interval (95%) between energy GHGs per primary energy consumption.



The ratio between GHGs and gross domestic product is the carbon intensity of economy. Such indicator is sensible to the country's energy mix, like the carbon intensity of energy, and even more sensible to economy structure: share of services and industry. Moreover, it should be considered that countries' GDP is also driven by activities linked to international bunkers, whose emissions are memo items in the emissions inventories submitted to UNFCCC and not considered in the national emissions statistics. The following graphs (from Figure 2.24 to Figure 2.26) do not include memo items. The role of such items will be considered in the next paragraph. All European countries reduced the carbon intensity of economy and Italy's figures, considering chain linked volumes GDP, have always been below the EU27 average, but in the last years the trajectories are approaching. In 2023 Italy and EU27 values are 0.2 t CO_2eq/k€ and 0.21 t CO_2eq/k€, respectively. The same pattern is confirmed considering purchasing power standards GDP (0.17 t CO_2eq/k€ in Italy *vs* 0.18 t CO_2eq/k€ in EU27). Sweden and France have the lowest values: 0.09 t CO_2eq/k€ and 0.15 t CO_2eq/k€, respectively (chain linked volumes). Poland and Czechia are at the upper end with 0.58 t CO_2eq/k€ and 0.44 t CO_2eq/k€, respectively (chain linked volumes).

The reduction since 1995 for EU27 is -56.8% and ranges from -40.5% for Italy to -75.8% for Romania with chain linked volumes, while considering purchasing power standards EU27 reduced by -74.9% spanning from -65.5% for Italy to -90% for Romania. The reasons of such reductions are manifold and concern both the common increase in efficiency of industry and the increasing share of value added from services, whose carbon intensity is far lower than those of manufacturing industries.

Figure 2.24 – GHGs per GDP (chain linked volumes, reference year 2020, upper graphs; current prices, purchasing power standards, lower graphs). For each country the bars on the right picture are 1995, 2005, 2020 and 2023 values. Data in ascending order of 2023 value. OC – Other countries.



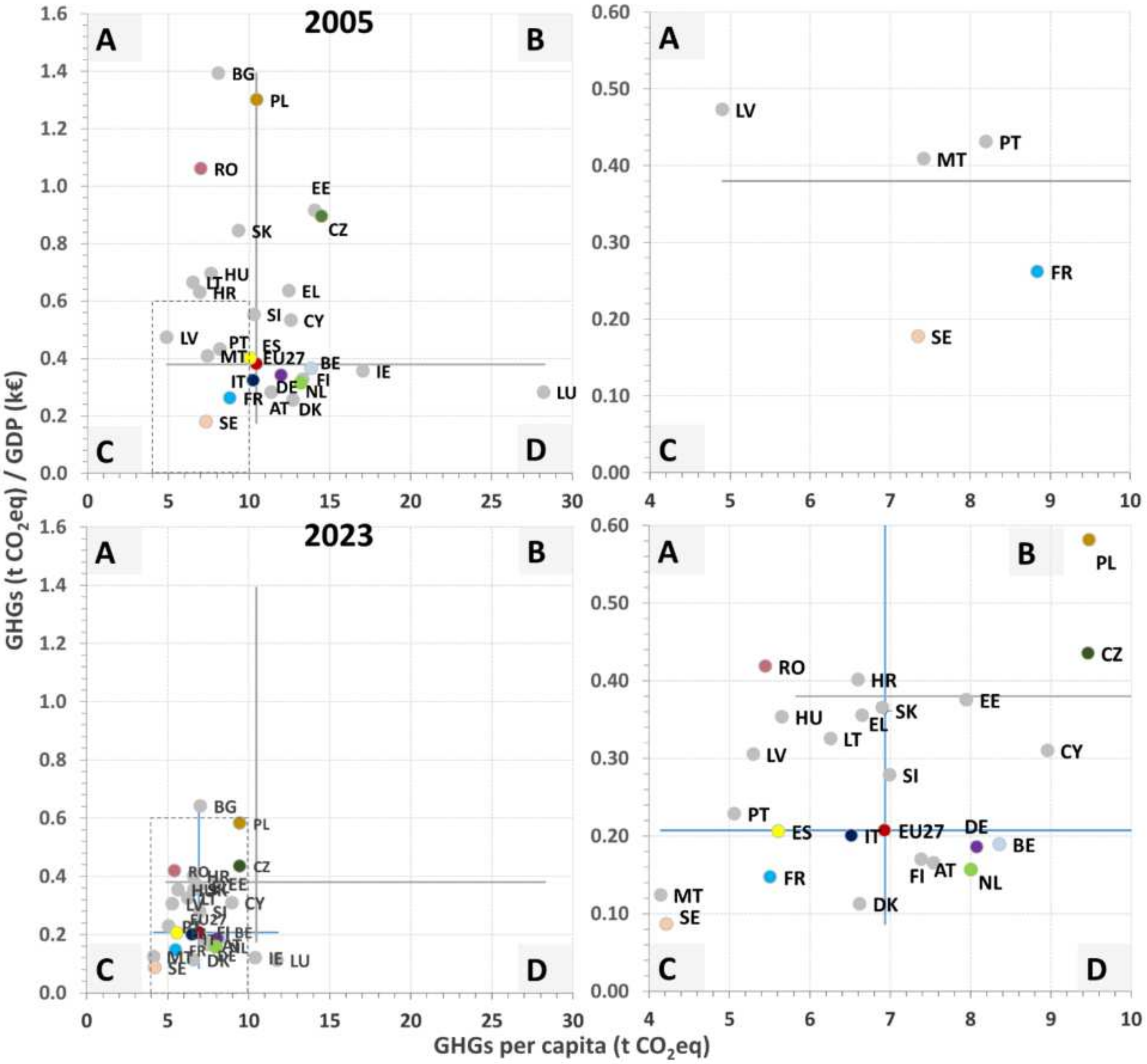
The following graphs show how the countries "moved" in the phase space defined by GHGs per capita and GHGs per unit of GDP from 2005 to 2023 (chain linked volumes, reference year 2020). EU27 average is the centroid of the countries' cloud. The crossed axes on EU27 value separate four quadrants with different performances. The pictures on the right are the zoomed box which inscribes the biggest Member States in 2023. In the quadrant C, at the bottom left corner, there are the best performing countries with lower GHGs per capita and lower GHGs per GDP than EU27 average, while in the quadrant B, at the upper left corner, there are the worst performing countries, with higher GHGs per capita and higher GHGs per GDP than EU27 average. The countries' cloud became more and more "concentrated" moving toward the bottom left corner. France, Sweden, and Italy were in the quadrant C since 2005 (Figure 2.25). In 2023 Spain is on the verge of quadrants A and C, while the Poland and Czechia are fully in the quadrant B. Germany, Belgium, and the Netherlands are in the quadrant D, with higher GHGs per capita but lower GHGs per GDP than EU27 average.

The distance that each country travelled since 2005 in the phase space along the bottom left direction provides a measure of the progress made in the decarbonization process. The distance of two points in the two-dimension Euclidean space, P = (p_x , p_y) and Q = (q_x , q_y), is calculated as:

$$\sqrt{(p_x - q_x)^2 + (p_y - q_y)^2}$$

Among the examined countries, Belgium and the Netherlands travelled the longest distances, followed by Spain, Czechia, and Germany. Poland and Romania moved the shortest distances reducing significantly the GHGs per GDP with only slight decrease of GHGs per capita.

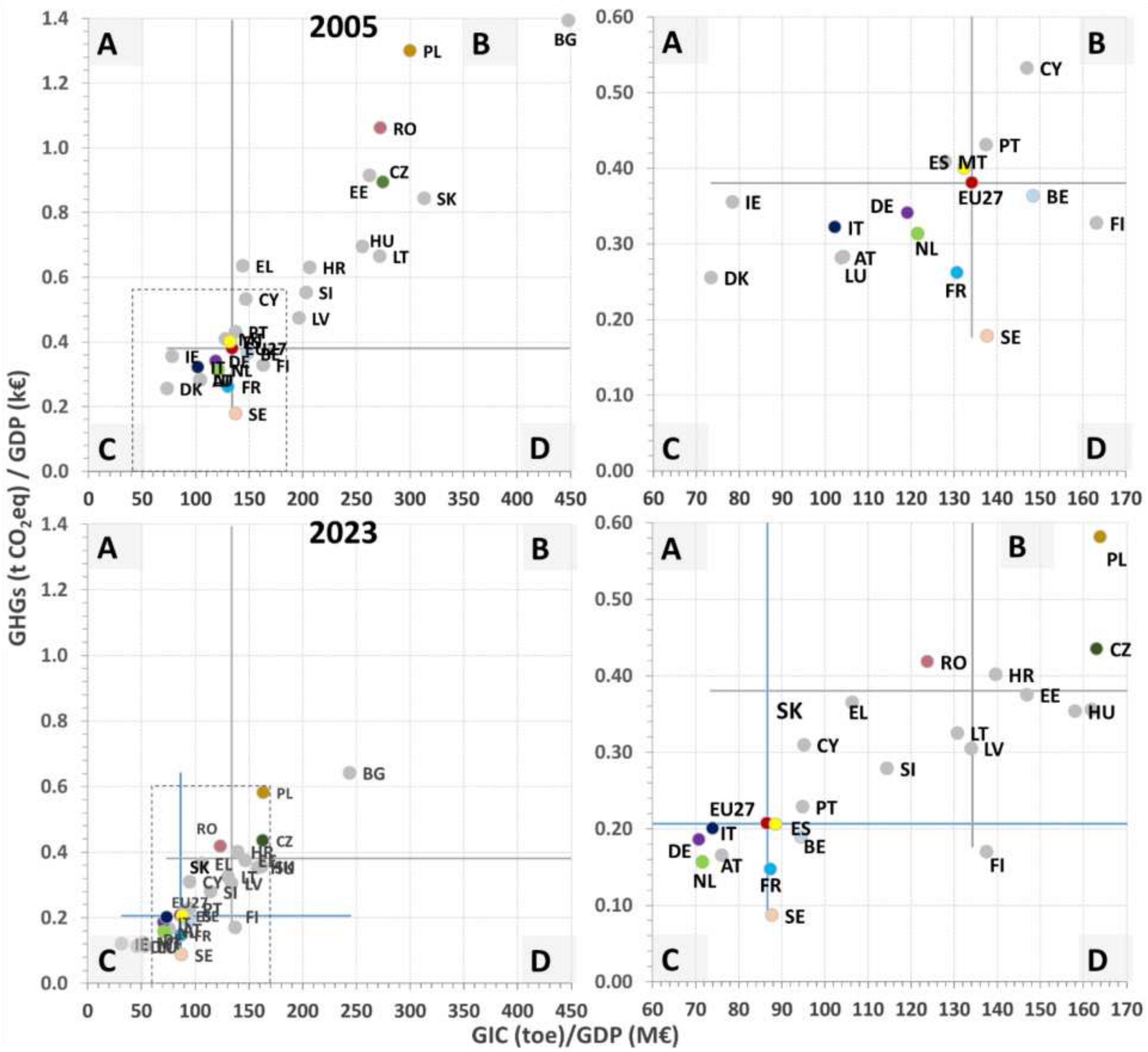
Figure 2.25 – In the phase space defined by emissions per capita (abscissa) and economy carbon intensity (ordinate) is shown the position for each Member State on the left. On the right it is shown the enlarged box that inscribes the biggest Member States in 2023. The grey axes in the bottom graphs are those plotted in 2005.



Even more interesting is the positioning of countries in the space defined by GHGs per GDP and gross inland energy consumption per GDP (Figure 2.26). In such picture both abscissa and ordinate report intensities indicators giving a portray of the efficiency and decarbonization of economy. Broadly speaking, the efficiency improves using less energy per GDP (moving on the left of x-axes), while decarbonization improves with less GHGs per GDP (moving on the bottom of y-axes).

Among the examined countries only Poland, Czechia, and Romania are still in the quadrant B with the worst performances in 2023, although travelling in this phase space longer distances than any other countries since 2005. On the other end Italy travelled the shortest distance. Such phase space makes clear how Germany and other countries, as Spain and the Netherlands, approached, and in some cases overcame, Italy from 2005 to 2023.

Figure 2.26 – In the phase space defined by economy energy intensity (abscissa) and economy carbon intensity (ordinate) is shown the position for each Member State on the left. On the right it is shown the enlarged box that inscribes the biggest Member States in 2023. The grey axes in the bottom graphs are those plotted in 2005.



GHGs per capita, energy and carbon intensities by economy show that Italy had some of the lowest values since 2005 and the biggest countries gradually moved toward the quadrant that Italy, together with few other countries, occupied already in 2005.

The comparison of indicators among Italy and the biggest EU27 countries shows that Italy has historically high energy efficiency with a significant share of renewable energy and natural gas in the energy mix, and GHGs per capita lower than EU27 average. The gross energy intensity per GDP in Italy is among the lowest in EU27, while carbon intensity per GDP is just below EU27 average and very close to values recorded in Germany and Spain, among the biggest countries. The carbon intensity per gross energy consumption is lower in EU27 than Italy because of the significant share of nuclear heat in many European countries. Many countries have improved their GHG emissions performance compared to GDP, sometimes achieving better results than Italy. The historical pattern of GHGs emissions by country, GHGS per capita as well as carbon and energy intensities by GDP, should be considered setting the targets for emissions reduction by country, as well as in the negotiation processes.

The indicator of carbon intensity per GDP need further details that will be examined in the next paragraph.

2.1.2.1 International bunkers

The decarbonization and efficiency indicators with GHGs from international bunkers (international flights and shipping) require a premise on the composition of national emission inventories and energy balance.

GHG emissions inventories submitted to the UNFCCC Secretariat include emissions from international aviation and maritime activities. Such emissions, although methodologically consistent with IPCC guidelines (2006), are reported as "memo" items and are not included in total national emissions.

Similarly, for energy consumption, the items that make up a country's gross inland energy consumption must be considered in relation to GHGs from international bunkers. In Eurostat's energy balance, gross inland energy consumption includes the consumption of international aviation but not those of international maritime activities.

In particular, the main items in the budget can be explained by the following equations:

GAE= PPRD + RCV_RCY + IMP – EXP + STK_CHG (1)

where

GAE: gross available energy;

PPRD: primary production;

RCV_RCY: recovered or recycled products;

IMP: import;

EXP: export;

STK_CHG: stock changes.

GIC = GAE – INTMARB (2)

where

GIC: gross inland energy consumption;

INTMARB: international maritime bunkers;

NRGSUP = GIC – INTAVI (3)

where

NRGSUP: total energy supply;

INTAVI: international aviation;

AFC = NRGSUP – (TI_E – TO) – NRG_E – DL (4)

AFC = FC_E + FC_NE (5)

where

AFC: energy available for final consumption;

TI_E: transformation input of energy:

TO: transformation output;

NRG_E: energy consumption in the energy sector;

DL: distribution losses;

FC_E: energy uses of final energy;

FC_NE: non-energy uses of final energy.

Equations (2) and (3) show that in the gross inland energy consumption is not considered the energy consumption by international maritime bunkers, while the consumption by international aviation is included. Therefore, a decarbonization indicator that considers total emissions reported in the inventories should be the ratio between GHGs to total energy supply (NRGSUP), as both terms are without international bunkers. Similarly, decarbonization indicators can be drawn up with gross inland energy consumption (GIC) or with gross available energy (GAE) considering the international aviation in the first case and of all international bunkers in the second case.

The energy available for final uses (AFC) includes energy and non-energy uses. The former component is directly related to GHGs from combustion, while the latter is involved in transformation processes not directly related to atmospheric emissions. Final uses consist of total energy without transformation losses, energy branch sector consumption and distribution losses.

This report has not the aim to examine in detail the components of gross domestic product, but in the first approximation it can be considered that GDP is also determined by activities related to international aviation and international navigation.

The biggest European countries have very different share of GHGs from international bunkers. The GHGs from such sectors are very notable in some countries: the EU27 average in total GHGs with bunkers in 2023 is 7.3%. For the biggest countries, it ranges from 0.3% in Romania to 23.5% in the Netherlands.

In the light of such different contributions, it is reasonable to investigate the dynamics of decarbonization and efficiency indicators considering the role of international bunkers. Carbon intensity per gross domestic product and carbon intensity per energy consumption will be considered. The GHGs in such indicators include the emissions by international bunkers. The first indicator is equal to the ratio between GHGs and gross domestic product (GDP). The second one is equal to the ratio between energy GHGs and gross available energy (GAE), without final consumption for non-energy uses (FC_NE): such measure can be defined as gross available primary energy. Regarding the efficiency indicator, carbon and energy intensities will be calculated through the ratio between gross available energy (GAE) and gross domestic product (GDP).

Figure 2.27 – Share of national GHGs in the inventories and international bunkers GHGs (2023 data). Countries in descending order of international bunkers GHGs share.

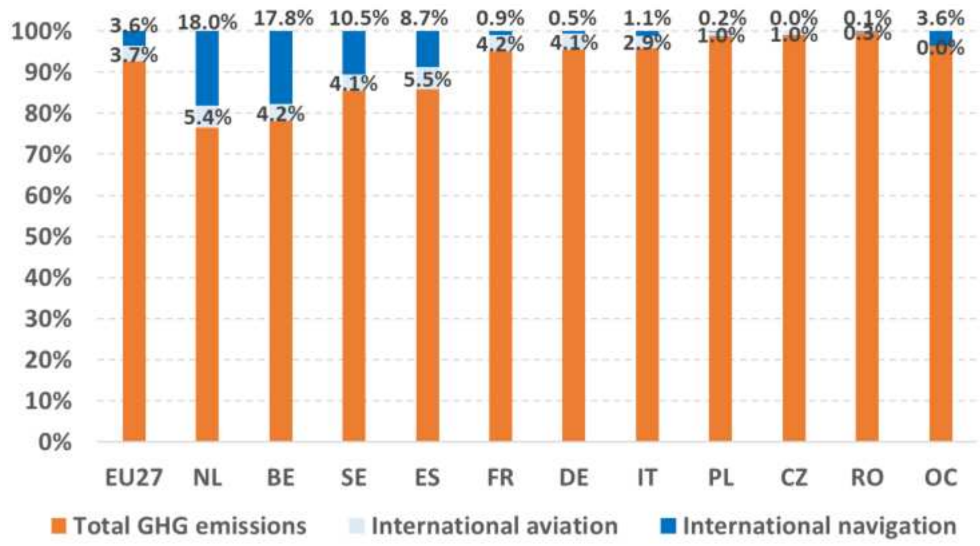
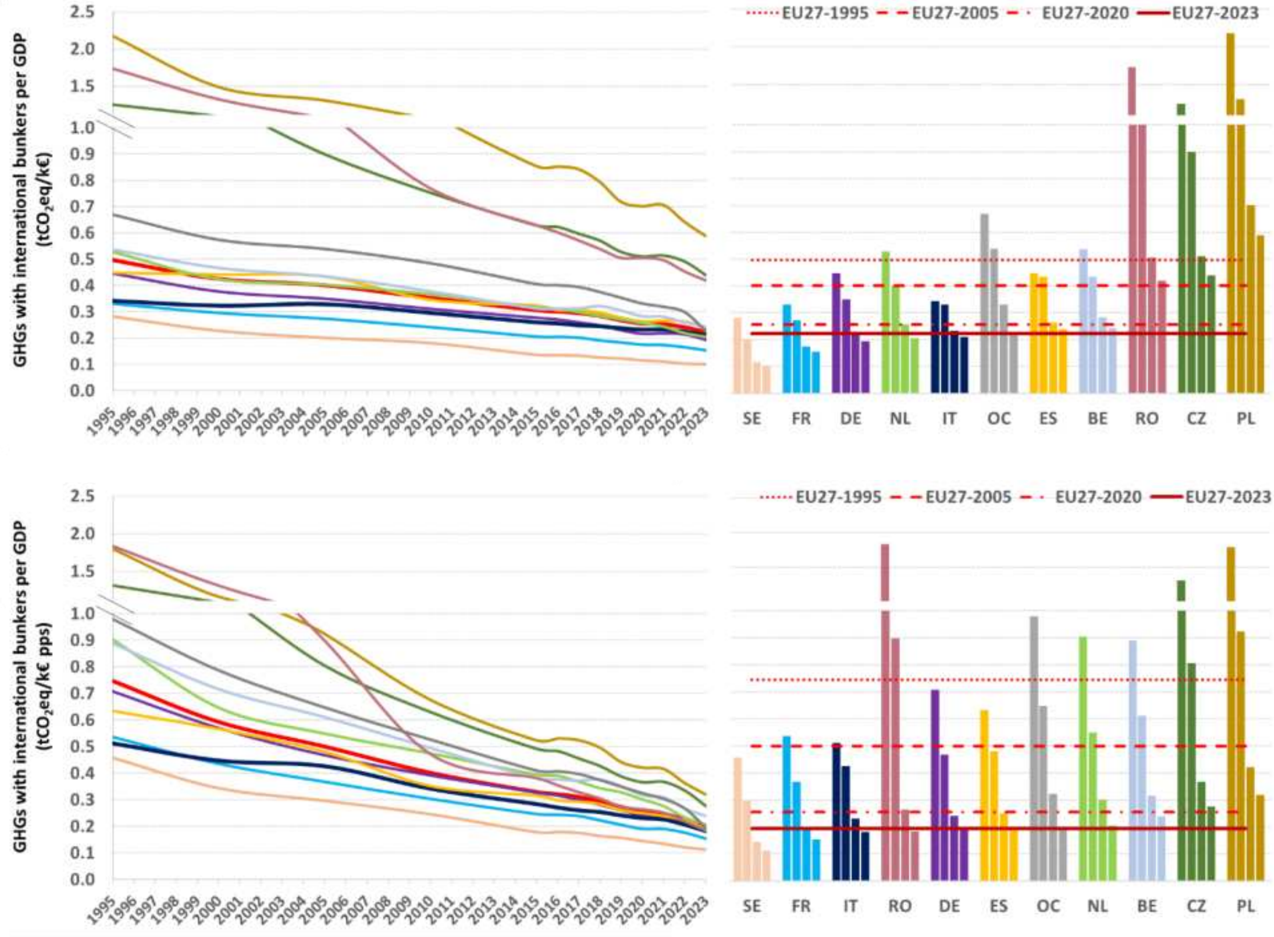


Figure 2.28 shows the GHGs per GDP and should be compared with Figure 2.24. The indicator highlights the role of international bunkers because where GHGs from such activities have a significant share, as in Belgium and the Netherlands, the carbon intensity is significantly higher than without such GHGs. Whereas in Figure 2.24 the intensities of Belgium and the Netherlands are quite below the EU27 average,

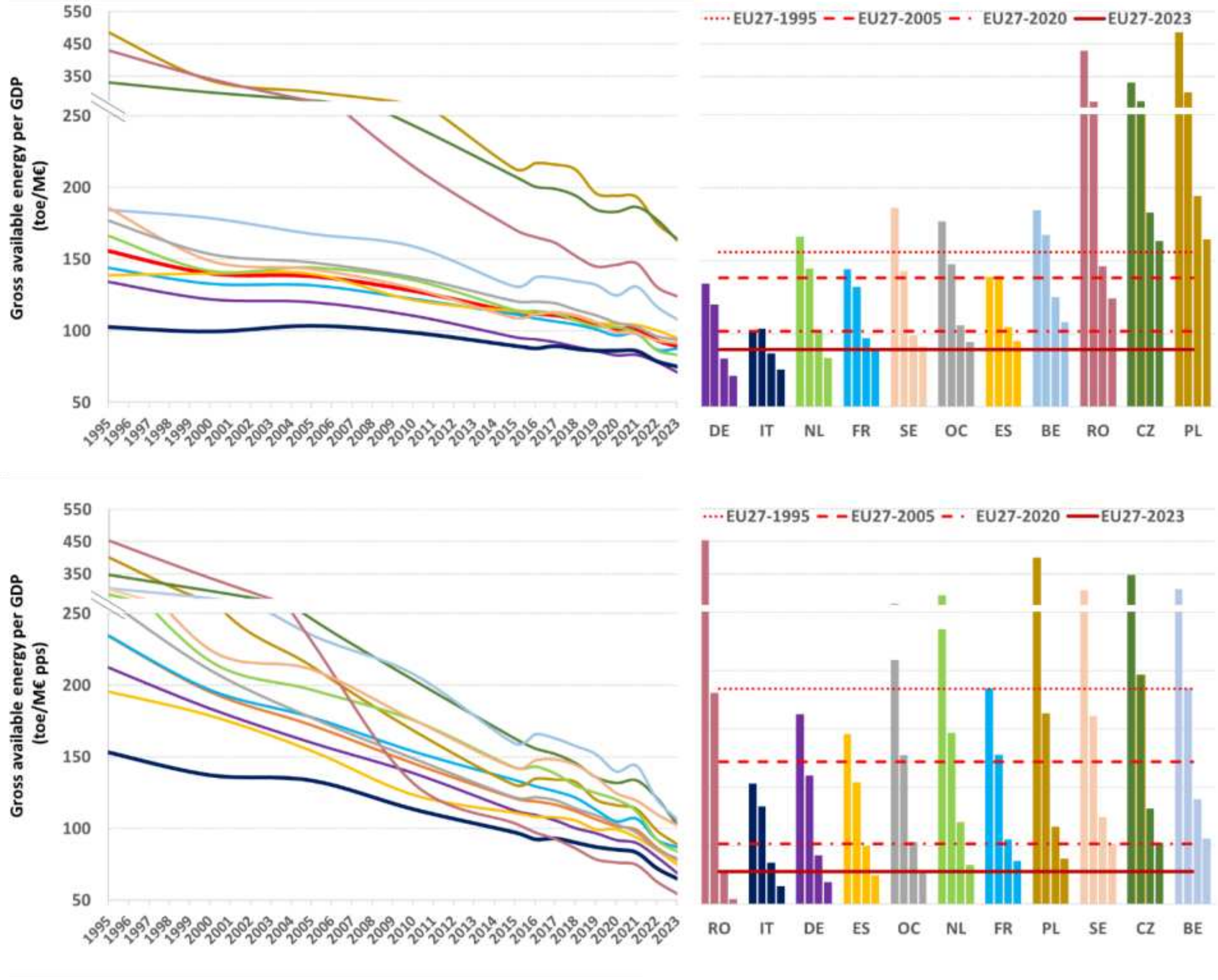
in Figure 2.28 the intensity of Belgium is higher than the European average and the intensity of the Netherlands is closer to the EU27 average. This indicator changes the countries' ranking, mainly considering the purchasing power standards GDP. According to such metric, Italy's carbon intensity is only higher than those recorded in France and Sweden, where the role of energy with zero GHGs (nuclear energy in both countries and bioenergy in Sweden) is notable.

Figure 2.28 – GHGs with international bunkers per GDP (chain linked volumes, reference year 2020, upper graphs; current prices, purchasing power standards, lower graphs). For each country the bars on the right picture are 1995, 2005, 2020, and 2023 values. Data in ascending order of 2023 value. OC – Other countries.



The gross available energy per unit of GDP shown in Figure 2.29 (cf. Figure 2.9) confirms the proximity of Italy and Germany with lowest values among the largest countries. The relevant amount of energy consumed by international bunkers in the Netherlands and Belgium moves the energy intensity per GDP of these countries towards higher values than that shown in Figure 2.9.

