Environmental impact of Italian Industry in 2024

Arianna Paini*, Luca Preite*, Maria Vittoria Rizzo **, Roberta Stefanini*, Giovanni Paolo Tancredi, Giuseppe Vignali***

** Department of Engineering for Industrial Systems and Technologies, University of Parma – Parco Area delle Scienze 181/A, 43124, Parma (Italy), arianna.paini@unipr.it, luca.preite@unipr.it, roberta.stefanini@unipr.it, giuseppe.vignali@unipr.it)