Figure 2.29 – Gross available energy per GDP (chain linked volumes, reference year 2020, upper graphs; current prices, purchasing power standards, lower graphs). For each country the bars on the right picture are 1995, 2005, 2020, and 2023 values. Data in ascending order of 2023 value. OC – Other countries.



2.1.2.2 Sectoral efficiency and decarbonization

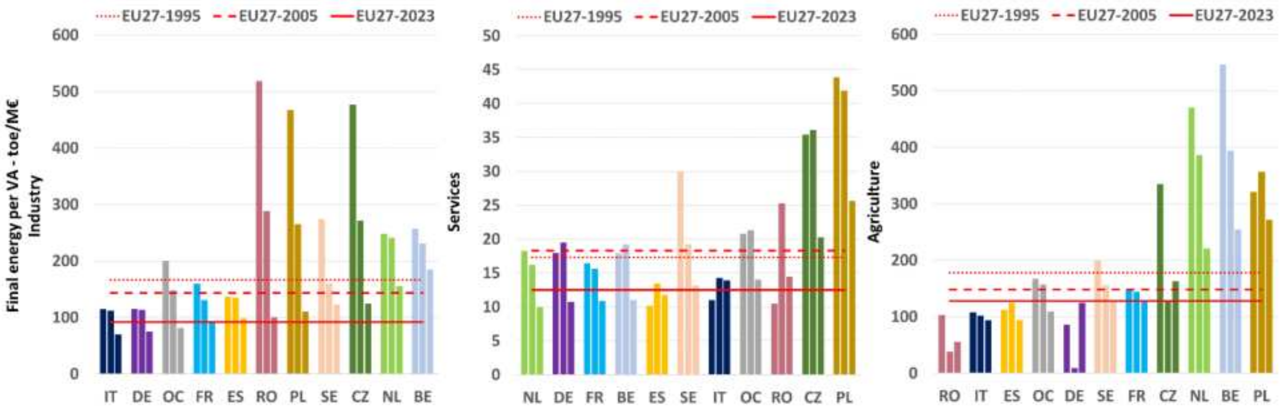
The comparison of efficiency and decarbonization indicators at sectoral level among Member States shows a rather heterogeneous picture. The chain linked volumes with reference year 2020 has been used for value added by sector. Figure 2.30 compares the final energy intensity in 1995, 2005, and 2023 in the examined countries for the industry, services, an agriculture.

The final energy intensity in Italian industry, ratio between final energy consumption and value added, has always been the lowest among the biggest countries, together with Germany, both countries with decreasing trends. In 2023 only Ireland, Denmark, and Malta have lower industry energy intensities than Italy. Among the countries examined the Netherlands and Belgium show the highest energy intensities for industry. The sector energy intensity in Italy decreased with an average annual rate of -2.6% from 2005 to 2023, while the European average is -2.4%.

In commercial and public services Italy shows an intensity higher than the European average in 2023. Italy is the only country, among the biggest ones, whose energy intensity in this sector did not decrease so much since 2005. The outcome is also due to the accounting of energy consumed by heat pumps, whose data accounting in Eurostat started since 2017 for Italy, although previously present. The accounting of such item in 2005 would have set higher energy intensity. Countries as France and Germany regularly reported energy consumed by heat pumps since 2005. Anyway, with available data the average annual rate of energy intensity from 2005 to 2023 decreased by -0.1% in Italy *vs* -2.1% in EU27.

The agriculture sector shows a general decrease of energy intensity in EU27. In 2023, among the considered countries, only Romania has lower energy intensity than Italy. The average annual rate of energy intensity from 2005 to 2023 decreased of -0.5% in Italy *vs* -0.8% in EU27.

Figure 2.30 – Final energy consumption per value added in 1995, 2005 and 2023. Countries in ascending order of 2023 value. OC = other countries.

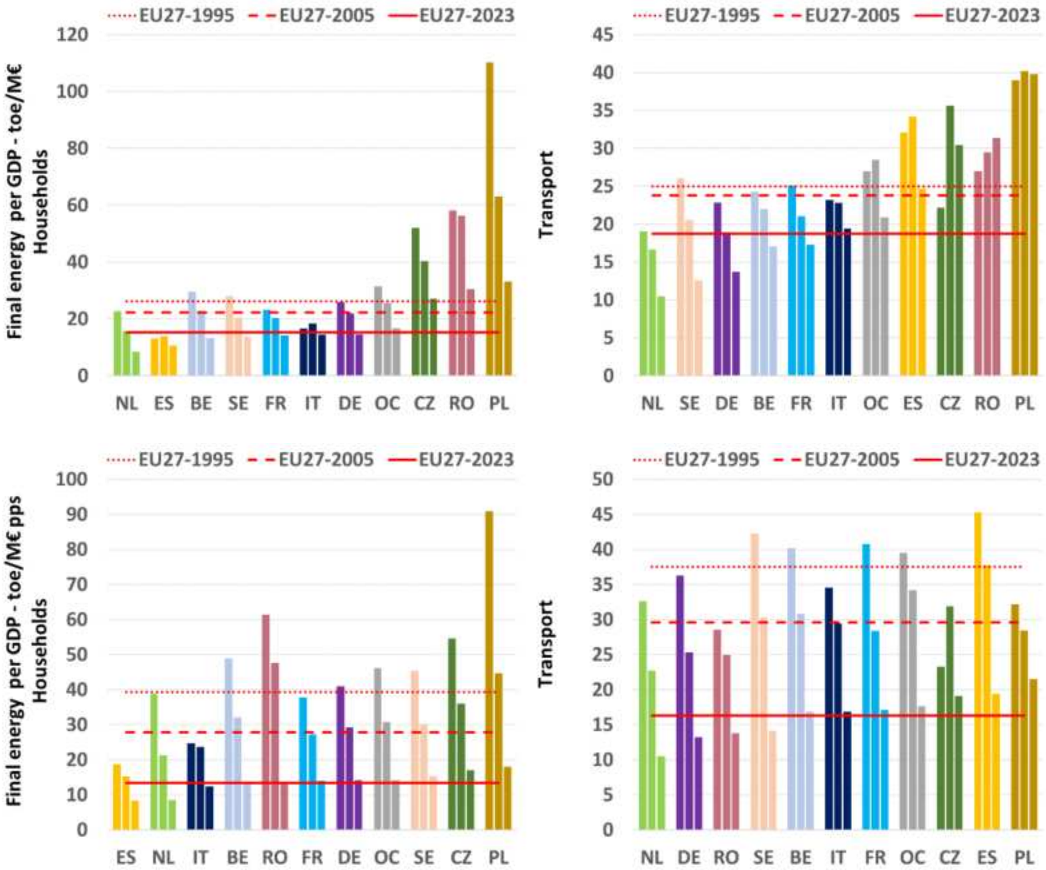


The GDP will be considered to assess the energy intensity of those sectors not directly linked to value added output, such as households and transport (Figure 2.31). In the households the Italian energy intensity in 2023 is 14.4 toe/M€ *vs* 15.3 toe/M€ in EU27, figures with GDP chain linked volumes. From 2005 to 2023 the biggest countries reduced the energy consumption per GDP (chain linked volumes): from -1.3% per year in Italy to -3.5% per year in Poland.

The Italian energy intensity for transport in 2023 is over the EU27 average (19.4 toe/M€ *vs* 18.7 toe/M€, figures with GDP chain linked volumes). The Italian reduction rate since 2005 is -0.9% per year, against -1.3% in EU27. In 2023, the intensities in the countries with lower figures than Italy are from -7.8% in France to -44% in the Netherlands lower than EU27 average.

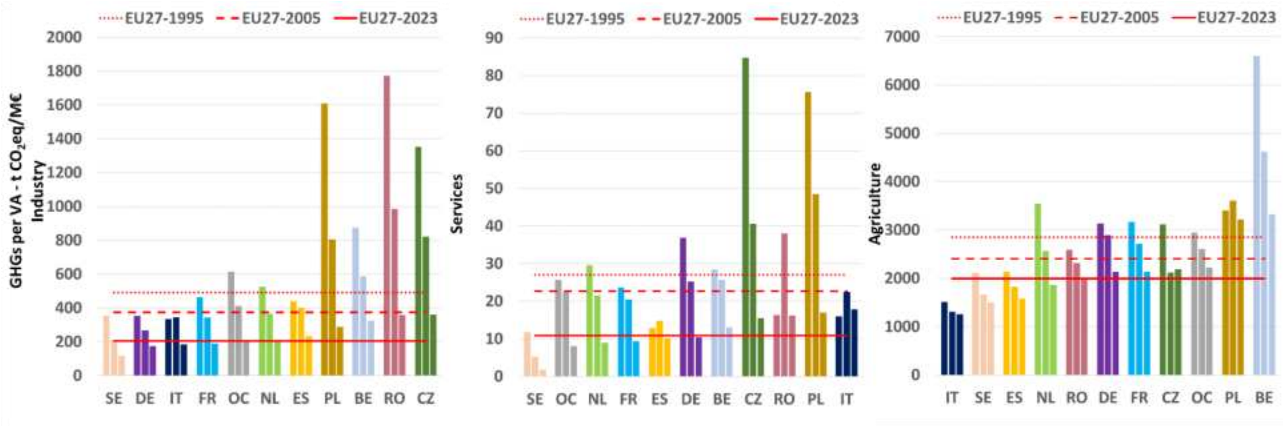
The ranking of the examined countries for households and transport shows that the Italian energy intensity is near the EU27 average. However, transport performances in Italy have wide room for improvement.

Figure 2.31 – Final energy consumption per GDP in 1995, 2005, and 2023 (chain linked volumes, reference year 2020, upper graphs; current prices, purchasing power standards, lower graphs). Countries are in ascending order of 2023 value. OC = other countries.



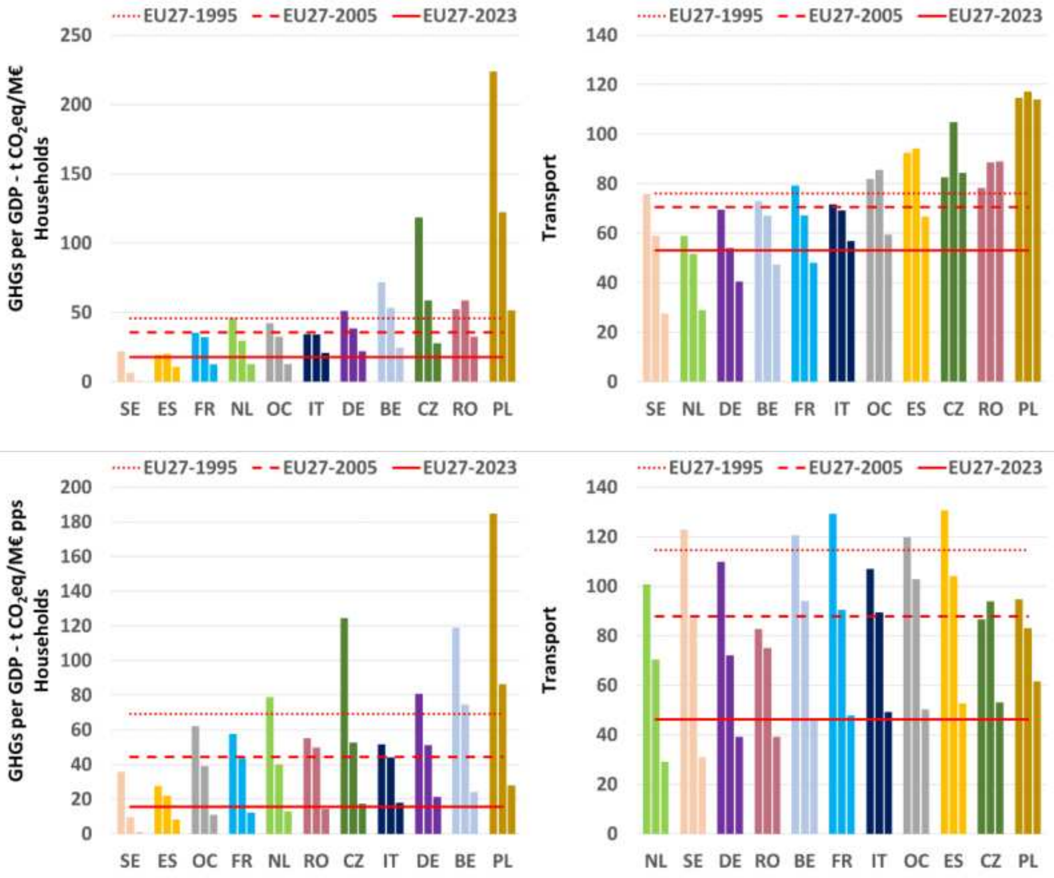
What is seen for energy intensity is reflected in the carbon intensity (t CO_2eq/M€), but this indicator is more sensible to the role of renewable energies, nuclear power and electricity import in the countries' energy balance, because such sources do not produce GHGs, even though the combustion of bioenergy produces CH_4 and N_2O. Although at the lower end, the carbon intensity of Italian industry in 2023 is higher than those of Sweden and Germany, among the biggest countries. As for agriculture Italy recorded the lowest intensity. The Italian intensities for industry and agriculture are respectively 9.1% and 44.6% lower than EU27 average. On the other hand, the carbon intensity of services in Italy is the highest among the biggest countries, 65.5% higher than EU27 average (17.9 t CO_2eq/M€ vs 10.8 t CO_2eq/M€). Such configuration deserves more details which are provided in the following pages (Figure 2.36-Figure 2.37).

Figure 2.32 – GHGs per value added in 1995, 2005, and 2023. Countries are in ascending order of 2023 value. OC = other countries.



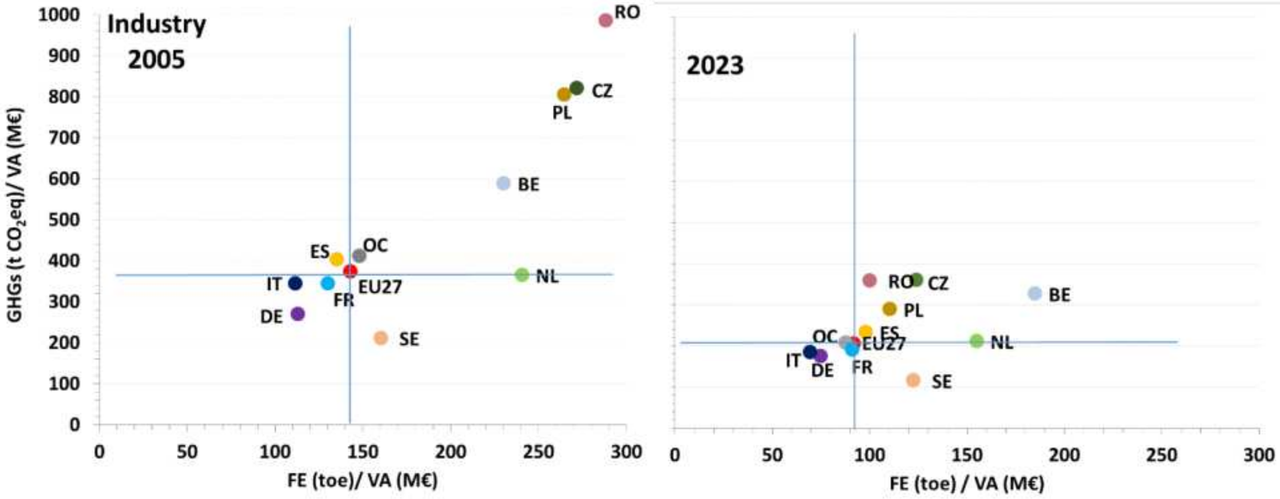
The carbon intensities of households and transport in Italy are just over the EU27 average (+16.3% for households, +7.2% for transport in 2023; figures with GDP chain linked volumes), showing some potential to reduce GHGs in households in Italy, especially considering that the electrification of final consumption in such sector is much below the EU27 average (19.8% *vs* 25.9% in 2023). Moreover, the district heating in Italy supplies only 2.2% of households' final consumption in 2023, whereas the UE27 average is 8.5%. On the other end, the Italian renewable share on households' final consumption is higher than the EU27 average (25.5% *vs* 23.5% in 2023). As for transport a detail will be provided in the next pages, here it is enough to note, as done for energy intensity, that the ranking of carbon intensity in the examined countries shows that Italy has wide room for improving the sector performances.

Figure 2.33 – GHGs per GDP in 1995, 2005, and 2023 (chain linked volumes, reference year 2020, upper graphs; current prices, purchasing power standards, lower graphs). Countries are in ascending order of 2023 value. OC = other countries.



The position of the biggest EU States in the space defined by the carbon and final energy intensities by sector added value has been investigated. For each sector, all countries move to the lower left corner from 2005 to 2023. Figure 2.34 shows the space for industry. It is evident that the countries are clustering around a narrow cloud with better performances. European industry reduced the energy intensity by 35.7% from 2005 to 2023, while carbon intensity decreased by 45.3%. Italy reduced the energy and carbon intensities by economy respectively by 37.6% and 46.8%.

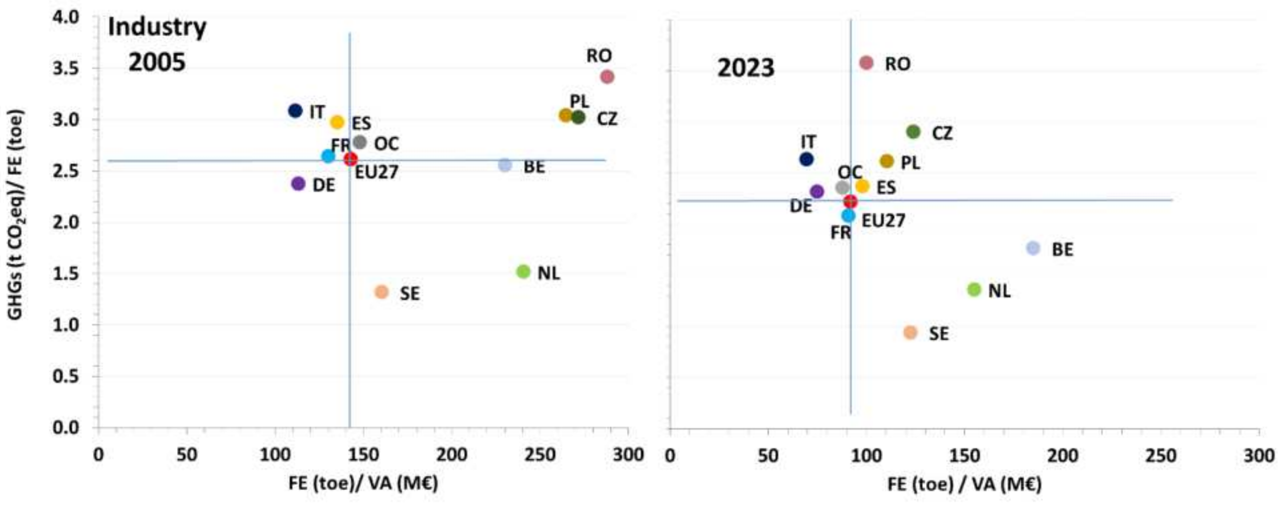
Figure 2.34 – Member States' position in the phase space defined by energy (abscissa) and carbon intensities (ordinate) per value added for the biggest European countries and the groups of other countries.



If the previous graph portrays the dimensions of efficiency (x-axes) and decarbonization (y-axes) of the sector's economy, the next one depicts on the y-axes the decarbonization of the energy mix used in the final consumption (less GHGs per final energy consumption moving toward the bottom of y-axes). Such dimension is directly linked to the use of no GHGs' emitting sources, as renewables, or sources whose emissions occurred in the transformation sector, as electricity and heat.

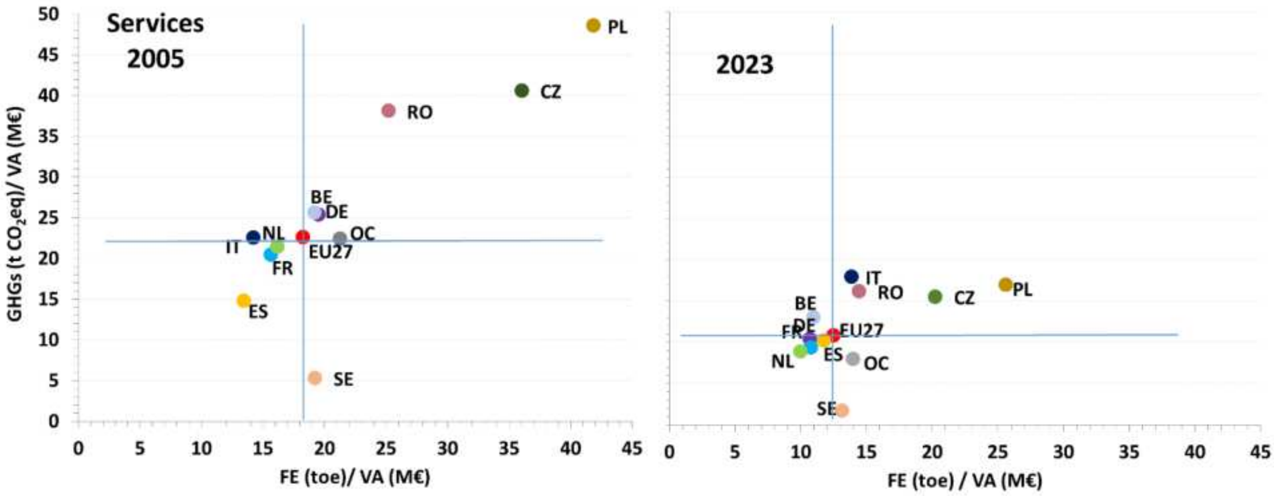
The shift in the space shown in the Figure 2.35 is mainly driven by the increase of energy consumption with no direct emissions in the sector. Italy shows the decrease of carbon intensity by energy consumption since 2005, as well as some room to improve such dimension if compared to Germany, although the distance between the two countries decreased. The carbon intensity by energy of Italy in 2005 was 29.9% higher than Germany and 18.2% higher than EU27, while in 2023 it is 13.8% higher than Germany and 18.6% higher than EU27.

Figure 2.35 – Member States' position in the phase space defined by energy intensity by value added (abscissa) and carbon intensities per final energy (ordinate) for the biggest European countries and the groups of other countries.



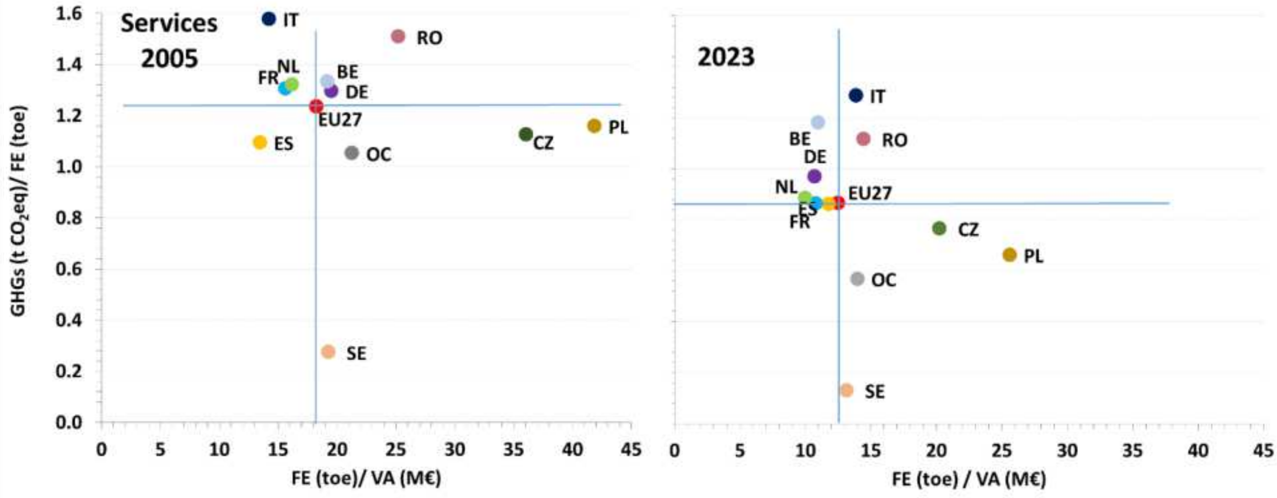
Unlike industry, the intensity by economy for services shows that Italy has lost many positions if compared to other countries, although reducing its carbon intensity per value added, from 22.5 t CO_2eq/M€ to 17.9 t CO_2eq/M€ in the period 2005-2023. Energy intensity did not change significantly (14.3 toe/M€ in 2005, 13.9 toe/M€ in 2023). All other countries and EU27 average show much larger decreases both for energy and carbon intensity than Italy (energy intensity: -31.6% EU27 and -2.5% Italy; carbon intensity: -52.1% EU27 and -20.4% Italy).

Figure 2.36 – Member States' position in the phase space defined by energy (abscissa) and carbon intensities (ordinate) per value added for the biggest European countries and the groups of other countries.



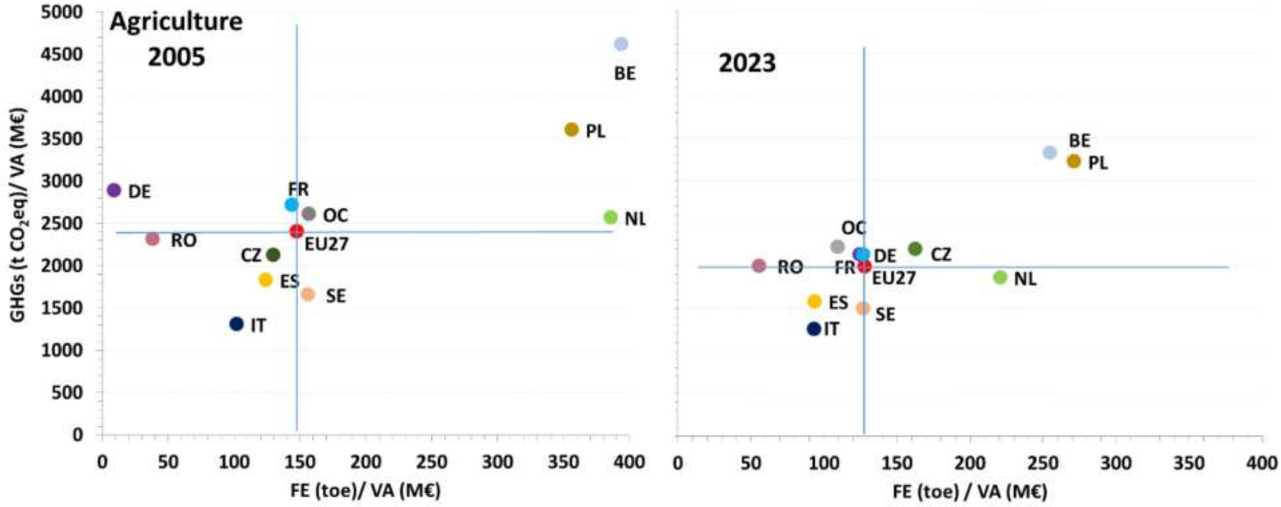
The following graph shows that services in Italy have the highest carbon intensity per energy as compared to the main European countries (+49% higher than EU27 average in 2023). Such configuration cannot be uniquely interpreted in terms of performance for Italy, because it is mainly due to the allocation in this sector of GHG emissions by fossil waste burnt in incinerators with energy recovery. As stated in the National Inventory Report (ISPRA, 2025a): "*Emissions from these plants are allocated in the commercial/institutional category because of the final use of heat and electricity production which is mainly used for district heating of commercial buildings or is auto consumed in the plant.*" Such approach makes incomparable the GHGs from services with the final energy consumption in energy balance, because the final fossil energy consumption in energy balance is significantly lower than the amount reported in CRF (Common Reporting Formats submitted to UNFCCC). The fossil energy consumption for services reported in the energy balance and CRF of Germany, France, and Spain are closer than data of Italy. Adding the amount of energy by fossil waste considered in the CRF to the final consumption of energy balance, the Italian carbon intensity per energy would be lower by about 12% in 2023, with some improvement of the position in the space of phase. Notwithstanding such correction the carbon intensity would remain +31% higher than EU27 average in 2023, showing room of improvement in the sector's performances.

Figure 2.37 – Member States' position in the phase space defined by energy intensity by value added (abscissa) and carbon intensities per final energy (ordinate) for the biggest European countries and the groups of other countries.



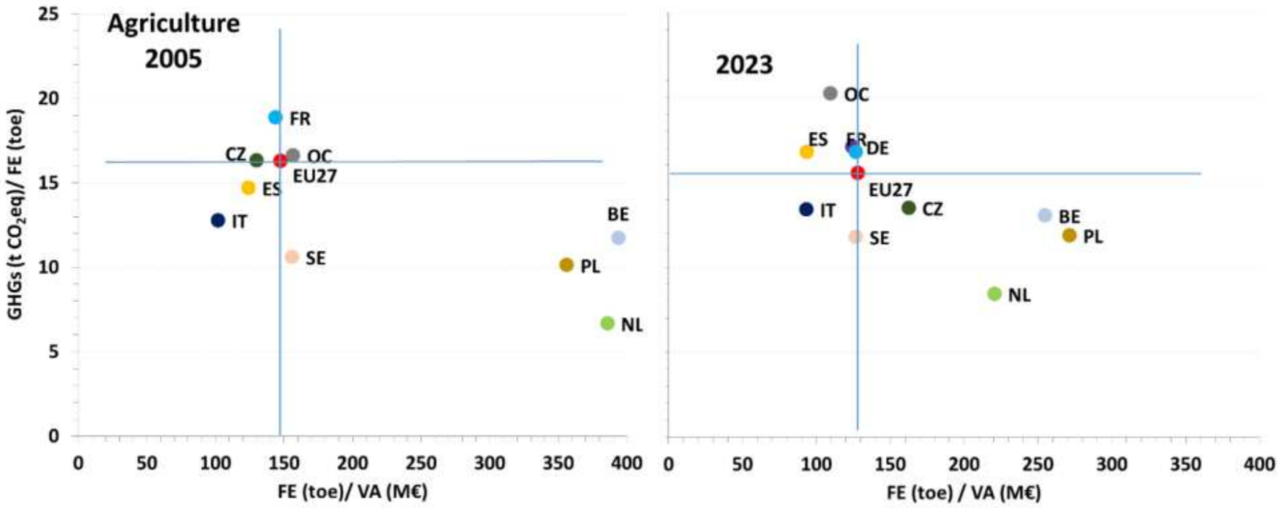
The agriculture is the sector with highest absolute intensities, and the following graph shows that in 2022 Italy occupies the position at the lower left corner of the graph, together with Sweden.

Figure 2.38 – Member States' position in the phase space defined by energy (abscissa) and carbon intensities (ordinate) per value added for the biggest European countries and the groups of other countries.



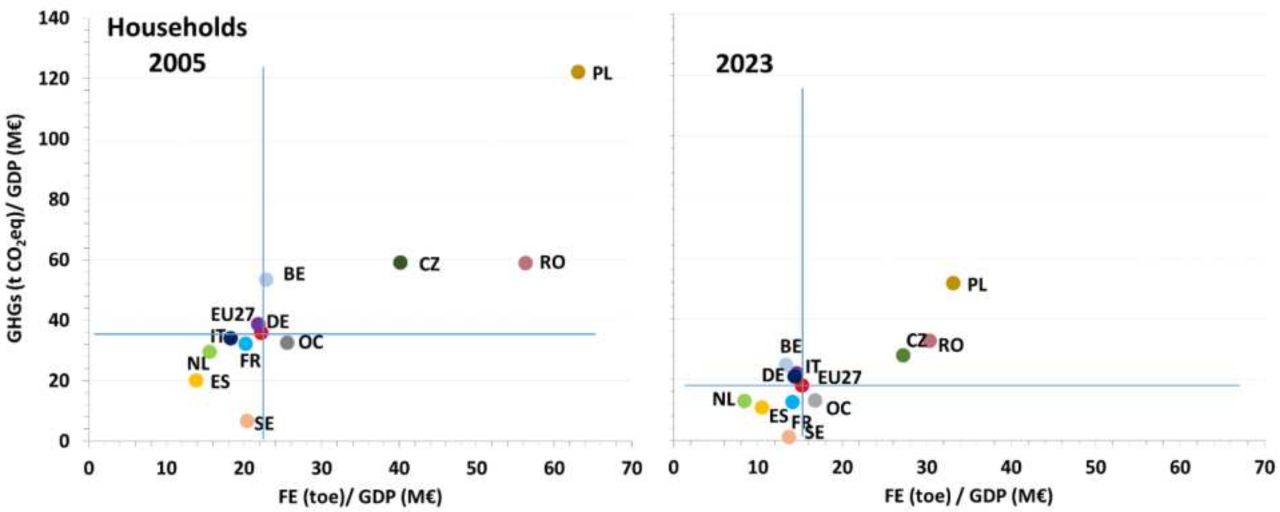
The good position of Italian agriculture is confirmed in the next Figure. Carbon intensity per energy of Germany in 2005 is out of the scale (319.1 t CO_2eq/toe).

Figure 2.39 – Member States' position in the phase space defined by energy intensity by value added (abscissa) and carbon intensities per final energy (ordinate) for the biggest European countries and the groups of other countries.



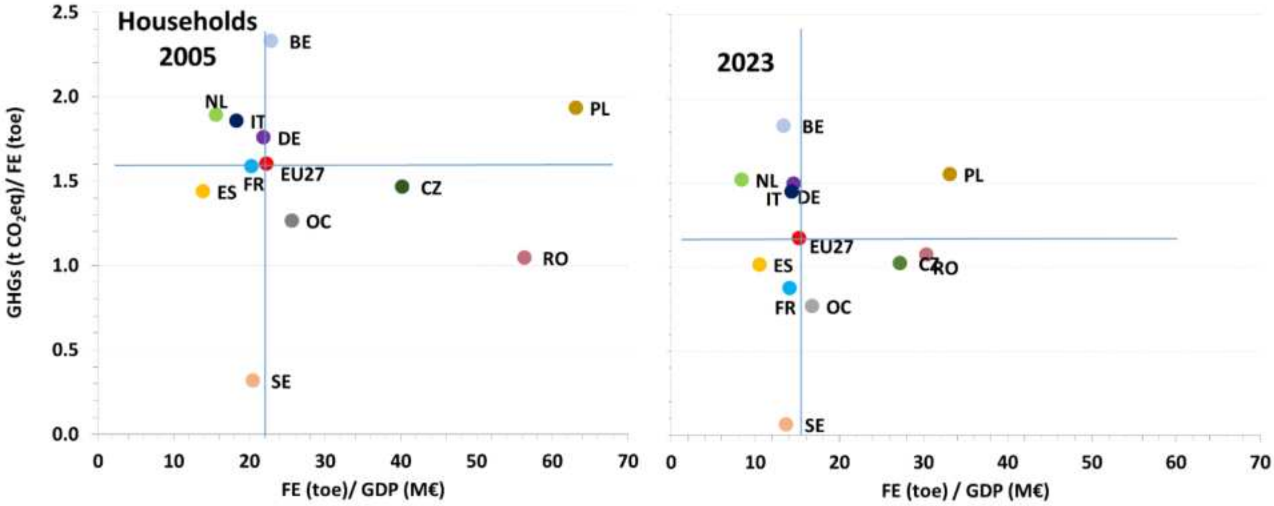
The intensities per GDP are reported in the following graphs for households and transports. For the household sector, too, the Italian energy intensity has been overcome or reached by countries that had higher values in 2005, such as Germany and Belgium. From 2005 to 2023 Italy experienced the lowest improvement of energy intensity per GDP (Italy -21.5%; EU27 -31.4%) and carbon intensities per GDP (Italy -38.8%; EU27 -49.9%). Since 2022 Italy and Germany overlap.

Figure 2.40 – Member States' position in the phase space defined by energy (abscissa) and carbon intensities (ordinate) per GDP for the biggest European countries and the groups of other countries.



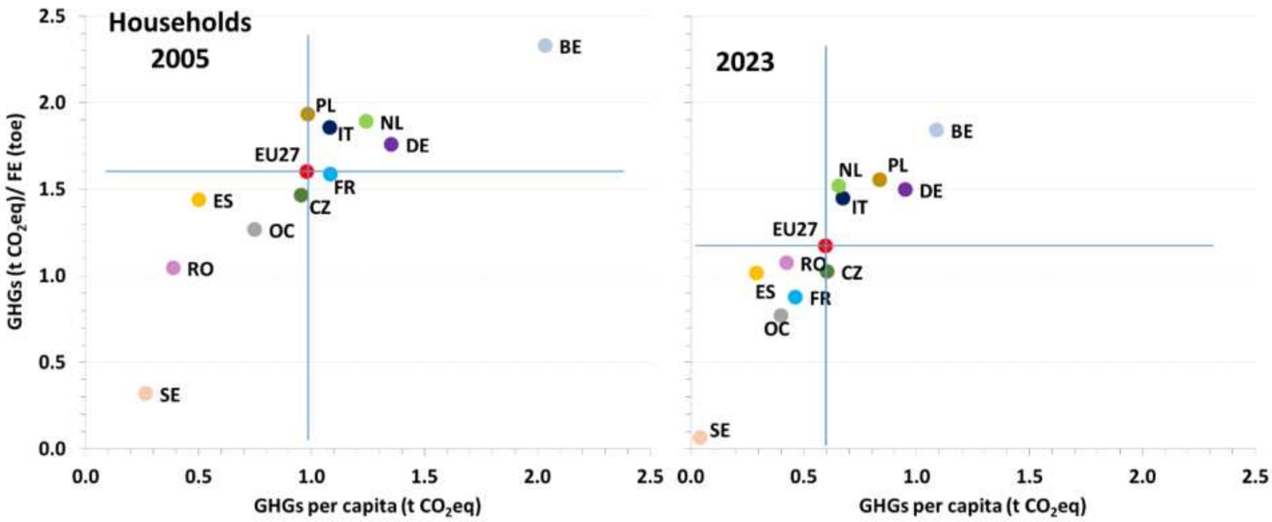
The Italian carbon intensity per final energy shown Figure 2.41 is over the European average and aligned to Germany and the Netherlands. The electrification of final consumption is a key factor to reduce the carbon footprint of households and Figure 2.14 shows the gap between Italy and the European average for this sector.

Figure 2.41 – Member States' position in the phase space defined by energy intensity per GDP (abscissa) and carbon intensities per final energy (ordinate) for the biggest European countries and the groups of other countries.



Another dimension which deserves attention in the households is GHGs per capita. Together with carbon intensity per energy consumption, such indicator provides further insights in the decarbonization process. Since 2005 the EU27 average moved toward the bottom left area, showing the reduction of the carbon footprint in the residential sector, notwithstanding a wide range among countries. Indeed, all countries, except Romania, reduced both carbon intensity and GHGs per capita compared to 2005. The "travel" length, as defined in paragraph 2.1.2, spanned from 0.05 for Romania, which travelled the shortest distance, to 1.06 for Belgium, which run the longest one. Italy moved consistently to EU27 average along a quite similar distance (0.58).

Figure 2.42 – Member States' position in the phase space defined by GHGs per capita (abscissa) and carbon intensities per final energy (ordinate) for the biggest European countries and the groups of other countries.



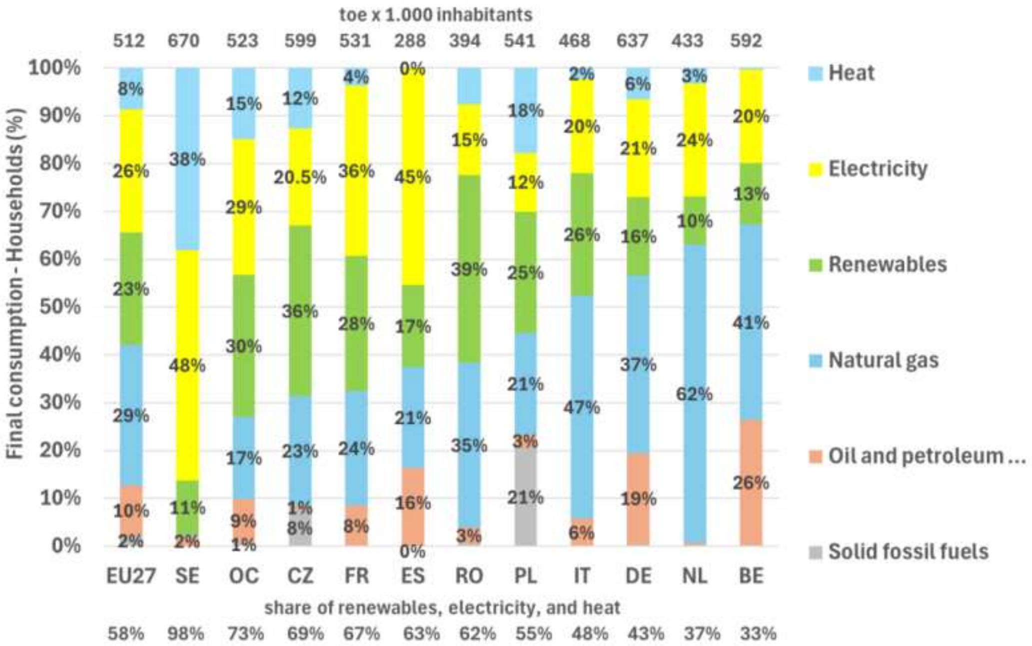
The details on households' final energy uses are provided in Figure 2.43, Figure 2.44, and Figure 2.45. Figure 2.43 shows the share of energy consumption by energy carrier and the average energy consumption per 1.000 inhabitants.

The average energy consumption in EU27 in 2023 is 512 toe per 1.000 inhabitants, 9.5% above the Italian figure. The energy consumption per capita among the considered countries spans from 670 toe per 1.000

inhabitants in Sweden to 288 toe per 1.000 inhabitants in Spain. Germany, the biggest country, recorded 637 toe per 1.000 inhabitants.

Natural gas is the main source of energy in EU27 (29.5%), followed by electricity (25.9%) and renewables (23.4%). Oil and petroleum products supply 10.3% of energy, while solid fuels account for 2.3%. The heat provides 8.5% of final energy. It is noteworthy noting that the GHGs from electricity and heat consumed in households are accounted in the 1.A.1.a of CRT, while the combustion of bioenergy is considered a net zero CO_2 emitting process. Electricity, heat, and renewables account for 57.8% in EU27. Sweden and the group of minor countries recorded in 2023 the highest share of no emitting items, respectively 97.5% and 72.9%. At the last end there are the Netherlands and Belgium with 36.9% and 32.6%. The Italian figure is 47.5%.

Figure 2.43 – Share of final energy consumption in households by energy carrier in EU27 and biggest countries in 2023. Countries in descending order of share of renewables, electricity, and heat. OC = other countries.



As shown in Figure 2.44, the main purpose of energy consumption in EU27 is space heating (62.5% with 320.2 toe per 1.000 inhabitants out of 512.2 toe per 1.000 inhabitants), spanning from 39.2% in Spain to 70.8% in Belgium among the examined countries. The European average share of energy consumption for water heating is 15.1% (77.1 toe per 1.000 inhabitants), from 9.5% in France to 21.3% in the Netherlands. Lighting and electrical appliances consumption accounts for 14.5% in EU27 (74.3 toe per 1.000 inhabitants, all by electricity), with the wider span recorded: from 7.6% in Czechia to 33.4% in Spain. The European share for cooking is 6.4% (33 toe per 1.000 inhabitants), from 1.7% in Sweden to 9.7% in Romania. Space cooling accounts only for 0.6% of energy consumption in EU27 (3.2 toe per 1.000 inhabitants, all by electricity), from no consumption in Sweden and Poland to 2% in Italy.

The electricity carrier is mainly used for lighting and electrical appliances (56% in EU27), although even other uses are satisfied by electricity: space heating (15.7%), water heating (10.7%), and cooking (12.8%), while for the space cooling the share is 2.4%. The mentioned figures must be compared with the shares of energy consumption by use in Italy: 61.2% for lighting and electrical appliances, 8.4% for space heating, 7.5% for water heating, 6.7% cooking, and 9.9% for space cooling. As for the latter item it must be emphasized that Italy has one of the highest energy consumptions (9.2 toe per 1.000 inhabitants in Italy *vs* 3.2 toe per 1.000 inhabitants in EU27).

Figure 2.44 – Disaggregated final energy consumption in households by energy carrier and use in EU27. The labels on the bars of left-hand graph are the energy consumption 1.000 inhabitants by energy carrier. The labels on the right-hand graph are the energy consumption 1.000 inhabitants by energy carrier and use.

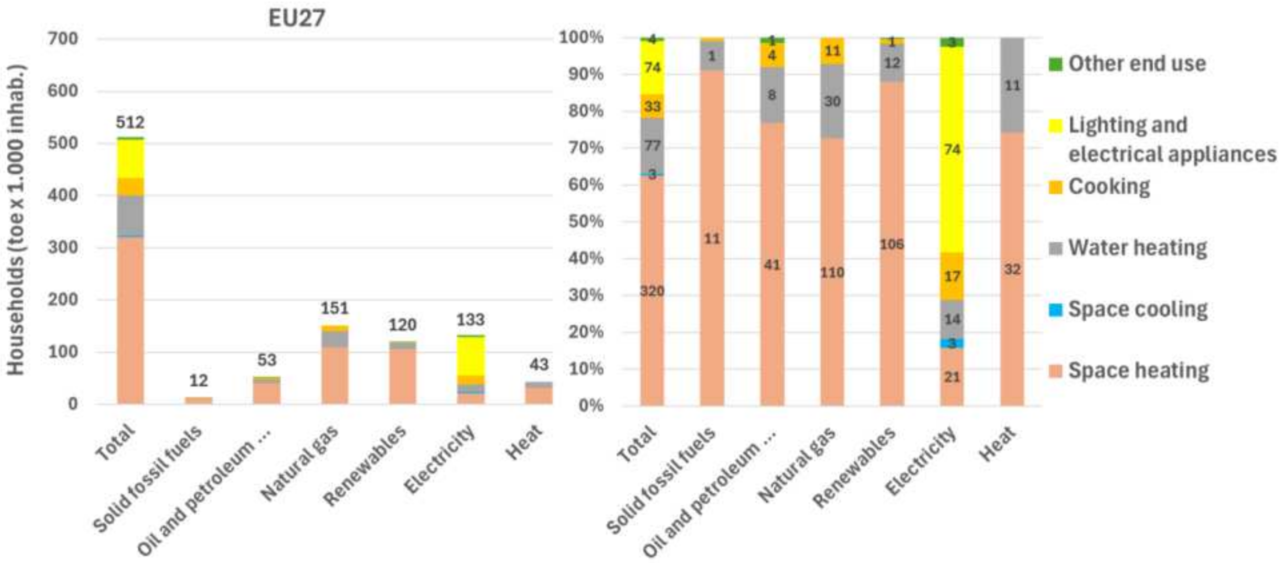
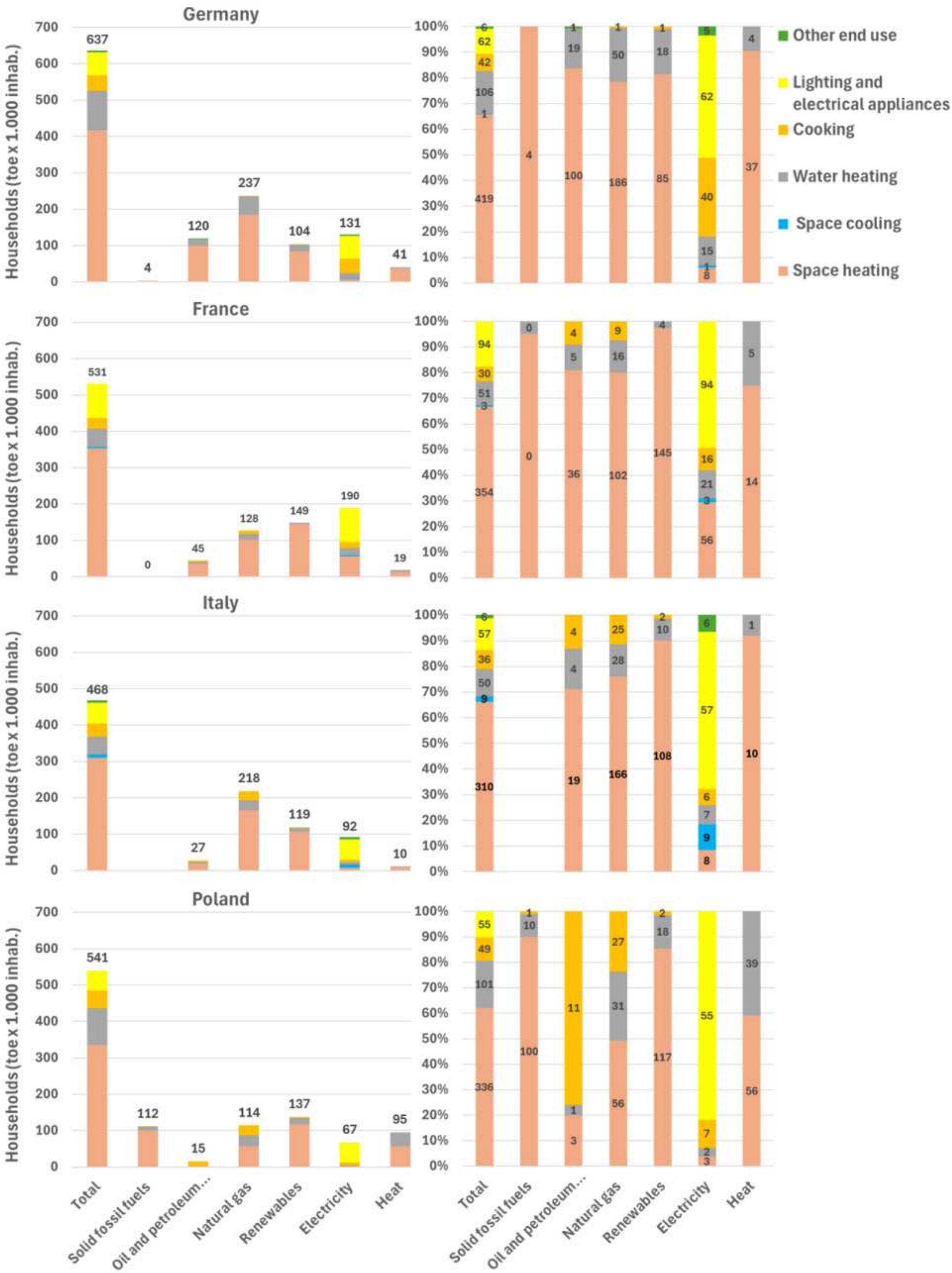


Figure 2.45 shows the details of households' final energy uses in the four European countries with the highest energy consumption and GHGs in the sector: Germany, France, Italy, and Poland. As already seen in Figure 2.43, among the four countries France has the highest share of energy consumption by sources whose GHGs are accounted in other sectors (GHGs from electricity and heat production are accounted in sector 1.A.1.a. of CRT) or do not occur at all (renewables). The country has the highest electricity consumption per 1.000 inhabitants among the considered countries: 189.8 toe against 67.4 toe in Poland, 92.4 toe in Italy, and 131 toe in Germany. Even the energy consumption by renewables in France is higher than the European average and the other considered countries (149.3 toe per 1.000 inhabitants *vs* 120.1 toe per 1.000 inhabitants in EU27). Poland recorded 137.1 toe of renewable energy consumption per 1.000 inhabitants. Italy and Germany recorded respectively 119.4 and 103.8 toe per 1.000 inhabitants. As for heat consumption in Italy has the lowest share among the considered countries (2.2% against 3.5% in France, 6.4% in Germany, 17.6% in Poland). Italy has the lowest heat consumption per 1.000 inhabitants among the considered countries: 10.4 toe against 18.8 toe in France, 40.8 toe in Germany, 94.9 toe in Poland. The EU27 average consumption of heat is 43.4 toe per 1.000 inhabitants.

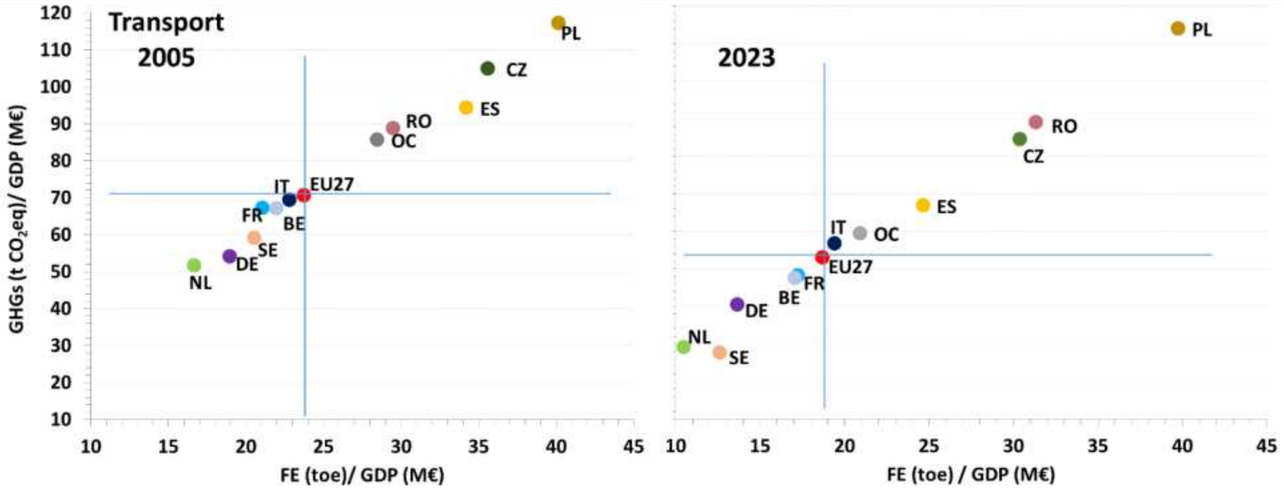
Such data make clear the room of improvement for Italy in the households, mainly on the side of electrification of final consumption and use of district heating.

Figure 2.45 – Disaggregated final energy consumption in households by energy carrier and use in Germany, France, Italy, and Poland. The labels on the bars of left-hand graph are the energy consumption 1.000 inhabitants by energy carrier. The labels on the right-hand graph are the energy consumption 1.000 inhabitants by energy carrier and use.



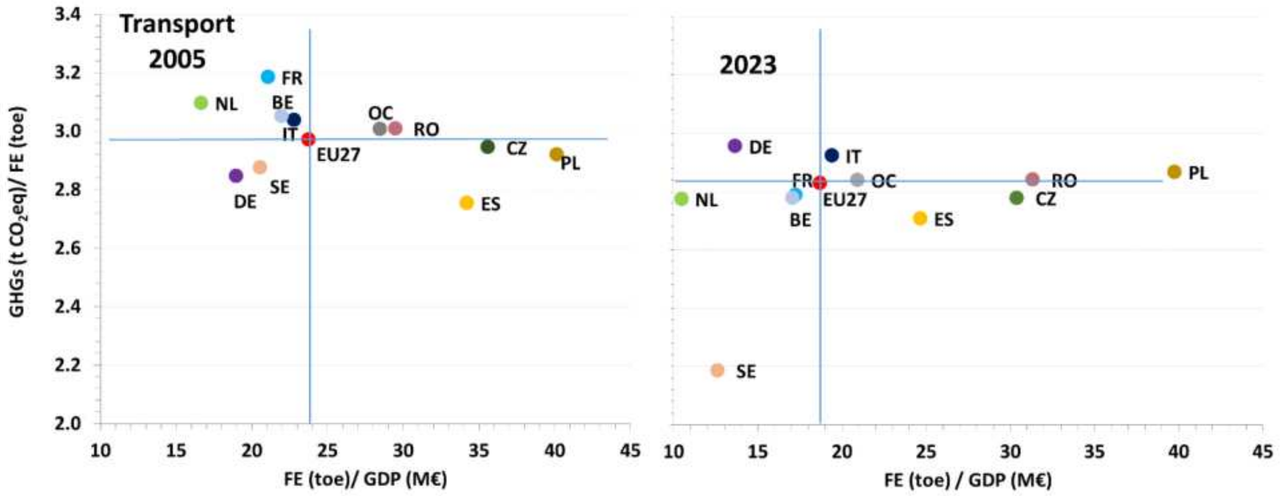
The sector of transport shows a linear correlation between GHGs and energy consumption, mainly made up of fossil fuels. Almost all countries shifted towards lower intensities. The EU27 average decrease on the two dimensions shown in Figure 2.46 was about 21% for energy intensity and 25% for carbon intensity, respectively. On such dimensions Poland recorded marginal downward shift and Romania recorded a countertrend. Italy and Czechia recorded the lowest rates of reduction among countries which reduced significantly their intensities. The final energy intensity per GDP, as well as the carbon intensity per GDP, of Italy are close to the European average.

Figure 2.46 – Member States' position in the phase space defined by energy (abscissa) and carbon intensities (ordinate) by GDP for the biggest European countries and the groups of other countries.



The carbon intensity per energy consumption in Germany and Italy (Figure 2.47) are the highest among the biggest country. Germany is the only country whose carbon intensity increased compared to 2005 (+3.9%). For all other countries the carbon intensity recorded some decrease with relevant differences among countries, from -1.8% in Poland to -24% in Sweden. Italy recorded one of the lowest reductions (-3.8%). EU27 reduced carbon intensity per energy consumption by -4.8%.

Figure 2.47 – Member States' position in the phase space defined by energy intensity by value added (abscissa) and carbon intensities per final energy (ordinate) for the biggest European countries and the groups of other countries.

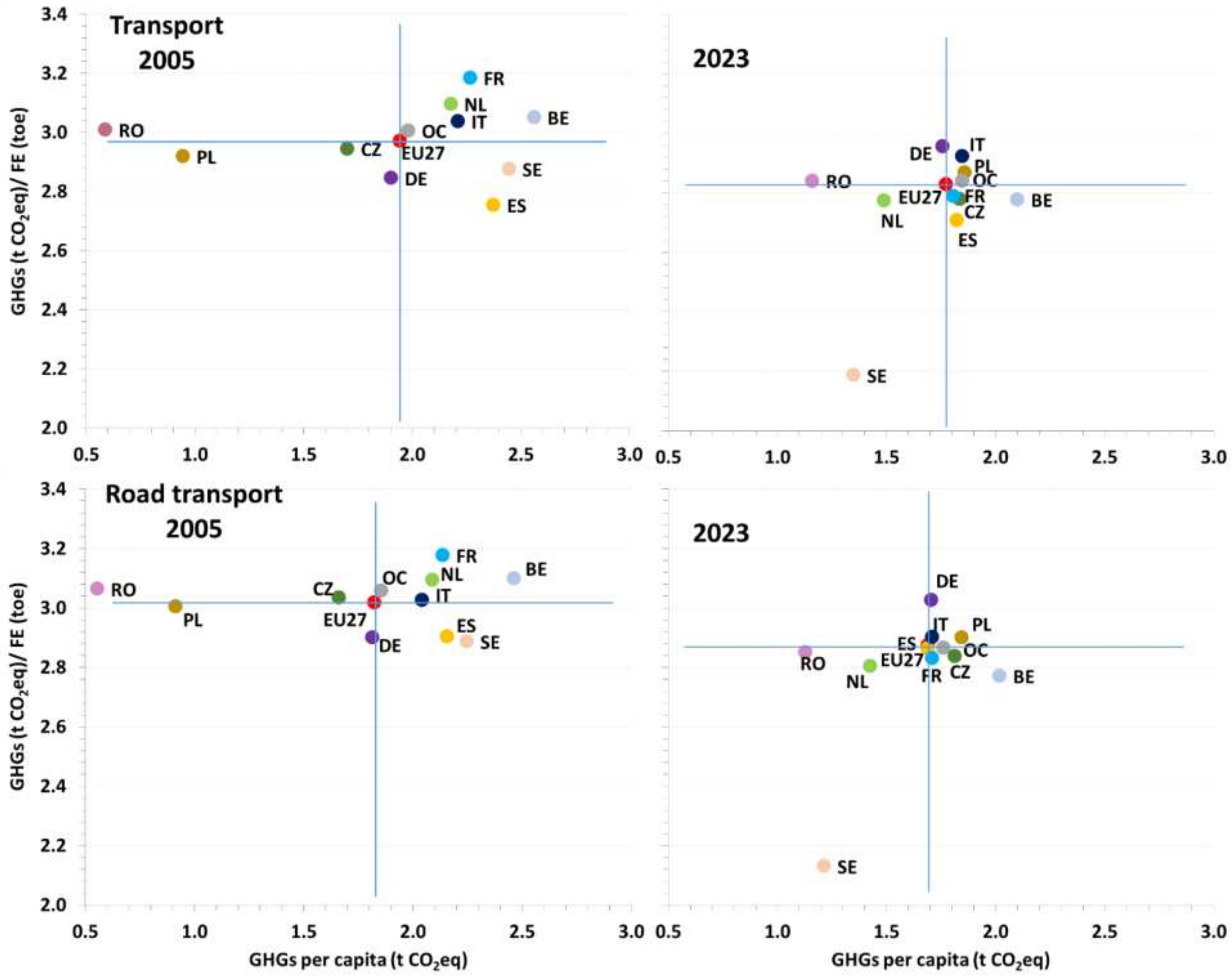


For transport, as for households, the positioning of countries in the phase space defined by GHGs per capita and carbon intensities per final energy consumption has been examined. Moreover, since road transport represents 95.3% of sector's European emissions in 2023, from 89.9% in Sweden to 99.2% in Poland, particular attention deserves such subsector. The no energy final consumption in the sector has been allocated in road transport according to the GHGs share.

GHGs per capita of the whole sector increased only in Czechia (+7.9%), Poland (+96.4%), and Romania (+97.3%), while all other countries decreased from -7.7% in Germany to -44.8% in Sweden; the European average is -8.7%. Italy recorded -16.5%. The increasing GHGs per capita in Czechia, Poland, and Romania cannot be read only in terms of performance. Such countries started from lower level of mobility compared to the other countries so the increase of GHGs per capita shows the alignment to European standard.

Considering only road transport there is a turnover at the top position of carbon intensity per energy in 2023 compared to the whole sector picture, with Germany which recorded the highest value and many countries, with Italy among them, which approached the EU27 average. The outcome for Italy is explained by the role of other transport items. Even though such items have minor share, both on the energy consumption side (7%) and the GHGs side. Italy's carbon intensity for transport other than road is the highest among the biggest countries, because of the higher share of GHGs from domestic navigation and domestic aviation compared to other countries and EU27 in 2023 (navigation: 2.1% in EU27 and 4.3% in Italy; aviation: 1.7% in EU27 and 2.2% in Italy), so the role of such items is crucial to place Italy at the top of carbon intensity per energy consumption in the sector of transport. Anyway, as already reported transport other than road accounts for about 7% of GHGs from transport and any improvements of carbon intensity for this section would lead to minor effects for the whole sector.

Figure 2.48 – Member States' position in the phase space defined by GHGs per capita (abscissa) and carbon intensities per final energy (ordinate) for the biggest European countries and the groups of other countries.



In 2023 GHGs from cars account for 59.9% of EU27 emissions from road transport and 57.1% of emissions from the whole sector. GHGs from cars in Italy account 63.9% of road transport emissions and 59.1% of transport emissions. There is a wide range in the Member States with shares of emissions from cars on road emissions going from 48.3% in Greece to 68.4% in Cyprus, even though all road emissions in Finland are due to cars. So, it is important to delve in the segment of road transport and break up GHGs from cars and other vehicles.

The positioning of MSs in the phase space defined by GHGs per capita and carbon intensities per GDP has been examined for the two segments of road transport: cars and other than cars (Figure 2.49). The picture shows that the carbon intensity per GDP reduced much more than emissions per capita in both segments. The GHGs per capita in EU27 in the period 2005-2023 reduced by 8.1% for cars and 6% for other vehicles, while the carbon intensity per GDP reduced by 24.6% and 22.9% respectively. In Italy, unlike the other countries, the growth of GDP is only slightly higher than the growth of population (respectively +3.7% and +1.6% since 2005), while in EU27 the GDP grew much more than population (respectively +3.1% and +25.6%. So, GHGs per capita in Italy reduced by 9.3% and GHGs per GDP reduced by 11.1% for cars, while for other vehicles the reduction was 26.3% and 27.8% respectively.

In the cars' segment the only countries, among the biggest ones, with higher GHGs per capita in 2023 compared to 2005 are Czechia, Poland, and Romania. The latter country is the only one which recorded also higher carbon intensity in 2023 than in 2005. As for other vehicles, beyond the mentioned countries, also Germany increased the GHGs per capita, while as concerns carbon intensity only Poland increased GHGs per GDP.

The overall performance of cars' segment allows to conclude that, among the biggest countries (excluding Czechia, Poland, and Romania for the reasons already mentioned), Italy reduced emissions per capita and per GDP lesser than other countries, while as concerns the segment of other vehicles the Italian shift towards lower emissions is much more relevant, better than EU27 average.

In absolute terms the GHGs per capita and per GDP of Italian cars in 2023 are respectively 7.8% and 11% higher than EU27 average, just over Spain, among the biggest countries. The mobility behaviour of citizens, as well as policies which determine the share between public and private mobility, explains the observed frame. It goes beyond the aims of this report to furtherly delve into such tangle but surely the number of cars could give some insight in this regard. As shown in Figure 2.50 the number of cars in Italy is the highest in Europe. Moreover, among the biggest countries the Italian share of oldest cars (>10 years) is higher than those recorded in France, the Netherlands, Sweeden, Germany, and Belgium.

Unlike the cars, for the other vehicles the GHGs per capita and per GDP in Italy are respectively 8.9% and 6.2% below the EU27 average.

Figure 2.49 – Member States' position in the phase space defined by GHGs per capita (abscissa) and carbon intensities per GDP (ordinate) for the biggest European countries and the groups of other countries.

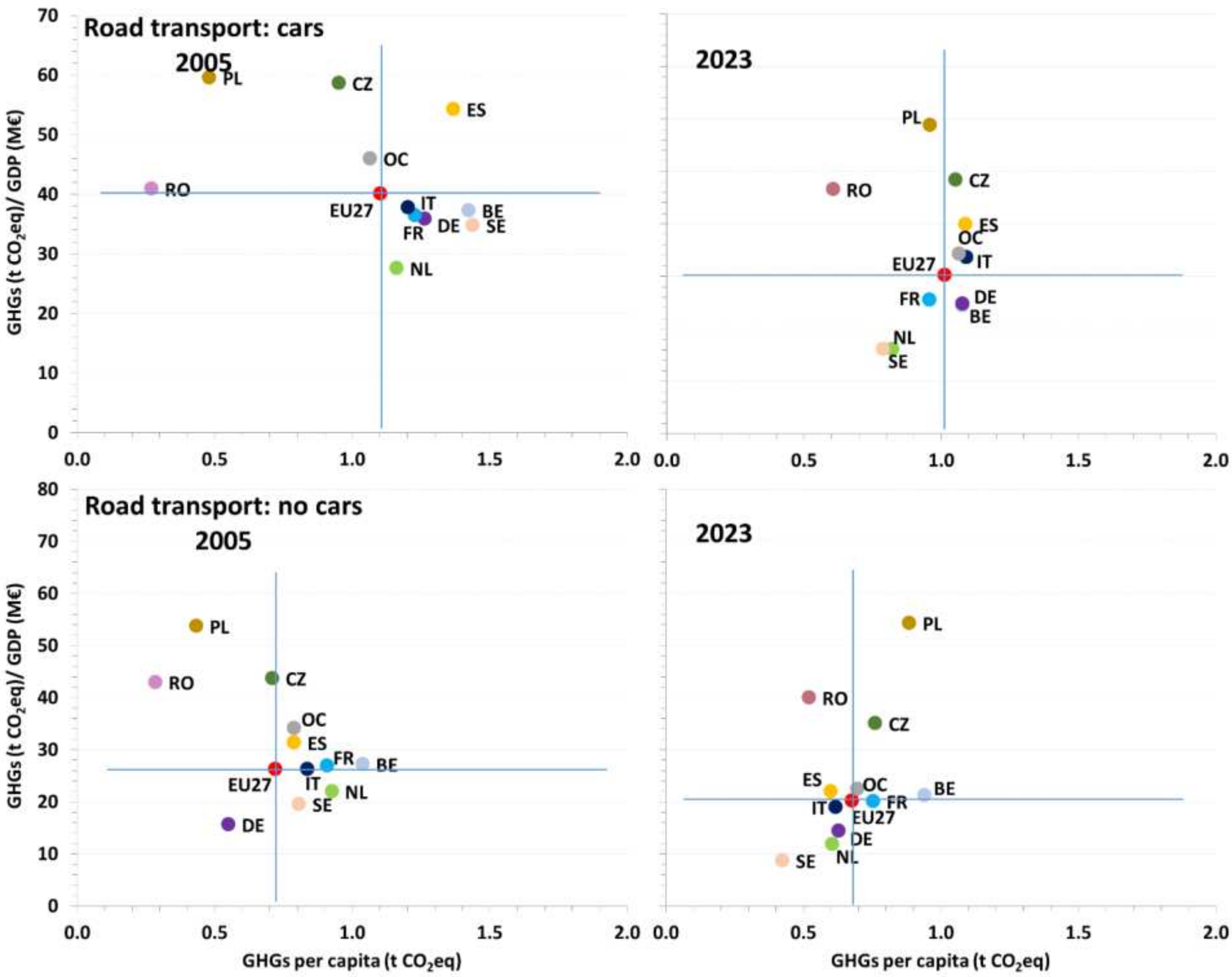


Figure 2.50 – Number of cars by age per 100 inhabitants in 2023. Dark grey, age of cars not available.

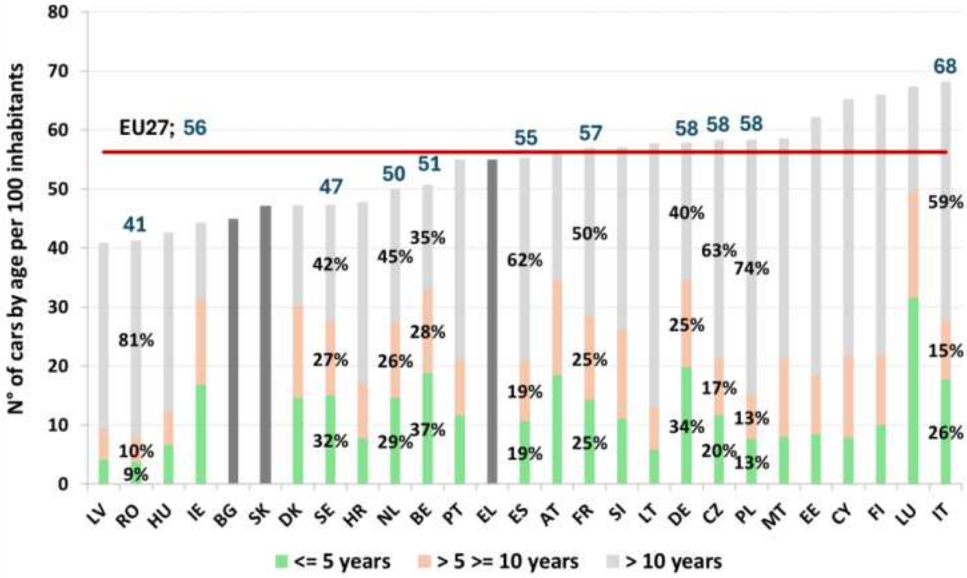
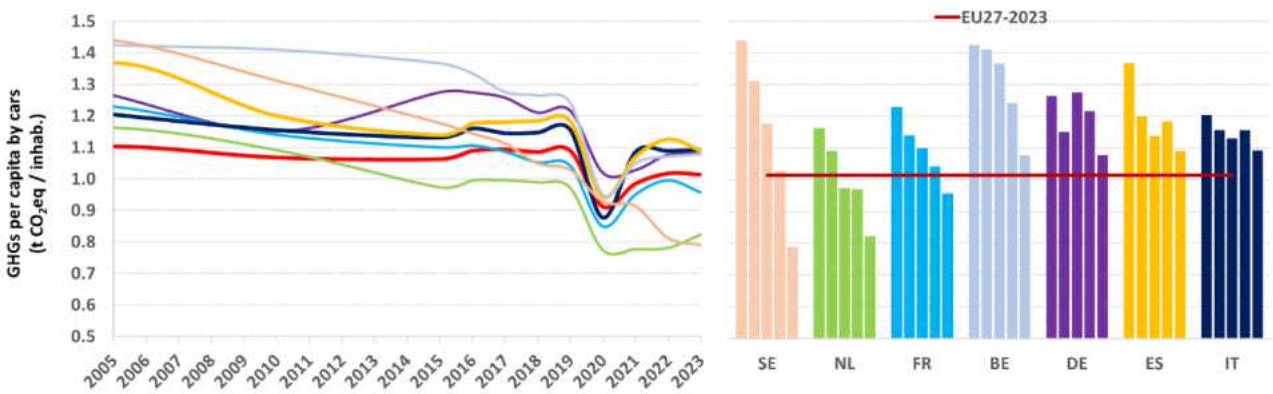


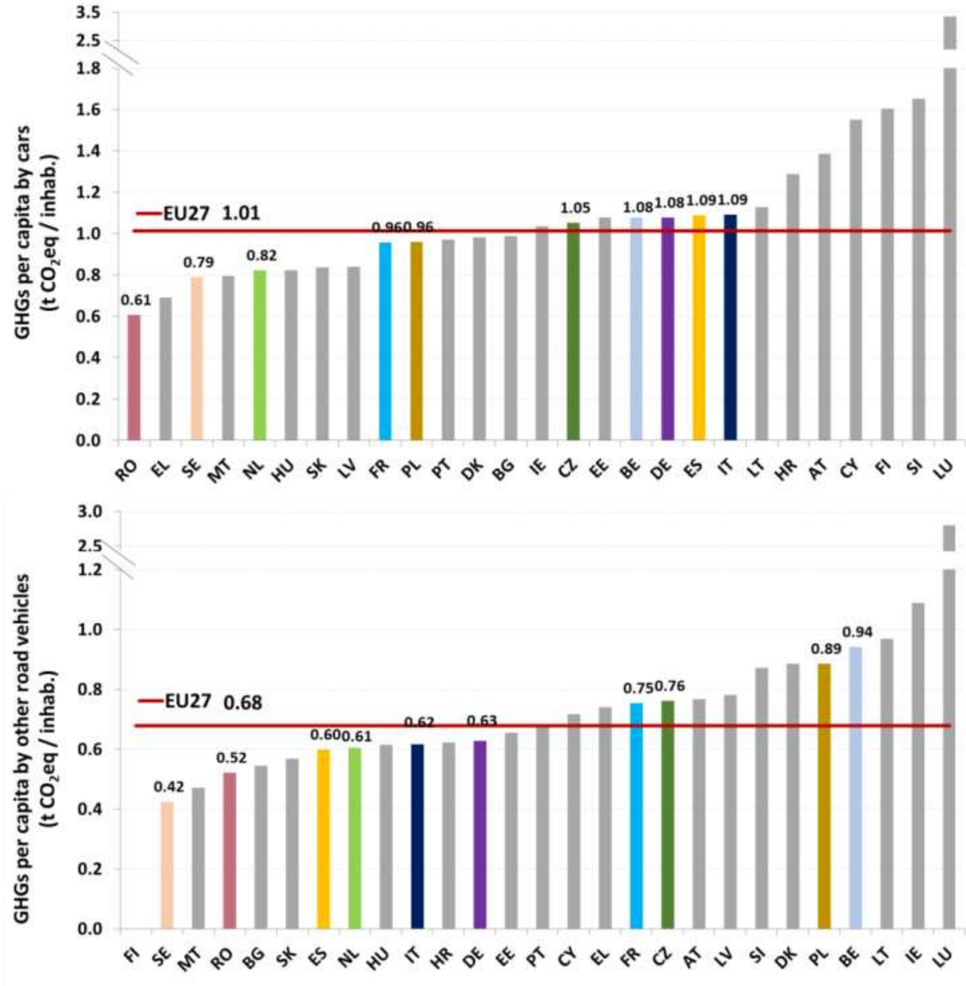
Figure 2.51 shows the trend of GHGs per capita since 2005 for the biggest European countries. Poland, Czechia, and Romania are not reported because, as already mentioned, for historical reasons had much lower values with an upward trend and cannot be compared with the considered countries for this indicator. The left-side graph shows that in 2020 the GHGs per capita fall in all countries because of the pandemic. Since 2021 a rebound has been recorded for most countries, but in 2023 Italy recorded the lowest reduction of emissions per capita compared to 2019 level (-5.5%). The other countries reduced their GHGs per capita compared to pre-pandemic levels from 7.9% in Spain to 23.3% in Germany. Such outcome is more evident in the right-side of Figure 2.51, where 2020 is non shown.

Figure 2.51 – GHGs per capita from cars by country. The bars on the right-side graph represent 2005, 2010, 2015, 2019, 2023. Data in ascending order of 2023 value.



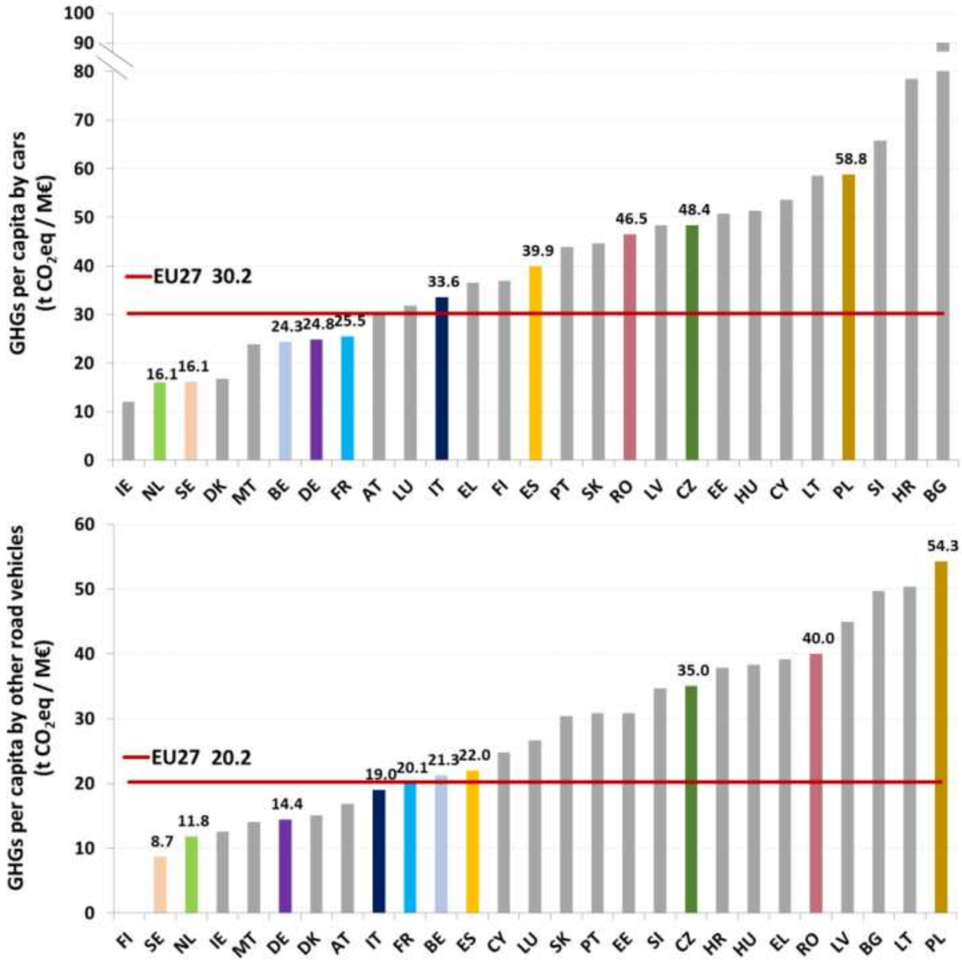
To sum up the situation for road transport Figure 2.52 shows the emissions per capita from cars and other vehicles in 2023 in all European countries. As for the cars, Italy recorded the highest emissions per capita among the biggest countries, while the ranking for other vehicles is quite different, and Italy is well below the European average.

Figure 2.52 – GHGs per capita from cars and other road vehicles by country in 2023. Data in ascending order.



Even emissions per GDP (Figure 2.53) place Italian cars over the European average and many positions after countries as Germany, France, and Belgium with better performances, while as concerns other road vehicles the emissions per GDP in Italy are lower than the European average.

Figure 2.53 – GHGs per GDP from cars and other road vehicles by country in 2023. Data in ascending order.



2.1.3 Kaya Identity and decomposition analysis

The analysis for the European data has been carried out with the same methodology and factors considered for the analysis on Italian data (see paragraph 1.3). The trend of *kaya identity* parameters for EU27 and Italy in the period 1995-2023 shows a quite different pattern for the driving factors in GHGs reduction. Whereas in EU27 the most powerful factor is the final energy intensity, in Italy both renewable sources and final energy intensity (final energy consumed per GDP) are the driving factors. Moreover, in EU27 population and GDP per capita increased, while in Italy such factors show a downward trend. The GHGs change is the integrated result of the driving factors change. In EU27 there is an absolute decoupling between economy and GHGs, while in Italy a relative decoupling is recorded for many years.

Figure 2.54 – Trend of Kaya identity parameters normalized to 2005 in EU27 and Italy.

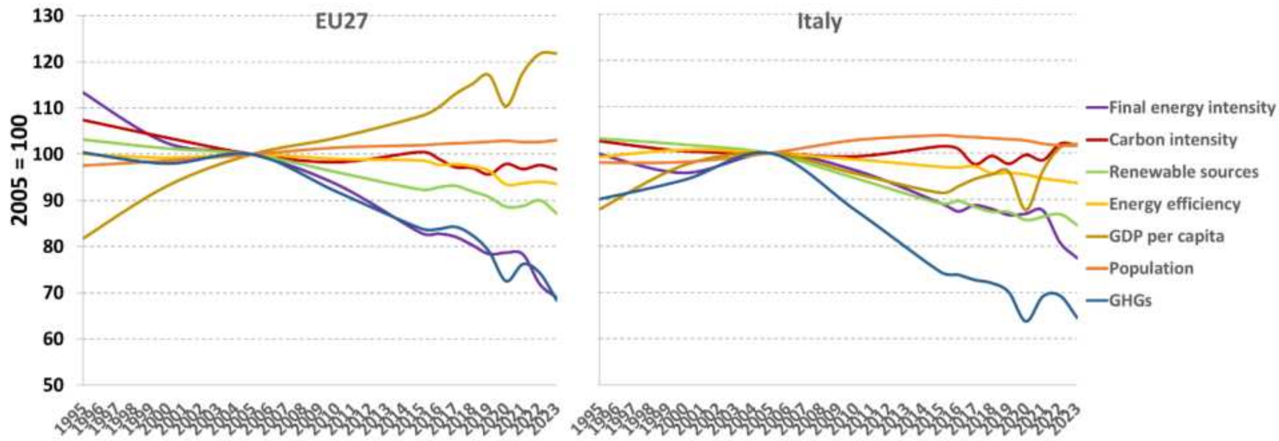


Figure 2.55 shows the decomposition analysis for EU27. The analysis for the EU biggest countries and Italy (Figure 2.56), carried out according *Logarithmic mean Divisia index* (Ang, 2005), allows to quantify the role of each factor to reduce the GHGs. The outcomes for Italy have been shown in more details in paragraph 1.3. The improvement of final energy efficiency played in Italy a less important role than in other countries because of the better performance of the indicator in Italy already in 2005. Moreover, unlike Italy, all countries recorded the sensible increase of GDP per capita since 2005.

Figure 2.55 – Decomposition analysis in the period 2005-2023 in the EU27.

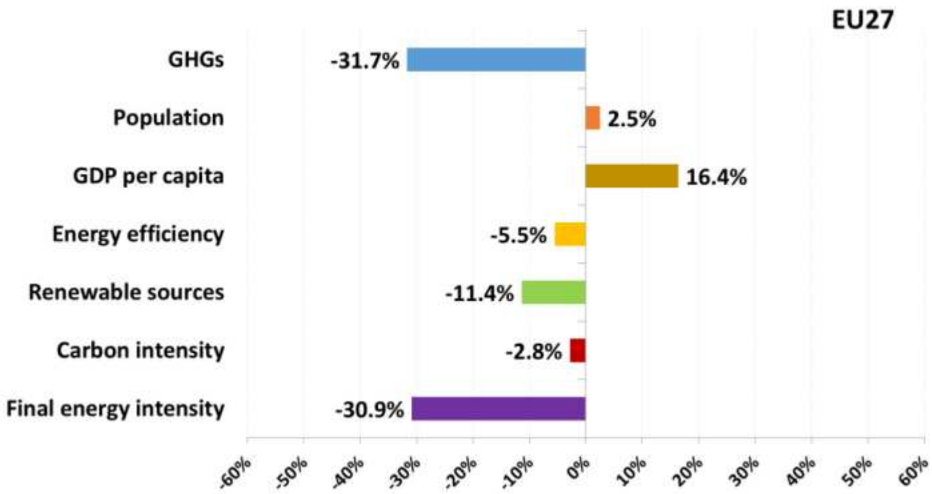


Figure 2.56 – Decomposition analysis in the period 2005-2023 in the biggest countries.

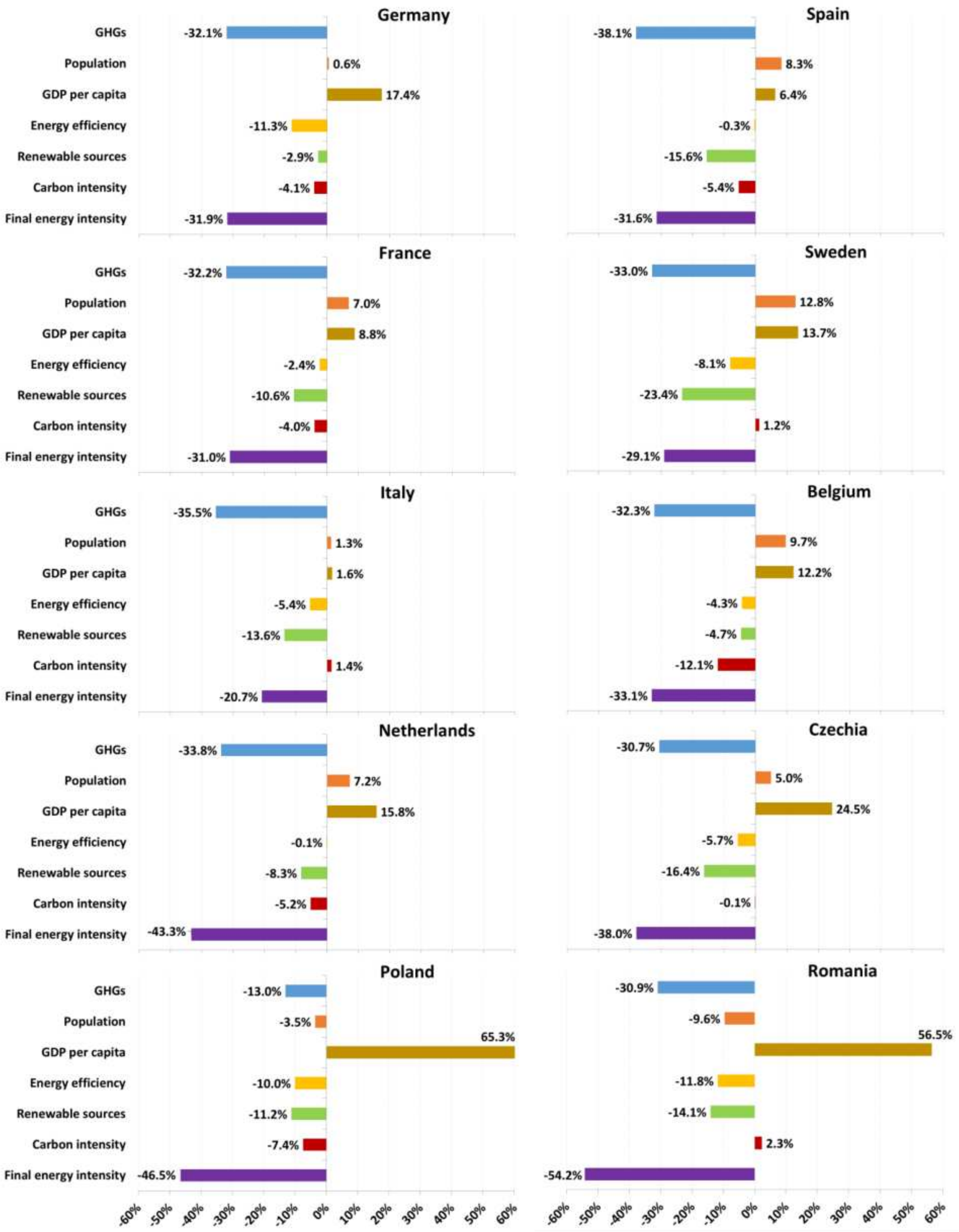


Figure 2.57 and Figure 2.58 provide the details of decomposition analysis since 1995 to 2023 at European level and for the biggest countries. The analysis up to 2015 has been carried out on five years basis, while after 2015 a year-by-year GHGs change has been decomposed in the driving factors. The examined countries show different patterns and different GHGs trend, but it is possible to find a quite common

pattern at European level as the relevant acceleration of GHGs reduction since 2017. The further decrease in 2020 was mainly due to the sharp contraction of economy because of the effect of the measures adopted to contrast the pandemic. The economy rebound in 2021 determined the GHGs increase in all countries, although with different rates, followed by the downward trend of the last years.

Figure 2.57 – Decomposition analysis in the EU27 since 1995 for the shown time frame. The average annual rate of GHG emissions is reported.

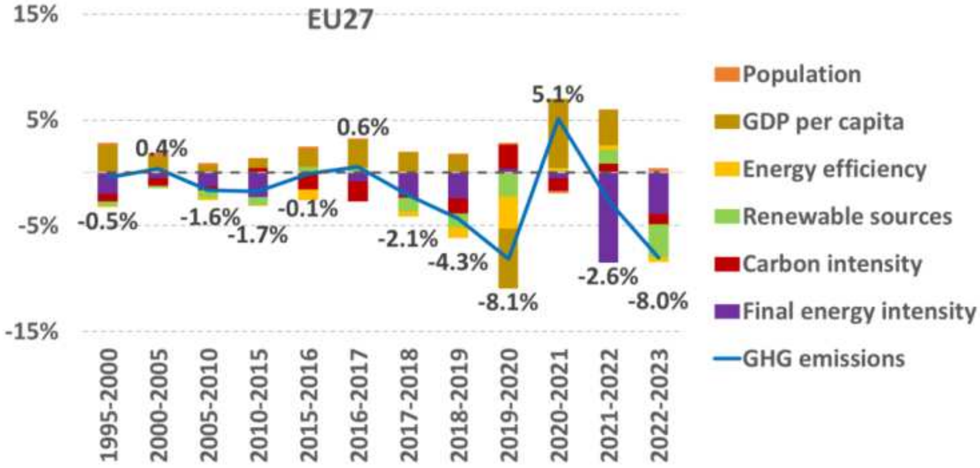
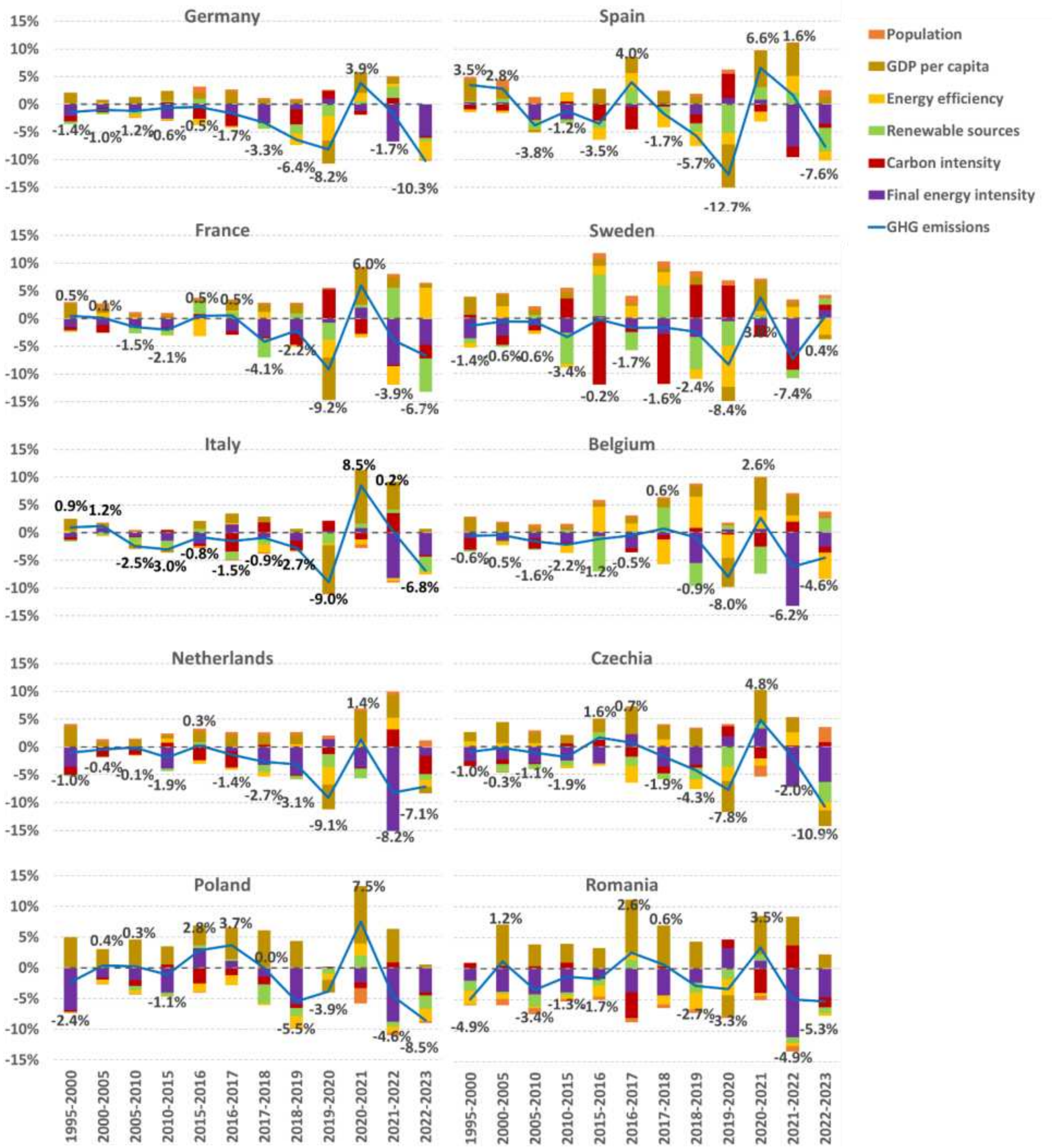


Figure 2.58 – Decomposition analysis in the biggest countries since 1995 for the shown time frame. The average annual rate of GHG emissions is reported.



In summary, higher decoupling between economy factor and GHGs has been observed in any countries than that recorded in Italy. The decoupling does not necessarily correspond to GHGs reductions in line with the targets. Decomposition analysis focuses on the relative change of the parameters, without assigning any weight to the starting points. The absolute values of parameters and relative trends in the biggest European countries have been investigated in the previous paragraphs. As already mentioned, the economic and energy efficiency of the Italian system is among the highest in Europe. The last edition of the *International Energy Efficiency Scorecard*, issued by ACEEE in 2022, reported for Italy the drop of four ranks since the previous edition in 2018, mainly due to buildings section, but Italy managed to rank within the top five, after France, UK, Germany, and the Netherlands. The ACEEE International Energy

Efficiency Scorecard evaluates the efficiency policies and performance of 25 of the most energy-consuming countries globally. ACEEE used 36 metrics, both policy and performance-oriented metrics, to score each country's efforts to save energy and reduce greenhouse gas emissions across four categories: buildings, industry, transportation, and overall national energy efficiency progress. "*Policy metrics highlight best practices in government actions and can be either qualitative or quantitative. Examples include national targets for energy efficiency, building and appliance labelling, and fuel economy standards for vehicles. The performance-oriented metrics are quantitative and measure energy use per unit of activity or service extracted. Examples include the efficiency of thermal power plants, energy intensities of buildings and industry, and average on-road vehicle fuel economy.*" (Subramanian *et al.*, 2022).

The efficiency improvement cannot be separated from the assessment of the potentials and cost effectiveness of the energy system change. Moreover, a mindful assessment of the countries' economy structure must be considered, especially concerning the role of services and industry which have very different energy intensities and carbon footprints.

2.2 Power sector

Data of power sector are from Eurostat database. Fuels are considered according to Eurostat nomenclature. Default emission factors for CO_2, CH_4, and N_2O (IPCC, 2006, 2019; Table 2.1) and GWP from AR5 (IPCC, 2013) have been applied to esteem GHGs. Data up to 2022 are final data. Preliminary data of electricity production in 2024 have been issued by Eurostat on 25 June 2025. On such data heat production and GHGs have been estimated according to the ratio of heat/electricity by thermal plants and the transformation efficiency recorded in 2023.

Table 2.1 – List of fuels used in the thermoelectric sector according to the Eurostat classification and default emission factors of CO_2, CH_4, and N_2O for stationary sources in the energy industries (IPCC, 2006, 2019).

Type	Fuels	Emission factors		
		CO_2 t/TJ	CH_4 kg/TJ	N_2O kg/TJ
Solid fuels	Patent fuels	97.5	1.0	1.5
	Anthracite	98.3	1.0	1.5
	Coking coal	94.6	1.0	1.5
	Other bituminous coal	94.6	1.0	1.5
	Sub bituminous coal	96.1	1.0	1.5
	Coke oven coke	107.0	1.0	1.5
	Gas coke	107.0	1.0	0.1
	Coal tar	80.7	1.0	1.5
	Lignite	101.0	1.0	1.5
	Brown coal briquettes	97.5	1.0	1.5
	Peat and peat products	106.0	1.0	1.5
	Oil shale and oil sands	107.0	1.0	1.5
Oil and oil products	Crude oil	73.3	3.0	0.6
	Natural gas liquid	64.2	3.0	0.6
	Refinery gas/Refinery feedstocks	57.6	1.0	0.1
	Liquefied petroleum gas	63.1	1.0	0.1
	Other kerosene	71.9	3.0	0.6
	Kerosene-type jet fuel (excluding biofuel portion)	71.5	3.0	0.6
	Naphtha	73.3	3.0	0.6
	Gas oil and diesel oil (excluding biofuel portion)	74.1	3.0	0.6
	Fuel oil	77.4	3.0	0.6
	Bitumen	80.7	3.0	0.6
	Petroleum coke	97.7	3.0	0.6
	Other oil products n.e.c.	73.3	3.0	0.6
Natural gas	Natural gas	56.1	1.0	0.1
Derived gases	Coke oven gas	44.4	1.0	0.1
	Blast furnace gas	260.0	1.0	0.1
	Gas works gas	44.4	1.0	0.1
	Other recovered gases	50.3	1.0	0.1
Other non-renewable	Industrial waste (non-renewable)	143.0	30.0	4.0
	Non-renewable municipal waste	91.7	30.0	4.0
Other renewables	Renewable municipal waste	-	30.0	4.0
	Primary solid biofuels	-	30.0	100.0
	Biogases	-	1.0	0.1
	Pure biodiesel	-	3.0	0.6
	Other liquid biofuels	-	3.0	0.6

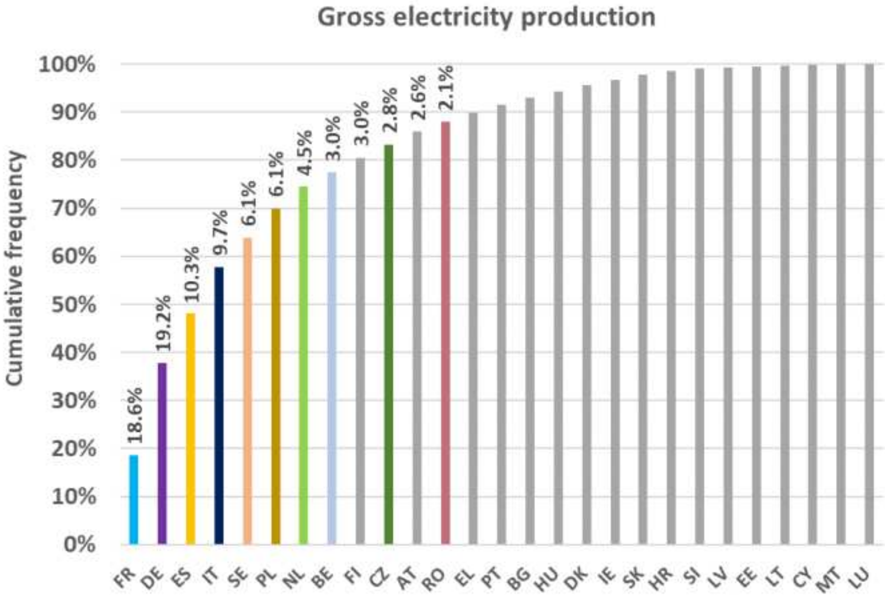
The power sector is one of the largest GHGs sources in Europe. Sector 1.A.1.a, according to the classification adopted by the Common Reporting Tables submitted to UNFCCC, represents emissions from "Public electricity and heat production", i.e. thermoelectric plants that supply electricity to the grid. The sector's GHGs in 2005 in EU27 were 33.6% of the energy emissions and 26.3% of total emissions, both shares sharply decreasing to 18.5% and 24.3% in 2023, respectively. However, it should be noted that sector 1.A.1.a does not represent the whole electricity system, since emissions from auto producers shall be allocated in the specific categories and subcategories (refineries, other energy industries, iron and steel plants and other manufacturing industries) of the Energy sector. In 2005, auto produced electricity from thermal energy in EU27 accounted for 12.3% with an increasing share (21.4% in 2023). GHGs due to electricity generation are therefore higher than the figures reported in sector 1.A.1.a of CRT.

The sector is therefore one of the main targets for measures aimed to decarbonize the economy, both for the GHGs emissions and for the renewable energy potential. The countries examined for comparison with Italy accounted for 82.6% of EU27 gross electricity production in 2023.

The power sector is characterized by a relatively small number of large point sources, unlike other sectors, such as transport, which even more relevant in emissive terms and characterized by millions of small and mobile sources with greater inertia as far as the deployment of renewable energies are concerned. Therefore, the electrification of final consumption is a key strategy to achieve the decarbonization.

The analysis of the main parameters of the power sector will concern the selected European countries, as illustrated in the previous chapter, and at aggregate level the group of other countries and EU27.

Figure 2.59 – Cumulative frequencies for gross electricity production in the EU27 Countries in 2023. The labels of country frequencies higher than 2% are reported.



The amounts of energy allocated to the production of electricity and heat in cogeneration plants have been calculated according to the methodology proposed by Eurostat (2016) for the compilation of national questionnaires by Member States.

The following equation defines the total efficiency (ε):

$$\varepsilon = (H + E) / F \qquad (1)$$

where H is the heat produced, E is the electricity produced, and F is the fuel energy.

The fuel used for electricity production, F*e*, and that used for heat production, F*h*, are given by the equations:

$$Fe = F – (H / \varepsilon = F \times [E/ (E + H)] \qquad (2)$$

$$Fh = F – (E / \varepsilon = F \times [H/ (E + H)] \qquad (3)$$

In this way it is possible to allocate the fuel energy used in cogeneration plants to produce electricity and heat to calculate the emission factor for electricity production.

The total efficiency (ε_t) and the electrical efficiency (ε_{el}) are calculated with the equations:

$$\varepsilon_t = (H + E) / F \quad (4)$$

$$\varepsilon_{el} = E / F \quad (5)$$

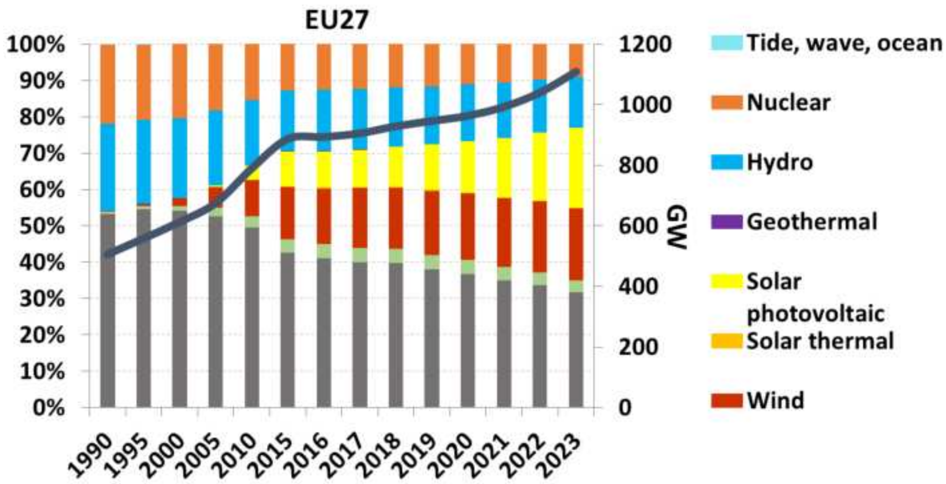
Another way for comparing the electrical efficiency of different countries considers only the share of fuel allocated to electricity generation after having parted the share of fuel for heat generation (according to equations 2 and 3). The electrical efficiency thus defined (equivalent electrical efficiency), ε'_{el}, will be given by the equation:

$$\varepsilon'_{el} = E / Fe \quad (6)$$

2.2.1 Power capacity and electricity production

The installed capacity in 1990 consisted mainly of thermoelectric plants (54% in EU27), nuclear (21.8%) and hydroelectric (24%). Wind and photovoltaic sources had marginal shares. In 2023 the thermoelectric capacity was 35%, 9.1% nuclear, 13.8% hydroelectric, 19.7% wind, and 22.1% photovoltaic. The total capacity has increased by 64.2% in 2023 compared to 2005, from 676 GW to 1,110 GW. The nuclear capacity is the only one with a notable reduction, from 123 GW to 101 GW (-18%). It is also noteworthy the increase of bioenergy net capacity from 15.8 GW in 2005 to 36.7 GW in 2023, representing 9.5% of total thermoelectric capacity. All main countries experienced considerable decreasing share of the thermoelectric capacity since 1990, as well as for nuclear capacity (except Czechia and Romania).

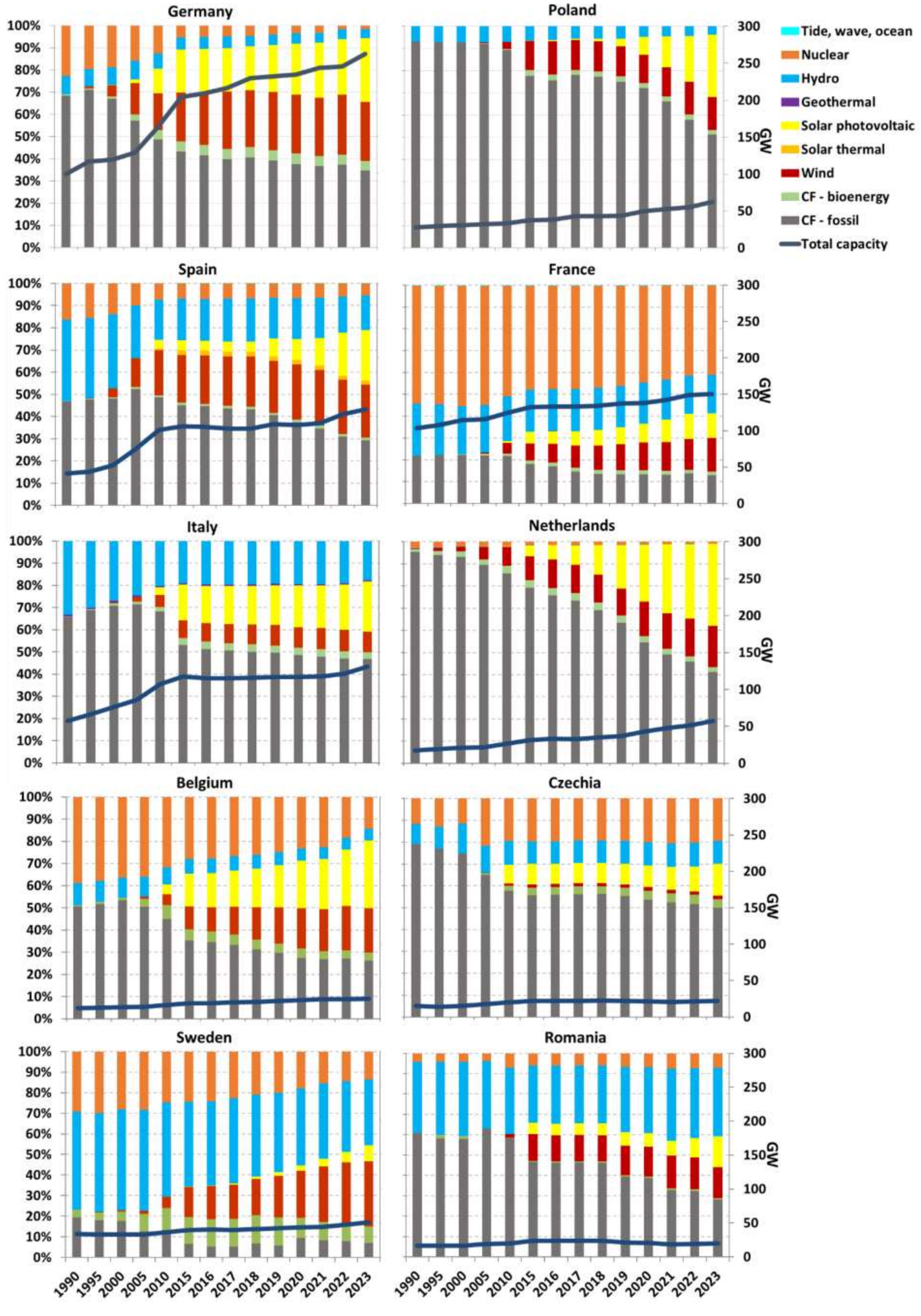
Figure 2.60 – Power capacity trend (blue line – right axis) and share by source in EU27 (bars – left axis). CF=Combustible fuels.



The power capacity among countries is very heterogeneous. In Poland, the thermoelectric plants cover about half of power share. The nuclear plants, which are not present in Italy and Poland among the main countries, make up significant share of the capacity in France (40.9% in 2023), Sweden (13.6%), Belgium (14.4%), and Czechia (19.4%); the share of nuclear plants in the other countries ranges from 0.9% in the Netherlands to 7.1% in Romania. Germany, Sweden, and Belgium recorded a downward trend of nuclear power capacity in the long run.

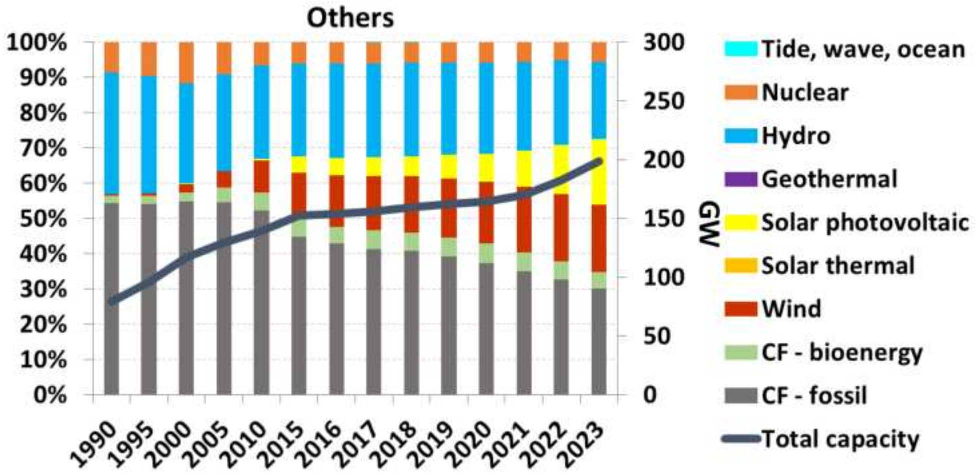
Since 1990, hydroelectric capacity has accounted for a considerable share of traditional renewable sources in Romania, Spain, France, Italy and Sweden. Wind power has increased in all countries since 2005. Photovoltaic plants begun to have significant shares only after 2010 and in 2023 is the most relevant renewable source in EU27.

Figure 2.61 – Power capacity trend (blue line – right axis) and share by source in the biggest European countries (bars – left axis). CF=Combustible fuels.



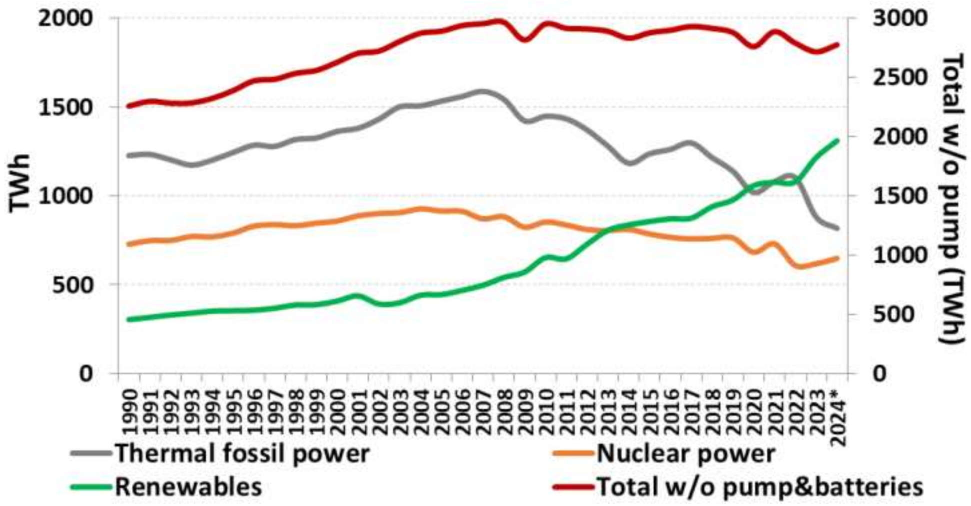
The group of smallest countries has 22% of hydro capacity in 2023, while the combustible fuels plants are 30.1% and nuclear plants are 5.6%. Wind and photovoltaic capacities are 19.1% and 18.5%, respectively.

Figure 2.62 – Power capacity trend (blue line – right axis) and share by source in the others European countries (bars – left axis). CF=Combustible fuels.



Gross electricity production without pumping in EU27 increased from 1990 to 2015 with an average rate of 1% per year, in the following years up to 2019 wide oscillation was recorded, with 2019 level approximately the same of 2015. In 2020 the electricity fell, due to measures adopted to contain SARS-CoV-2 pandemic. In 2021 there was a recovery (+4.6% compared to 2020), followed by a new slowdown in the next two years (-3.3% per year up to 2023 compared to 2021). From 2015 to 2023 the annual average rate has been -0.7%. Preliminary data on gross electricity production by source show that at European level the electricity in 2024 increased by 2.2% compared to the previous year. The production by fossil power decreased by 7.3% (solid fuels -14.6%; liquid fuels -3.4%, natural gas -3.3%), like electricity by bioenergy (-1.2%), while nuclear and renewables increased, +4.8% and +9% respectively. Renewable electricity overcame the fossil production since 2022. Electricity from renewable sources outweighed electricity from nuclear plants since 2013.

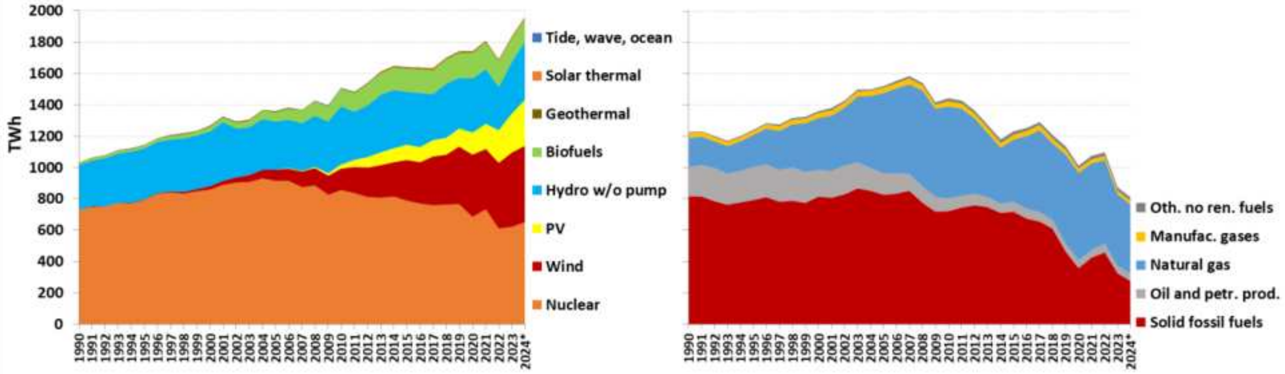
Figure 2.63 – Gross electricity production without pumping in EU27. Wind and PV are included in the green line of renewables.



* Preliminary data.

In Figure 2.64 the European gross electricity production since 1990 is shown at greater detail by renewable sources and fossil fuels.

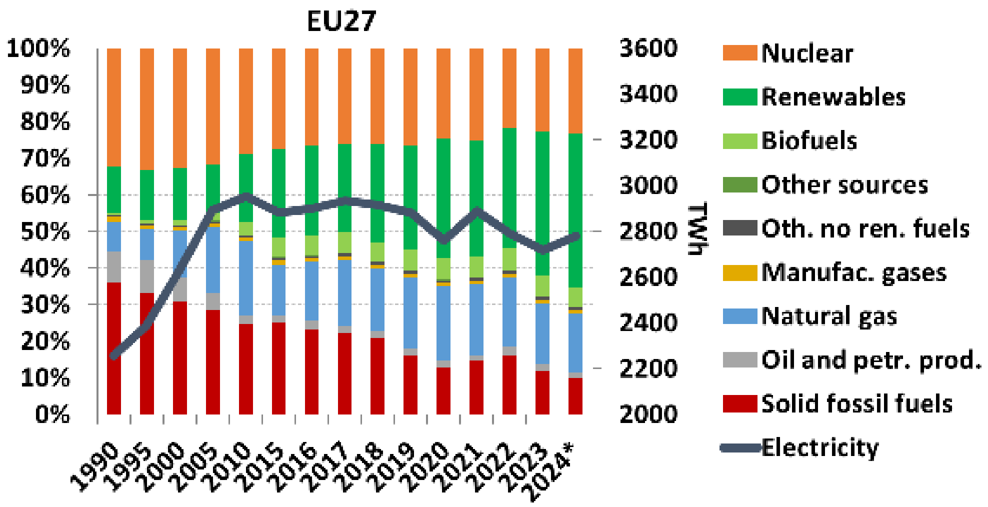
Figure 2.64 – Gross electricity production by sources in EU27.



* Preliminary data.

The share of EU27 electricity production without pumping in 2023 is 11.9% from solid fuels and 16.9% from natural gas. Oil and petroleum products account for less than 1%. All mentioned shares are lower than the levels recorded in 2022. Nuclear source accounts for 22.8%, just one percentage point over the previous year, while renewable energy (renewables and biofuels) is 44.8%, more than six percentage points over the previous year. All considered countries, except Germany and Romania, increased the electricity production since 1990, from 13.7% in Sweden to 85% in Spain. In Romania and Germany, the electricity production decreased by 10.6% and 7.5%, respectively. Preliminary data for 2024 show the further shrinking of fossil share, particularly evident for solid fuels (from 11.9% in 2023 to 9.9% in 2024). The share for natural gas decreases to 16%, while electricity by nuclear power and renewables reaches 23.4% and 47.3%, respectively.

Figure 2.65 – Gross electricity production without pumping (blue line – right axis) and share by source in EU27 (bars – left axis).



* Preliminary data.

The energy mix in the examined countries is quite heterogeneous, mainly as far as fossil fuels are concerned. In 2023, solid fuels make up 59.5% of electricity production in Poland, 39.4% in Czechia, and

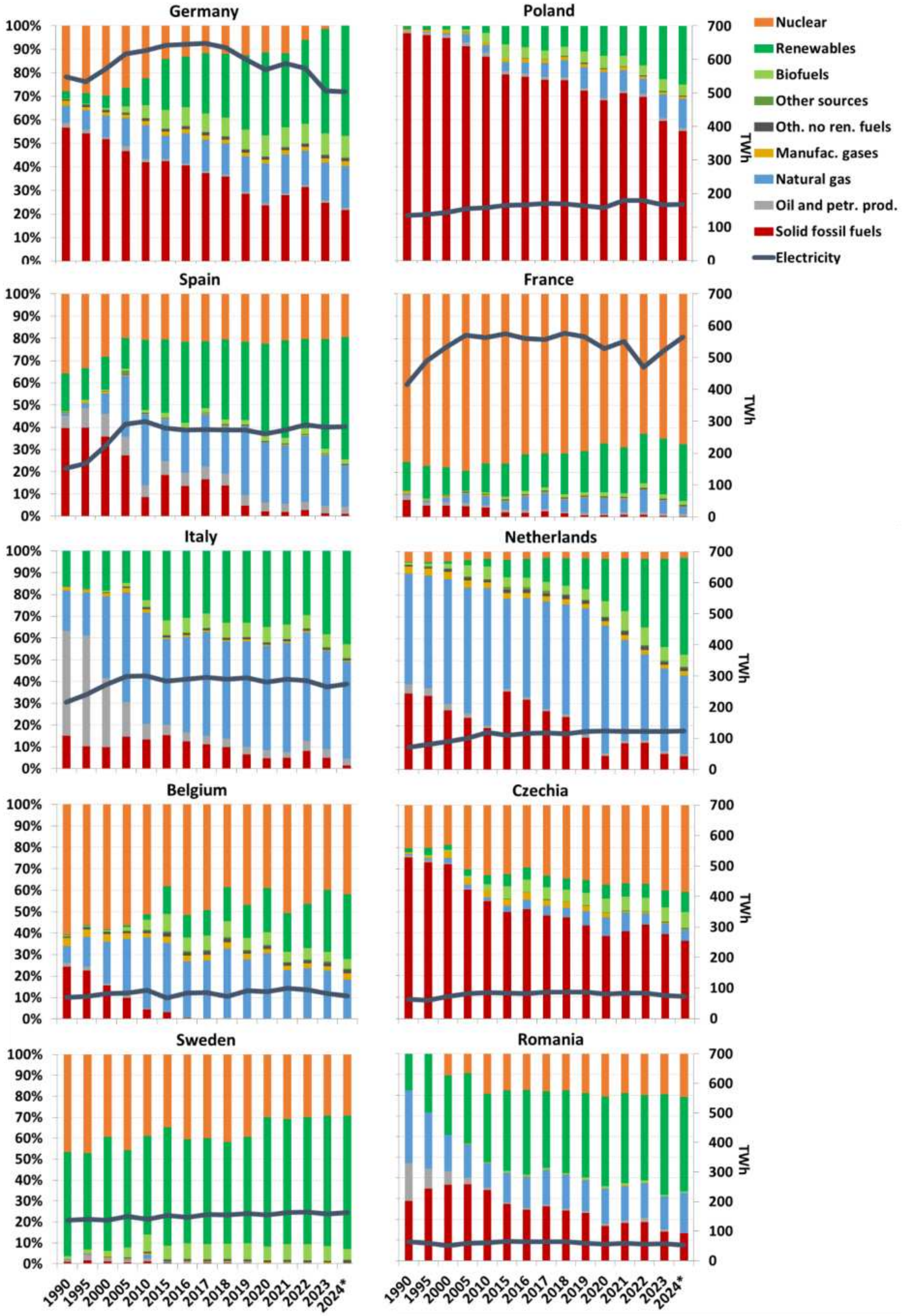
24.7% in Germany. Data of 2024 shows further contraction of solid fuels shares in Poland (55.2%), Czechia (36.4%), and Germany (21.7%).

France has the highest share of electricity production from nuclear plants in Europe (65% in 2023), followed by Belgium, Czechia (both with 40%), Sweden (29.2%), Spain (20.3%), and Romania (19.5%). In the other biggest countries, the nuclear electricity ranges from 1.3% in Germany to 3.3% in the Netherlands. Poland and Italy do not have nuclear plants. At EU27 level, the share of nuclear provides 22.8% of electricity with a downward trend since 1990, when it was 32.3%. The downward trend stopped in 2022, with 21.8%, and in the last years there is an upward tendency. The absolute production of electricity by this source increased quite constantly from 1990 to 2004, then a downward trend has been recorded with wide oscillation in the last years and an increase of electricity produced since 2023. The increasing trend in the last year has been mainly driven by France, the only country among the biggest, and the group of minor countries. All other countries recorded steady or decreasing nuclear production. In France the increase of nuclear electricity is not associated with an increase of power in 2023, while new nuclear capacity has been recorded in the group of minor countries.

Italy and the Netherlands have the highest share of electricity by natural gas in 2024, 44.7% and 35.9% respectively. Italy experienced a massive transition of its thermal power plants since 1990 with a sharp shrink of oil and petroleum products and the corresponding expansion of natural gas. Solid fuels show significant contractions in all countries although some countries as Germany, Poland, and Czechia still have relevant shares of such fuels, as already mentioned.

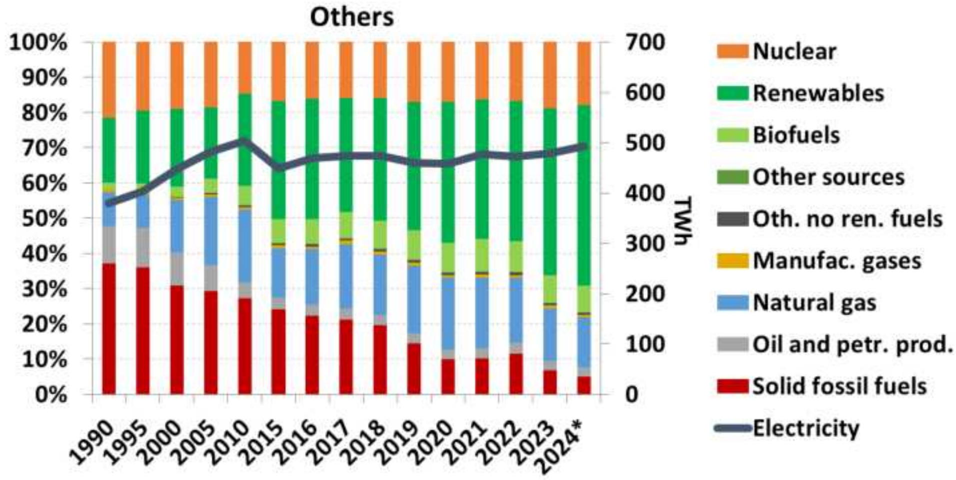
The renewable electricity share in EU27 has increased from 13.4% to 44.8% from 1990 to 2023, with further increase in 2024 (47.3%). Since 2005 the renewable share has shown a quite steady increasing trend. All countries recorded a notable increase of renewable electricity production with a strong acceleration since 2005 up to 2013 (average rate 7.8% per year). After 2013 the average growth rate slowed down up to 2017 (2.1% per year) and has resumed in recent years (6% from 2017 to 2024), with different rates among the States. Sweden has one of the highest renewable shares in Europe (69% in 2024), followed by Spain and Germany, with 57.2% and 56% respectively. Italy’s renewable share reached 49.3% in 2024.

Figure 2.66 – Gross electricity production (blue line – right axis) and share by source in EU27 (bars – left axis).



* Preliminary data.

Figure 2.67 – Gross electricity production (blue line – right axis) and share by source in the others European countries (bars – left axis).

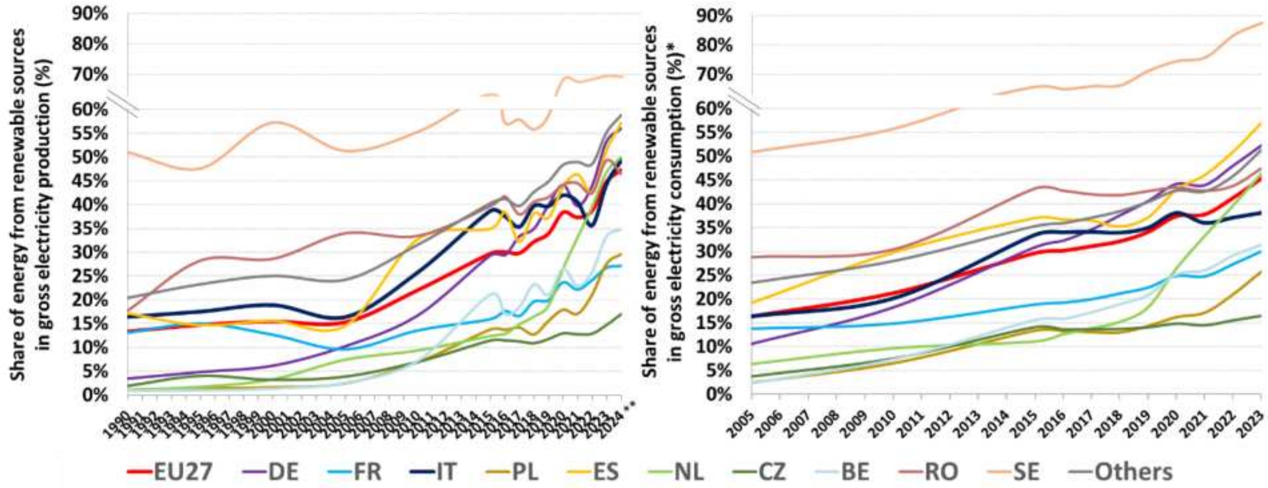


* Preliminary data.

Figure 2.68 shows the trend of renewable share in gross electricity production without pumping and gross electricity consumption, as required by European targets. Sweden has one of the highest shares in Europe. At European level the share has been growing rapidly since 2005. The Italian figures, as for electricity production, are higher than the EU27 average up to 2021. In 2022 Italy's renewable share is below the EU27 average (35.6% *vs* 38.7%) because of the serious lack of hydroelectricity. Preliminary data for 2024 show that Italy returns over the European average. The Netherlands recorded an astonishing surge of renewable share since 2019.

The renewable share for the achievement of the European targets in accordance with the Directive 2009/28/EC (up to 2020) and Directive (EU) 2018/2001 (up to 2030), refers to gross inland consumption of electricity, i.e., electricity production without electricity from pumping plus the net import of electricity. No provisional data are available for 2024. The available data show that Italy' share in 2023 is well below the European average (38.1% *vs* 45.3%). The countries with higher share than the European average are Sweeden (87.5%), Spain (56.9%), Germany (52.3%), Romania (47.4%), and the Netherlands (46.4%). For net importing countries, as Italy, the share of renewable electricity consumption is lower than the share of renewable electricity production.

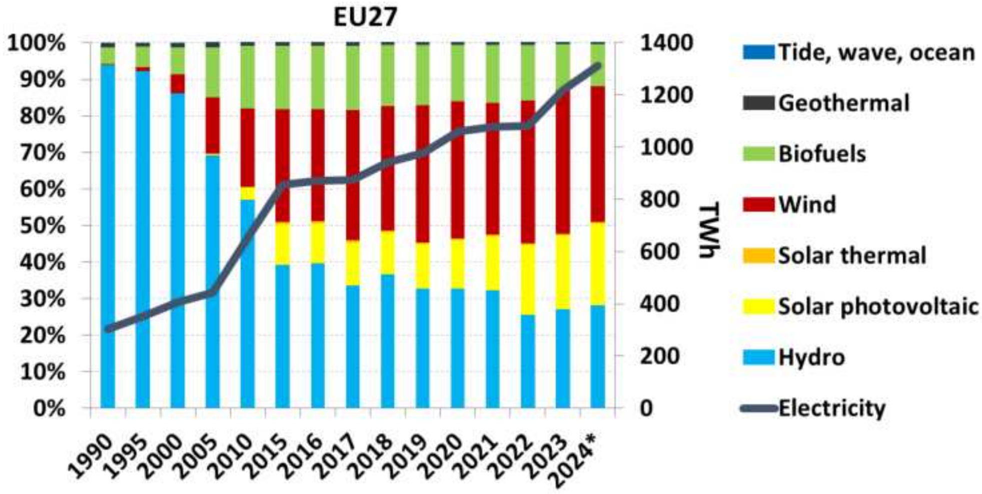
Figure 2.68 – Renewable share in gross electricity production (left side) and gross electricity consumption since 2005 (right side).



* Data until 2020 are based on Directive 2009/28/EC, while data from 2021 onwards follow Directive (EU) 2018/2001. ** Preliminary data.

Figure 2.69 shows in more details the renewable electricity production without pumping and the shares of sources. All the countries examined show marked increase of renewable electricity production with a strong acceleration since 2005, with an average rate of 5.9% per year up to 2024.

Figure 2.69 – Renewable share in gross electricity production by source (left side), and total renewable gross electricity production in EU27 (right side).



* Preliminary data.

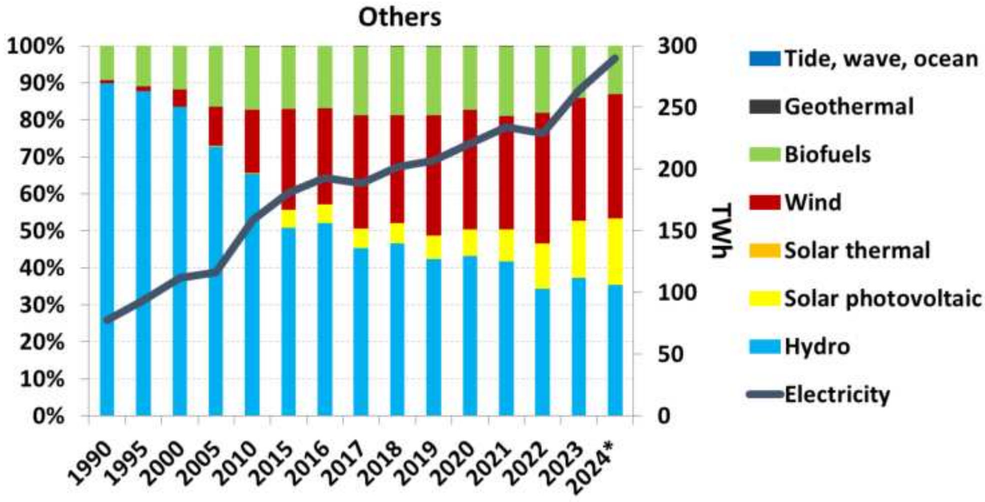
In 1990, almost all renewable electricity was from hydroelectric (94% in EU27). Countries show different development trends for the renewable sources related to the peculiarities of their power systems and national circumstances. Hydropower continues to cover more than a quarter of Europe's renewable production, with a share of 28.1% in 2024. In 2022 the hydropower has been hit by the serious drought which mainly affected the Mediterranean countries, as Italy, France, and Spain. Such countries recovered their hydro production in 2024 approaching their tops.

Among the examined countries, in 2024 hydroelectric power supplies about 55% of renewable production in Sweden and 58% in Romania, but the shares recorded in France, Italy, Czechia, and Spain are not less relevant (respectively 47%, 39%, 22%, and 21%). In the group of minor countries, the hydropower supply is over 35%. Such figures and the severe fall of electricity by hydro recorded in 2022 witness the relevance of a source which is volatile and sensitive to drought. The wind source shows considerable development in almost all countries, with shares going in 2024 from 26.2% in Romania to 54.5% in the Netherlands. At the lowest end there are Italy (16.7%) and Czechia (5.8%). Solar electricity (photovoltaic and solar thermal) plays a significant role in all countries, from 26.3% in Germany to 36.2% in Spain. At the lowest end there are France (15.4%), Romania (14%), and Sweeden (3.5%). Bioenergy covers 43.6% of renewable production in Czechia, followed by Germany with 16.4% and Poland with 15.5%. Italy, Belgium, and the Netherlands are between 10.8% and 13.1%. All other biggest countries range between 1.7% in Romania and 7.8% in Sweden. The long run of electricity from biofuels shows a downward trend in almost all countries. Among the countries under examination, the geothermal source is present with relevant share only in Italy (4.2% in 2024).

Figure 2.70 – Renewable share in gross electricity production by source (left side), and total renewable gross electricity production in the selected countries (right side).

* Preliminary data.

Figure 2.71 – Renewable share in gross electricity production by source (left side), and total renewable gross electricity production in the other countries (right side).



* Preliminary data.

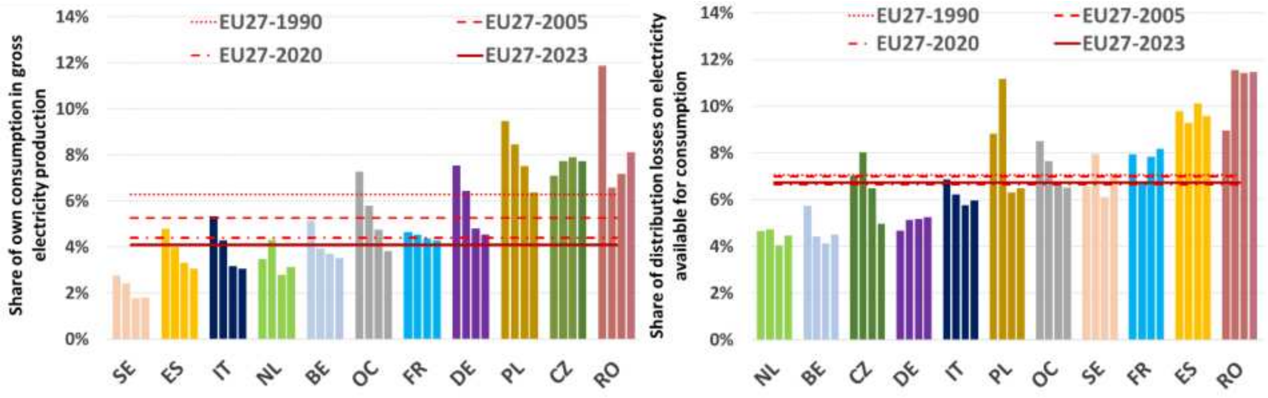
2.2.2 Efficiency of thermal power plants

The performance of the countries' power sectors will be compared through parameters such as the share of own consumption, the distribution losses and above all the transformation efficiency of the fuel energy to produce electricity and heat. In the case of cogeneration plants, it should be considered that not all the electricity and heat produced in such plants can be regarded to as cogeneration production. However, it is reasonable to compare the overall efficiency of the thermoelectric plants in different countries in terms of the transformation of the fuel energy into the final products regardless of the way in which the plants were used. In this respect, the distinction between cogeneration and non-cogeneration plants was made considering the activities classified by Eurostat: "combined heat and power" and "electricity only".

Own consumption is the consumption of electricity utilities functional to the electricity production and is an indicator of the energy required by the electricity generation system. The share of own consumption in Italy has always been below the EU27 average (3.1% *vs* 4.1% in 2023). In general terms, thermoelectric, geothermal and nuclear generation are the sources with the greatest demand of energy, while renewable sources, such as hydroelectric, wind and photovoltaic, have very low own consumption. The greatest own consumption in thermoelectric plants is related to plants powered by solid fuels and bioenergy, less energy is required by plants fuelled by oil and petroleum products, and even less own consumption is required by plants fuelled by natural gas. Therefore, in addition to the efficiency, a decisive parameter is represented by the fuel mix used by each country.

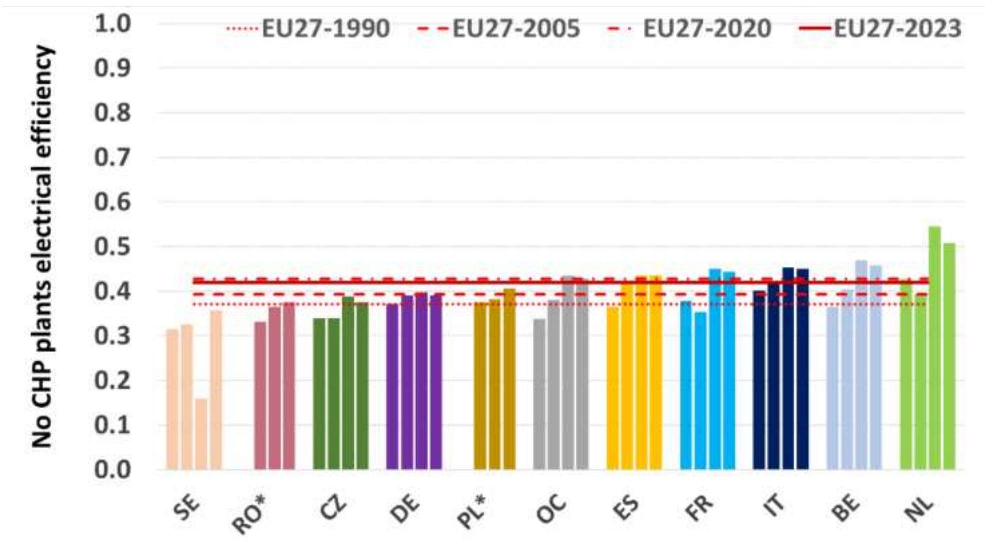
On the other hands, distribution losses give insight on the network performance, higher losses determine higher electricity production to supply the electricity demand. In 2023 the distribution losses compared to the electricity available for final consumption in Italy are lower than the EU27 average (6% *vs* 6.7%).

Figure 2.72 – Own consumption compared to gross electricity production (left side) and distribution losses on electricity available for final consumption (right side). For each country the three bars refer to 1990, 2005, 2020, and 2023. Data in ascending order of 2023 value. OC – Other countries.



The most important parameter to assess the efficiency of power systems is the transformation efficiency of fuels into electricity and heat. The electrical efficiency of Italian non-cogeneration plants shown in the following Figure 2.73 is just over the EU27 average (0.45 *vs* 0.419 in 2023).

Figure 2.73 – Electrical efficiency of no CHP plants. For each country the three bars refer to 1990, 2005, 2020, and 2023. Data in ascending order of 2023 value. OC – Other countries.



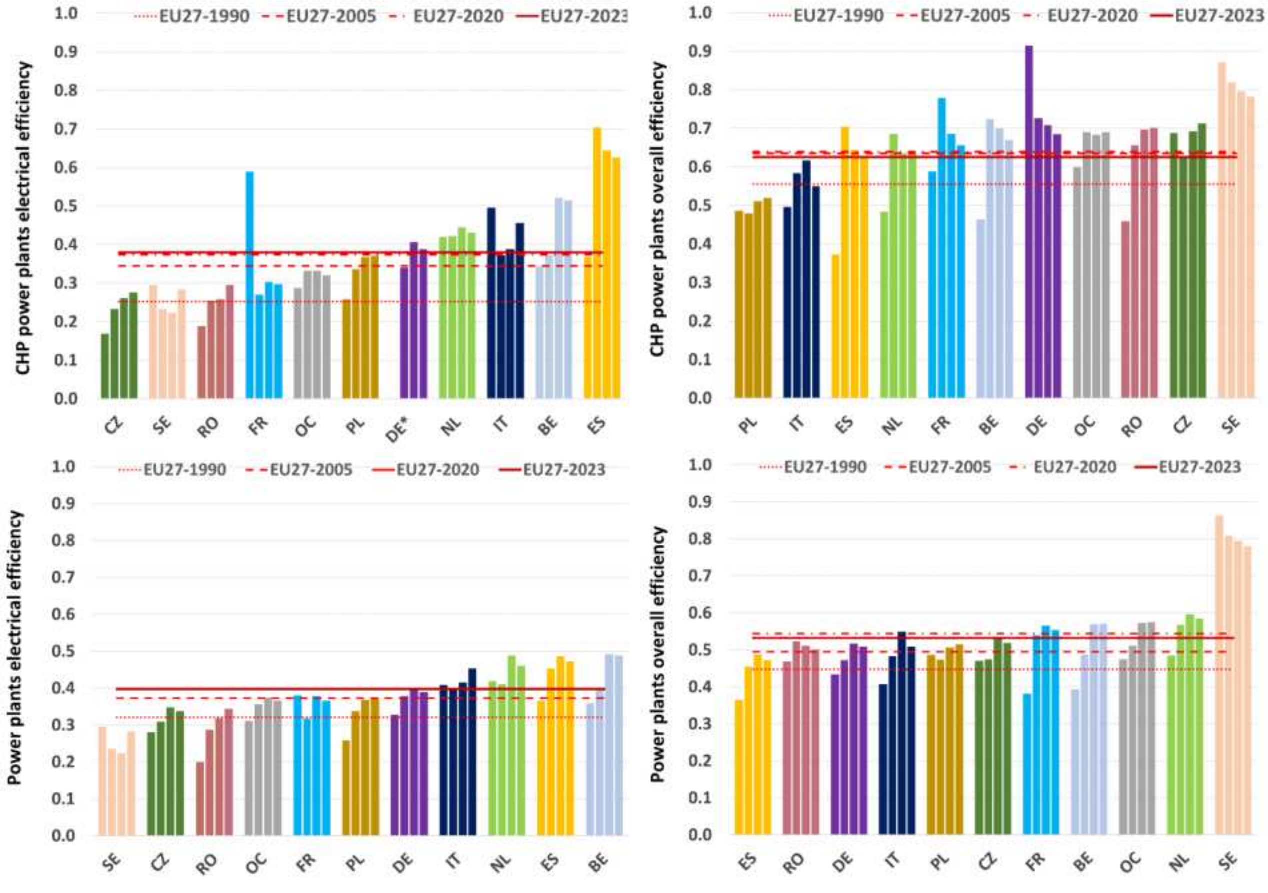
* 1990 not available.

As for CHP plants, the electrical efficiency in Spain shows the highest value among the main European countries (0.625), far higher than the EU27 average (0.38). Italy's electrical efficiency is 0.456. The total efficiency, for electricity and heat production, of the Italian cogeneration plants (0.55) is below the EU27 average (0.625).

The Italian electrical efficiency for all power plants (CHP and electricity only) in 2023 is 0.453, exceeded by the Netherlands, Spain, and Belgium, from 0.461 to 0.489. Sweden has the lowest electrical efficiency among the examined countries (0.283), well below the EU27 average (0.397). The overall efficiency of Italian plants, for electricity and heat production, is 0.509, below the EU27 average (0.532). Sweden shows the highest value (0.781), due to the highest ratio between heat and electricity recorded in this country in CHP plants (about 1.76), followed by Czechia (1.59). Italy is at the lowest end together with 0.21, while

Spain does not report heat production so there is no difference between electrical efficiency and overall efficiency for such country.

Figure 2.74 – Electrical and overall efficiency of CHP plants (up) and all power plants (down). For each country the three bars refer to 1990, 2005, 2020 and 2023. Data in ascending order of 2023 value. OC – Other countries.

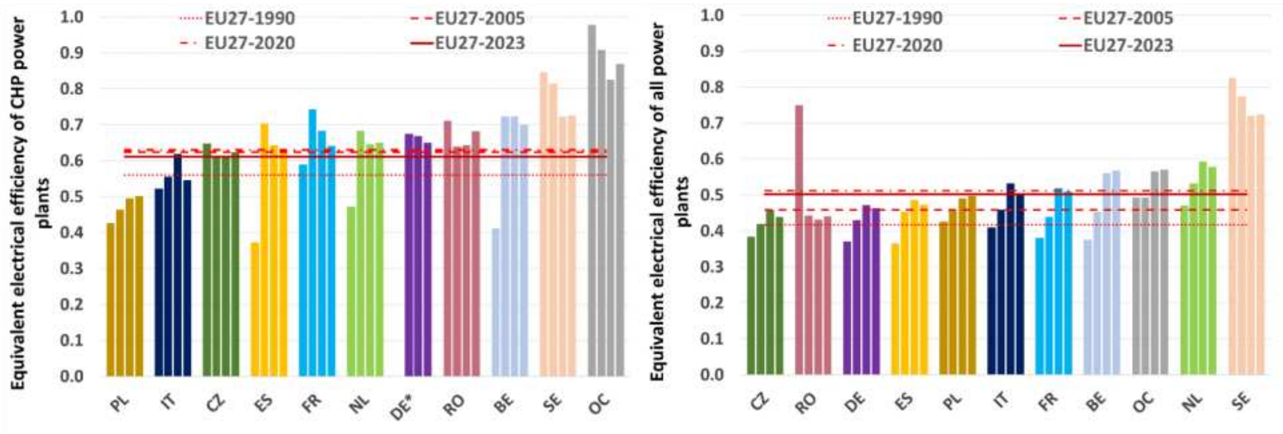


* 1990 not available.

The equivalent electrical efficiency of CHP plants, calculated after unbundling the share of fuels for heat production, is 0.546 in Italy, below the EU27 average (0.612). The values range from 0.501 in Poland to 0.726 in Sweden, while the average in the smallest countries is 0.869.

As for the equivalent electrical efficiency for all power plants in 2023, Italy (0.503) is near the European average (0.502). Sweden shows the highest value among the biggest countries (0.724). The average efficiency in the group of smallest countries is 0.57.

Figure 2.75 – Electrical and overall equivalent electrical efficiency for CHP plants (left) and all power plants (right). For each country the three bars refer to 1990, 2005, 2020, and 2023. Data in ascending order of 2023 value. OC – Other countries.



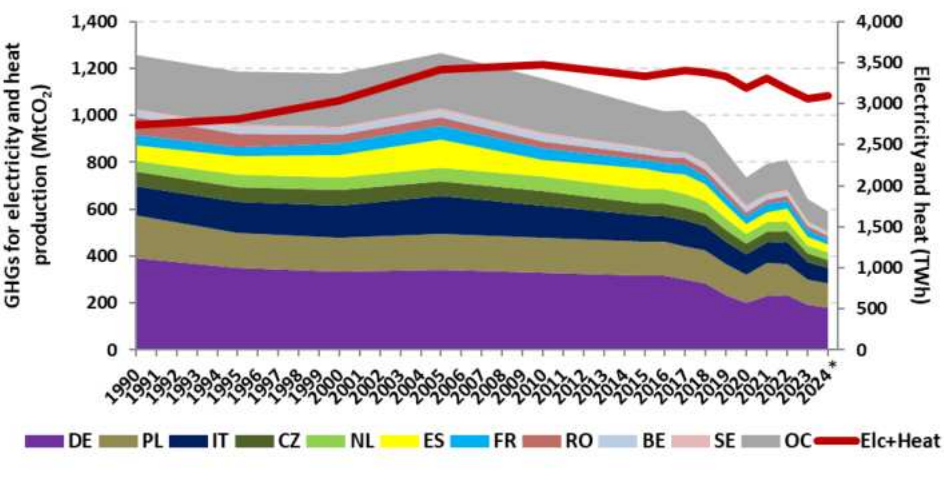
* 1990 not available.

2.2.3 GHGs from the power sector

The Tier 1 approach has been adopted to estimate the GHGs from the power sector of countries. Tier 1 methodology with default emission factors for the fuels consumed is adopted only to carry out international comparison. Such purpose requires a common methodology for the States. Moreover, the energy balance here adopted follows Eurostat allocation methodology concerning the self-production of heat. As already mentioned, such methodology requires that only the energy to produce the heat transferred to third parties is accounted in transformation, while the energy for heat self-production is accounted in industry. Italy complied such criteria since the 2024 submission starting, the revision of figures from 2021. A country specific approach, with national emission factors, is available for Italy (ISPRA, 2025c).

Since 1990 there has been a decoupling between electricity production and GHGs by power sector in almost all European countries, although emissions show a significant decrease only after 2005, with an increasing decoupling mainly due to the growing share of renewables. The following graph shows the cumulated contribution of each country to the EU27 GHGs by power plants and the trend of gross electricity and heat production.

Figure 2.76 – Contribute of EU27 countries to GHGs and gross electricity and heat production from thermal power plants.



* Preliminary data.

Preliminary data show that in 2024 the GHGs by power sector recorded decreased by 8.2% compared to the previous year (Table 2.2). GHGs for electricity and heat production are 592.4 Mt CO_2eq in 2024, 52.9% lower than 1990 level and 53.1% lower than 2005 level. Since 2005 a significant reduction of GHGs begun to take place. Overall, in 2024 the GHGs from power sector in the selected countries (505.1 Mt CO_2eq) account for 85.3% of EU27 sector's emissions and Italy's share is 10.9%.

Table 2.2 – GHGs estimated (Mt CO_2eq) for electricity and heat production in thermal power plants. Countries in descending order of 2024 value.

Source	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024*
EU27	**1256.6**	**1187.7**	**1177.4**	**1264.2**	**1157.1**	**1037.5**	**733.6**	**795.4**	**808.0**	**645.3**	**592.4**
Germany	393.3	350.5	333.1	341.5	327.5	318.3	201.5	230.1	235.3	191.2	180.1
Poland	181.4	150.2	146.7	154.5	149.4	142.9	119.8	138.9	132.7	109.3	105.2
Italy	123.3	130.4	137.0	160.1	137.0	110.6	88.8	87.1	95.2	74.2	64.3
Czechia	63.8	64.1	64.0	64.5	63.0	53.8	42.3	45.2	46.0	37.8	33.5
Spain	66.4	77.5	98.1	117.7	71.4	84.3	42.3	42.7	50.9	38.7	33.4
Netherlands	45.0	52.5	53.6	57.7	61.0	62.0	43.3	44.0	40.8	33.3	32.9
France	46.4	38.4	48.7	59.1	49.9	37.3	32.2	34.1	36.0	27.9	22.6
Romania	73.2	56.8	37.5	36.2	31.2	27.5	18.1	19.1	18.0	14.9	13.8
Belgium	26.2	28.3	26.0	25.9	23.8	18.0	16.4	15.3	15.6	12.9	12.0
Sweden	5.3	9.0	8.3	10.7	13.1	9.1	9.1	10.2	9.6	7.7	7.3
Others	232.1	229.9	224.4	236.4	229.9	173.7	119.7	128.7	127.9	97.2	87.3

* Preliminary data.

GHGs emissions factor for electricity and heat production due to fuel combustion in thermal power plants reduced since 1990. In 2024 the emissions factor in Italy, 371.1 g CO_2eq/kWh, is lower than EU27 average, 461.1 g CO_2eq/kWh. The European average reduction since 2005 (-23.2%) ranges from -8.3% in Romania to -29.2% in Italy.

Table 2.3 – GHGs emission factors for electricity and heat production by thermal power plants (g CO_2eq/kWh). Countries in descending order of 2024 value.

Source	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024*
EU27	**726.9**	**706.7**	**655.6**	**600.8**	**557.5**	**565.4**	**457.1**	**478.0**	**491.1**	**470.5**	**461.1**
Czechia	785.8	785.7	740.6	766.8	748.7	696.1	618.1	620.1	653.0	624.4	603.9
Poland	723.4	760.6	749.4	723.5	713.3	704.0	633.8	659.1	667.5	618.1	603.1
Romania	587.9	548.3	562.3	589.0	615.0	595.5	561.5	551.4	562.8	558.3	540.4
Germany	784.9	779.8	745.4	681.2	638.3	635.8	515.5	537.1	558.8	536.8	518.7
Belgium	877.6	818.6	649.0	583.5	455.4	446.8	401.1	419.9	437.4	434.8	501.2
Spain	928.8	893.6	780.2	628.6	501.6	653.8	451.1	447.1	450.9	456.8	464.1
Netherlands	572.6	505.8	448.8	445.6	411.4	496.3	373.5	400.7	412.1	388.9	404.2
France	951.5	855.7	547.0	519.2	576.7	507.7	379.8	393.1	362.7	360.3	383.2
Italy	691.7	666.3	623.8	523.9	477.8	441.1	370.0	414.1	436.2	407.8	371.1
Sweden	340.3	276.1	267.4	254.5	212.5	179.5	188.5	181.3	178.3	197.8	217.1
Others	666.1	656.8	597.8	560.9	522.1	512.7	398.7	399.6	420.5	384.7	365.6

* Preliminary data.

GHGs for electricity production have been estimated after unbundling the fuel energy consumption for heat production in CHP plants according to the methodology proposed by Eurostat (2016). EU27 GHGs in 2024 are 492.9 Mt CO_2eq and the countries examined account for 85.8%.

Table 2.4 –GHGs estimated (Mt CO_2eq) for electricity in thermal power plants. Countries in descending order of 2024 value.

Source	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024*
EU27	**991.1**	**989.1**	**1014.3**	**1068.3**	**969.6**	**881.5**	**598.1**	**664.6**	**687.4**	**536.7**	**492.9**
Germany	350.5	322.8	306.4	308.1	293.4	288.1	176.8	202.7	209.7	167.1	156.5
Poland	110.5	108.0	109.9	115.2	112.3	109.2	90.0	106.7	103.2	82.5	80.1
Italy	122.7	129.8	134.4	141.7	116.7	91.2	70.0	79.6	88.2	67.3	57.5
Spain	66.4	77.5	98.1	117.7	71.4	84.3	42.3	42.7	50.9	38.7	33.4
Netherlands	40.9	42.1	42.0	45.6	48.2	53.4	36.9	37.7	34.9	28.0	27.8
Czechia	46.2	43.3	49.8	48.4	46.5	41.5	31.8	34.3	36.3	29.2	26.0
France	46.4	37.0	40.9	45.6	43.1	31.7	25.6	27.6	29.0	21.5	17.2
Romania	16.9	25.5	20.6	24.8	23.0	21.1	14.2	15.4	14.6	12.2	11.1
Belgium	25.2	27.3	24.9	23.5	21.3	15.9	14.7	13.5	14.1	11.5	10.8
Sweden	1.7	3.4	3.3	3.6	4.8	2.7	2.7	3.2	3.1	2.8	2.4
Others	163.7	172.4	184.1	194.0	188.8	142.4	93.3	101.2	103.3	75.8	70.2

* Preliminary data.

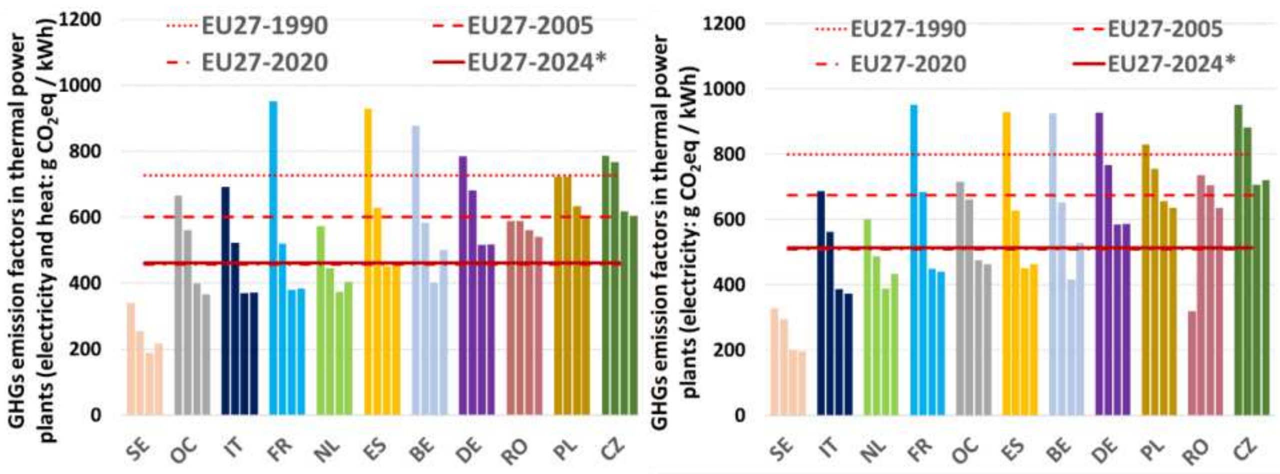
Italian emissions factor for thermal plants in 2024 (372.3 g CO_2eq/kWh) is well below the EU27 average of 513.4 g CO_2eq/kWh. Czechia, Romania, and Germany have the top four emission factors, from 719.9 g CO_2eq/kWh to 587.2 g CO_2eq/kWh, much higher than the European average.

Table 2.5 – GHGs emission factors for electricity production by thermal power plants (g CO_2eq/kWh). Countries in descending order of 2024 value.

Source	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024*
EU27	**799.4**	**783.5**	**729.1**	**674.3**	**623.6**	**639.0**	**508.7**	**533.3**	**544.5**	**523.7**	**513.4**
Czechia	952.3	934.0	865.4	882.8	868.7	812.2	707.0	719.1	767.2	739.7	719.9
Romania	319.4	601.7	657.1	736.3	797.4	739.2	705.7	695.1	675.6	665.1	635.8
Poland	830.8	799.0	779.3	754.5	736.9	721.0	655.6	682.9	694.7	644.9	634.7
Germany	928.1	906.0	824.6	767.1	710.7	702.1	584.7	610.2	629.0	611.0	587.2
Belgium	924.8	858.9	730.4	652.4	497.2	479.7	415.7	440.1	458.4	454.5	528.8
Spain	928.9	893.5	780.0	628.6	501.6	653.8	451.1	447.1	450.9	456.8	464.1
France	951.5	917.0	770.4	683.4	693.8	618.6	449.4	474.0	415.6	420.4	440.5
Netherlands	600.4	550.6	497.5	487.9	434.7	556.3	389.0	427.2	444.0	414.5	433.7
Italy	688.3	663.0	611.6	562.4	506.4	476.6	387.3	421.0	444.2	415.4	372.3
Sweden	327.3	339.6	368.0	294.7	232.8	191.1	198.3	198.0	196.4	201.9	196.2
Others	716.0	715.3	697.9	660.6	634.3	637.3	476.1	482.1	504.5	471.6	462.5

* Preliminary data.

Figure 2.77 – GHGs emission factors in thermal power plants (g CO_2eq/kWh). For each country the bars refer to 1990, 2005, 2020, and 2024. Data in ascending order of the 2024 value. OC – Other countries.



* Preliminary data.

The emission factors for total electricity and heat production by the whole power sector, including all renewables and nuclear power production, in Italy are higher than the European average (221.2 *vs* 191 g CO_2eq/kWh). All countries with lower emission factors than Italy have relevant amount of electricity by nuclear plants and/or higher renewable share. The average EU27 emissions factor shows a reduction of 48.4%, compared to the 2005 level. Italy reduced the emissions factor by 51.6%. Spain recorded the highest reduction rate since 2005, -70.8%, while, on the other side, Poland and Sweden have the lowest ones, -32.1% and -33.4% respectively, but Sweden has the lowest absolute emissions factor, with very lower reduction margin than all other countries. The emissions factor in Germany, which has the highest share of European GHGs by power sector, decreased by -35.4% since 2005.

Table 2.6 – GHGs emission factors for total electricity and heat production (g CO_2eq/kWh). Countries in descending order of 2024 value.

Source	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024*
EU27	**457.2**	**423.1**	**387.9**	**370.3**	**332.9**	**311.1**	**229.9**	**240.5**	**254.5**	**210.6**	**191.0**
Poland	719.2	753.4	741.4	714.6	697.7	662.1	573.3	595.3	579.7	508.3	485.6
Czechia	672.1	669.0	628.9	579.8	543.2	494.3	407.9	414.8	430.1	389.7	363.2
Germany	585.1	559.6	514.4	476.9	450.5	434.4	306.5	336.6	356.1	324.6	308.2
Netherlands	546.1	483.9	430.2	424.4	389.7	445.7	299.8	306.2	287.3	239.0	234.1
Romania	538.6	472.1	431.4	415.1	377.8	329.5	267.2	266.5	272.4	226.8	228.4
Italy	578.6	549.5	507.6	456.8	385.9	324.5	262.9	282.7	315.4	262.0	221.2
Belgium	359.9	370.7	293.4	279.2	231.8	237.7	174.3	145.1	157.0	148.9	153.9
Spain	439.0	468.2	444.0	406.8	239.5	303.6	162.8	157.4	176.9	138.4	118.6
France	111.5	77.7	85.5	95.7	84.9	62.5	57.9	58.9	72.2	51.1	38.7
Sweden	33.8	52.6	49.5	56.9	69.1	45.7	46.0	48.2	45.6	40.1	37.9
Others	460.6	445.5	398.1	384.6	351.9	303.3	210.2	215.3	220.3	167.8	150.5

* Preliminary data.

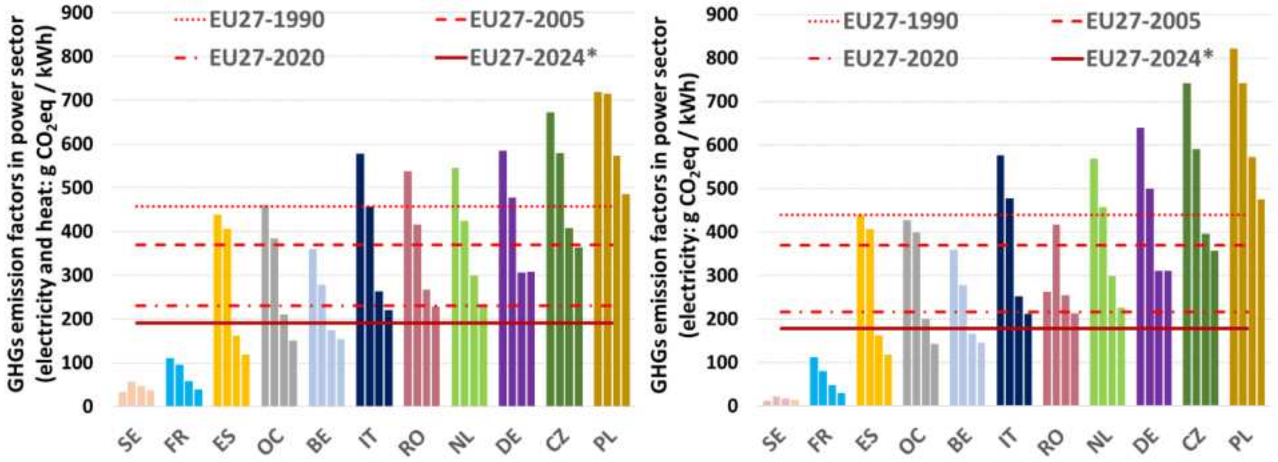
Also considering only the total electricity generation the average EU27 emissions factors have always been below the Italian ones, thanks also to the contribution of nuclear power in the European countries. Italy reduced the emissions factor by 55.7% since 2005, in line with the EU27 rate (-51.9%), while the reduction rates for the other two top emitters, Germany and Poland, are -37.9% and -35.9%.

Table 2.7 – GHGs emission factors for total electricity production (g CO_2eq/kWh). Countries in descending order of 2024 value.

Source	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023	2024*
EU27	**439.1**	**414.2**	**385.8**	**369.2**	**328.1**	**306.1**	**216.6**	**230.0**	**246.2**	**197.5**	**177.5**
Poland	822.0	788.0	767.8	741.7	715.0	664.6	572.3	596.7	577.6	496.6	475.6
Czechia	742.1	714.5	683.2	590.5	544.7	502.0	395.9	409.1	433.1	384.3	357.0
Germany	640.0	605.8	535.4	499.9	468.1	448.4	310.7	345.0	365.9	330.0	310.7
Netherlands	568.5	518.7	468.9	456.4	404.5	484.7	299.1	308.8	286.8	230.9	225.8
Romania	262.7	431.7	399.2	417.1	378.9	320.7	254.9	260.5	262.0	212.6	212.7
Italy	575.8	546.8	497.7	477.4	390.6	324.1	251.4	277.4	312.6	255.7	211.4
Belgium	359.1	371.7	301.2	278.2	228.5	231.3	165.9	135.6	149.2	140.1	145.4
Spain	438.9	468.2	443.9	406.8	239.5	303.6	162.8	157.4	176.9	138.4	118.6
France	111.5	75.6	76.7	80.0	76.5	55.1	48.4	50.1	61.9	41.4	30.5
Sweden	11.9	23.3	22.5	22.8	32.5	16.4	16.5	18.6	18.2	17.1	14.0
Others	426.9	424.4	407.9	399.0	369.9	311.6	200.5	208.5	214.7	155.6	142.3

* Preliminary data.

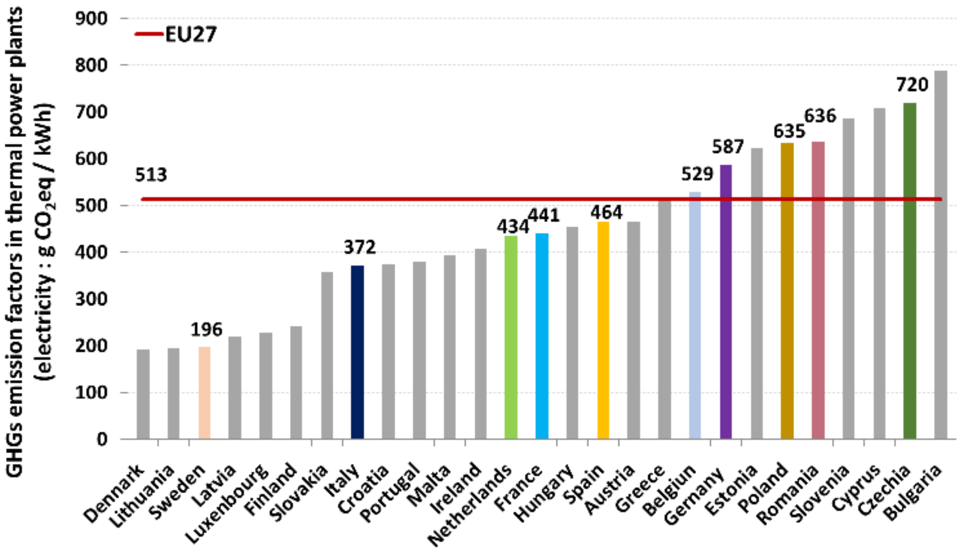
Figure 2.78 – GHGs emission factors in power sector (g CO_2eq/kWh). For each country the bars refer to 1990, 2005, 2020, and 2024. Data in ascending order of the 2024 value. OC – Other countries.



* Preliminary data.

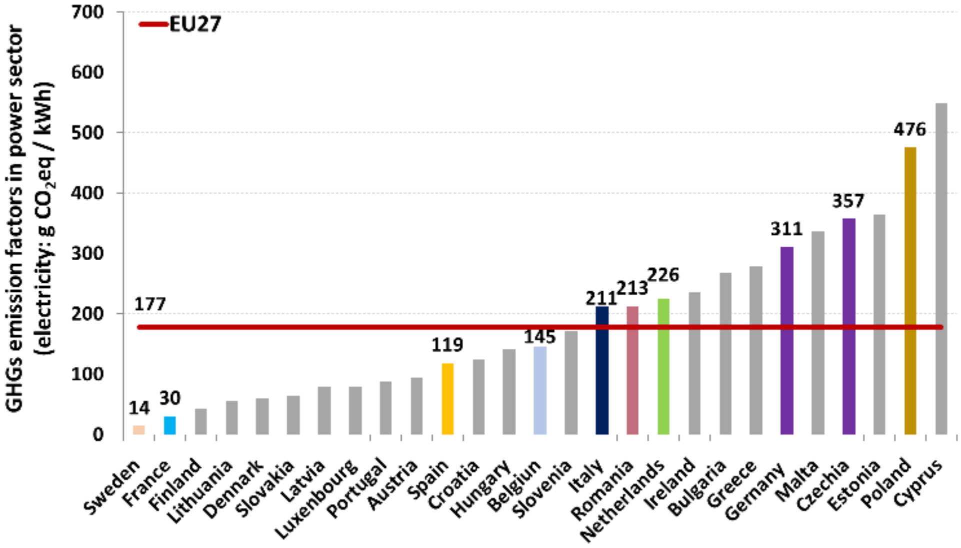
As concerns electricity production the outcomes allow to conclude that, among the biggest European countries, Italy's thermal power plants are in the lowest end of the GHGs emissions factor's range, apart Sweden which have shares of solid and oil fuels much lower than Italy. Italian emissions factor is well below the EU27 average. The Italian fuels mix, with greater share of natural gas than many other countries and the contribution of bioenergy, is a driving factor for the emission factor.

Figure 2.79 – GHGs emission factors in thermal power plants for electricity production (g CO_2eq/kWh) in 2024 (preliminary data). States in ascending order.



On the other side, as for the whole power sector, therefore also considering the no thermal renewables and nuclear power plants, the Italian emissions factor loses positions compared to other countries as France, Belgium, and Spain which have relevant amount of electricity from nuclear power plants without GHGs emissions. Overall, nuclear electricity share in EU27 was 23.4% in 2024 and 86.4% comes from the countries examined, with France accounting for 58.6% of European value. The nuclear electricity plays a key role for the correct interpretation of the emission factors in the countries with higher share of nuclear energy. Remind that the difference between the emission factors in Figure 2.79 and Figure 2.80 for each country is due to the contribution of nuclear and other renewables than bioenergy.

Figure 2.80 – GHGs emission factors in power sector for total electricity production (g CO_2eq / kWh) in 2024 (preliminary data). States in ascending order.

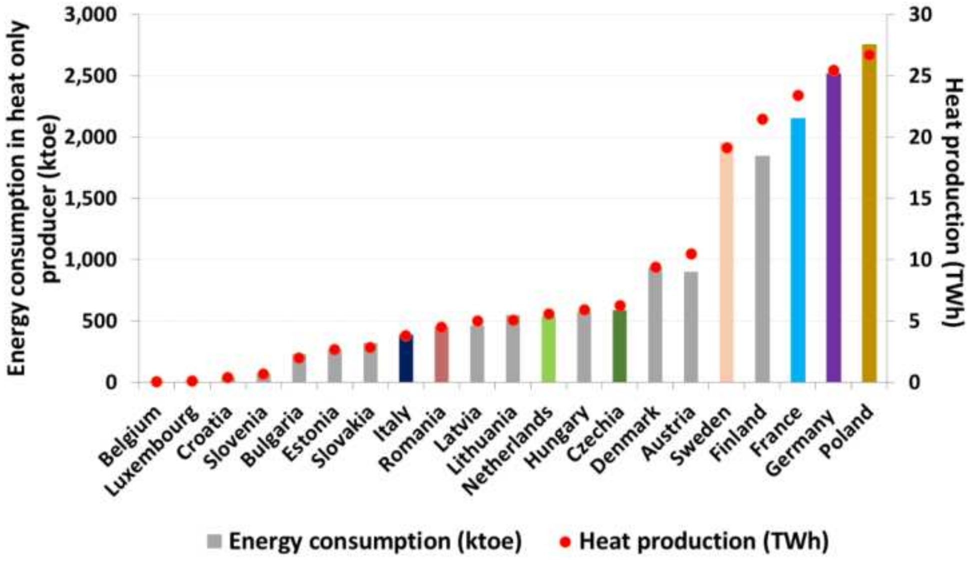


To sum up: as concerns the power sector, Germany, Poland, and Italy are the three biggest emitters in Europe. Because of many factors (fuel mix shift toward lower carbon fuels, increase of efficiency, increasing share of renewables) Italy reduced the emissions factor for electricity production by -63.3% from 1990 to 2024 and by -55.7% since 2005. The reduction in Germany was -51.5% since 1990 and -37.9% since 2005, while the figures in Poland was -42.1% since 1990 and -35.9% since 2005. The three countries account for almost 60% of EU27 GHGs from power sector.

2.2.4 Heat-only producers

Heat production accounts for a significant share of energy transformation processes. Plants dedicated to heat production for district heating and other uses (mainly for industry) consume an important share of the energy in the European balance. In 2023 the energy consumption of such plants in EU27 was 17.6 Mtoe of which 0.7 Mtoe from geothermal and solar thermal, and 0.35 Mtoe from heat pumps. The energy consumption by fuels was 16.5 Mtoe, of which 6.5 Mtoe from bioenergy. The consumption of bioenergy in 2023 is almost 2.5 times the 2005 level and about 9 times the consumption in 1990.

Figure 2.81 – Energy consumption and heat produced by heat-only producers in European countries (2023). Data in ascending order for energy consumption.



Total energy consumption in 2023 is 31.6% lower than that recorded in 1990. A marked fuel shift occurred, with sensible decrease of solid and liquid fuels being replaced by natural gas and bioenergy. The contribution of other renewable sources (geothermal energy and solar thermal) and heat pumps recorded an increasing trend and in 2023 represented 6% of total consumption.

As a result of fuel shift and decreasing energy consumed (-31.6% in 2023 compared to 1990) and heat production (-20.5%), GHGs registered a sharp decrease by 57.2% since 1990. GHGs emissions factor decreased by 46.1%. At EU27 level the GHGs from these plants were 37.2 Mt CO_2eq in 2023. Since 2005 the emissions factor decreased by 26.3% in EU27 (from 279.7 to 206.2 g CO_2eq/kWh).

Figure 2.82 – Energy consumption (left side), GHGs, and average GHGs emissions factor (right side) by source in heat only producer in EU27 (2023).

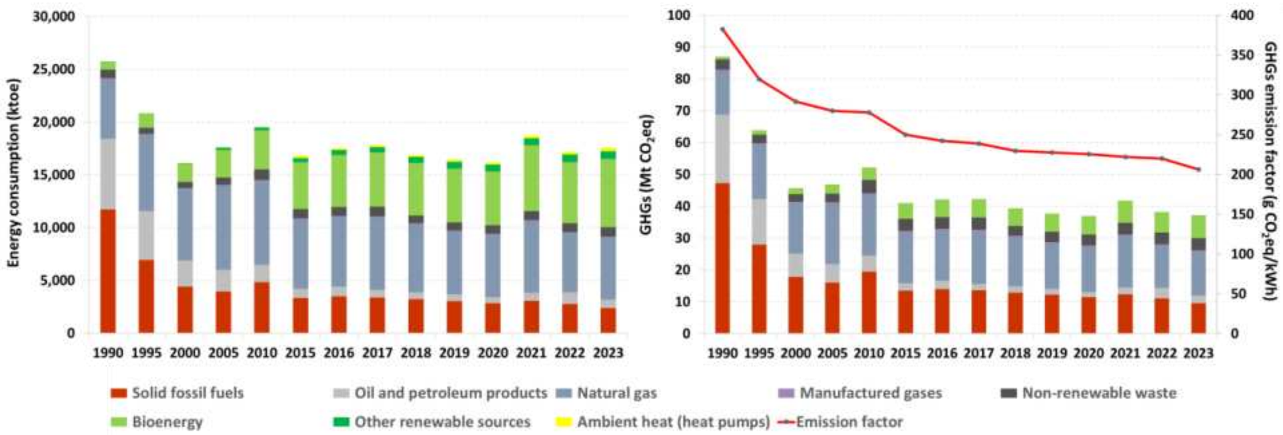
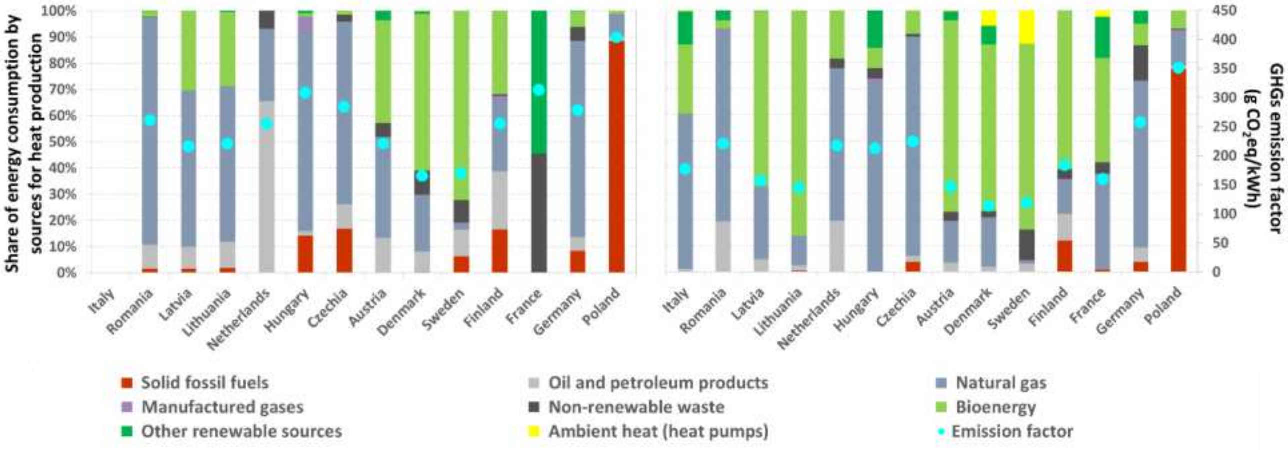


Figure 2.83 shows the share of energy sources and GHGs emissions factor for countries with heat production higher than 3 TWh, accounting for 95.2% of European heat production by heat-only producers. Italy's emissions factor in 2023 is 14% lower than the EU27 average. The relevant solid fuels or non-renewable waste consumption in Poland and Germany results in higher emission factors, respectively 98.1% and 45.4% higher than the Italian one.

Figure 2.83 – Share of energy sources for heat only producer plants and GHGs emission factor in the greatest heat producers in 2005 (left) and 2023 (right). Countries in ascending order of heat produced in 2023.



CONCLUSIONS

National data

The main outcomes of this report can be summarized as follows:

- Gross inland energy consumption increased from 1990 until 2005 when it peaked at 189.4 Mtoe, then there was a reduction accelerated by the economic crisis with the minimum value of 149.8 Mtoe reached in 2014. In 2020 there was a further contraction of energy consumption due to measures aimed to contain SARS-CoV-2 pandemic (-8.9% lower than 2019 level and -4.4% lower than 1990 level). In 2021 it was recorded a rebound of consumption (+8.8% higher than 2020), with 154.1 ktoe, followed by further setback in 2022 and 2023, which is only 0.4% higher than 2020. The renewable share in gross inland consumption grew from 4.4% to 20.5% from 1990 to 2023.
- GHGs increased since 1990 until 2005, the following decrease was accelerated by the economic crisis in 2009. In 2020 GHGs, as well as energy consumption, was heavily affected by lockdown measures. In 2021 and 2022 the GHGs rebounded, although to level below the 2019 level. The GHGs in 2023 decreased by 6.8% compared to the previous year. GHGs in 2023 are 26.4% below the 1990 level, and 35.5% below the 2005 level.
- GHGs from plants subject to EU ETS represent 29.8% of total GHGs in 2023, while GHGs from sectors in ESR are 69.6% of total GHGs. The latter compartment is involved in the national targets of emissions reduction, while the former is subject to market and to emissions cap set at European level. The ETS emissions decreased by 53.6% from 2005 to 2023, while the ESR emissions decreased by 22.6%, to be compared with the national target of -43.7% to achieve in 2030.
- National methane emissions, without the contribution of natural sources, represent on average 10.6%$\pm$0.8% of CO_2eq emissions from 1990 to 2023. Methane emissions without LULUCF decreased from 55 to 45.2 Mt CO_2eq, -17.9%. The reduction of methane emissions is lower than the reduction of total GHGs (-26.9%). Agriculture contributes with 46.1% of methane emissions, while the waste sector accounts for 40.9%. Fugitive emissions make up 6.2%, and unburned methane in the energy sector accounts for 6.8%.
- The trends of gross inland energy consumption (GIC), gross domestic product and GHGs show an increasingly decoupling. Such decoupling is mainly due to fuel shift towards lower carbon content fuels, such as natural gas, and, most of all, to the increasing share of renewable energy since 2007.
- The energy and carbon intensities by GDP decreased since 1995. The gross inland energy consumption per GDP decreased from 101.1 toe/M€ in 1995 to 74 toe/M€ in 2022 (-26.8%). Over the same period, GHGs per GDP fell by 40.5%, from 336.7 t CO_2eq / M€ to 200.3 t CO_{2eq}/M€, while energy GHGs per primary energy goes from 2.81 t CO_2eq/toe to 2.21 t CO_2eq/toe, with a reduction of 21.3%. The average carbon intensities by sector shows notable differences among sectors depending upon the different deployment of renewable sources and electrification of final energy consumption. Transport recorded the highest carbon intensity in the last years with the lowest decrease since 1990.
- The overall decreasing energy intensity per value added at national level is partly due to increased efficiency in industry and the declining share of value added of this sector compared to services, which have significantly lower energy intensity.
- The analysis of decomposition shows that the reduction of GHGs since 2005 is mainly driven by increasing renewable share and decreasing energy intensity by economy.

Italy and the biggest European countries

The main outcomes can be summarized as follows:

- Italy's ratio between final and primary energy consumption, a measure of transformation efficiency, has been historically higher among the biggest European countries. Italy is one of the largest European countries with the lowest gross inland energy consumption per GDP.

- The renewable energy per gross inland consumption in Italy is greater than the EU27 average since 2005. The Italian renewable share accelerated sharply since 2007, with an increasing distance between the Italian and European average up to 2020, when the Italian share decreased quite abruptly approaching the European average. In 2023 Italy's share is, among the countries considered, second only to Sweden's one. However, the European target in 2030 of renewable share concerns the gross final consumption and Italy's overall share is well below the European average in 2023 (19.6% vs 24.6%) and behind countries as France, Germany, and Spain. The 2030 target for Italy is lower than the European average target: 38.7% *vs* 42.5%.
- Italian GHGs per capita increased until 2004, unlike most European countries, which recorded decreasing emissions per capita since 1990. Italian emissions per capita were always below the EU27 average and in 2023 are higher to those recorded in Spain, France, Romania, and Sweden where the nuclear energy represents a not negligible share of inland consumption.
- The energy intensity per GDP also considering the energy consumption by international bunkers confirms that, among the largest countries, Italy and Germany have the lowest values.
- At sectoral level, the final energy and carbon intensities per value-added show that Italian industry, as well as agriculture, has one of the lowest values among the 27 European States, with the highest levels of electrification of final consumption among the biggest countries (39% vs 32.6% in EU27). On the other hand, the electrification of households in Italy is much below the EU27 average (19.8% *vs* 25.9% in 2023), showing a potential to reduce the sector's carbon footprint. Even the transport sector in Italy has wide room for reducing emissions, mainly in the segment of cars. Italian emissions per capita and per GDP for such segment are over the European average and one of the highest among the biggest countries.
- The results of decomposition analysis on GHGs change since 2005 show that, among the driving factors, the decreasing final energy intensity and the increasing renewable energy were decisive to reduce European emissions. The outcomes of decomposition analysis show that in Italy the improvement of final energy efficiency played a less important role than in other countries, because of the better performance of the indicator in Italy since 2005 and lower margin of improvement.
- The comparison among the largest countries of the European Union shows greater decoupling between GDP and GHGs in other countries than the one observed in Italy, although indicators as energy efficiency, energy consumption per GDP, and GHGs per GDP performed better in Italy than European average since '90s and many countries with much higher values approached Italian values.
- The Italian GHGs emissions factor in thermal power plants for electricity and heat production is well below the European average. The emissions factor calculated also considering all other sources (nuclear and renewable energy) shows that the Italian value is higher than the EU27 average because of the zero emissions benefit of nuclear plants in many European countries. All countries with lower emission factors than Italy have relevant amount of electricity by nuclear plants and/or higher renewable share.

To sum up: the results show that Italy has one of the more efficient economies among the biggest countries in Europe, in terms of energy consumption by GDP. The Italian energy intensity per GDP is one of the lowest in Europe despite the still relevant role for industry in the Italian economy. Low energy intensity often corresponds to more service-based economies with a minor share of industrial activities. EU27's carbon intensity per energy consumed is lower than Italian one, also due to the not negligible share of nuclear energy, while on the renewables side, after Sweden, Italy recorded the highest share on gross inland consumption among the biggest countries.

GHGs trends depend on many factors. The emission reductions in European countries are mainly due to the decreasing energy intensity and increasing renewable energy consumption. Independently from contingencies, there is a clear decoupling between GDP and GHGs in the European countries, often higher than in Italy, although decoupling does not necessarily correspond to GHGs decrease in line with the targets. The potential for reducing emissions must be assessed also considering the starting points of the driving factors and the costs to change the energy system, as well as the economy structure, especially concerning the ratio between services and industry.

Sectoral decarbonization indicators in Italy show sectors, such as industry and agriculture, with energy and carbon intensities by GDP among the lowest in Europe and sectors, such as households and transport, with wide room of improvement. The Italian electrification level in households is well below the European average. Italian GHGs per capita for cars are over the European average and one of the highest values among the biggest countries. Such outcomes are consistent with the worrying distance of Italian GHGs projections from the target to be achieved in 2030 (ISPRA, 2025b; MASE, 2024). The GHGs reduction targets are focused on the partition between biggest energy and manufacturing industries (subject to emissions trading system, ETS) and other sectors (ruled by Effort Sharing Regulation, ESR). The country's targets are set only for sectors not subject to the ETS, i.e. transport, services, households, agriculture, waste and small industry, while emissions from large plants as thermal power plants, refineries, cement plants, steel plants, etc. are in the European cap and trade system of emissions trading. Such commitment does not change with the introduction of the so called ETS-2, which will come into operation in 2027 for buildings, road transport and additional sectors, e.g. fuel combustion by industry not covered by the existing ETS.

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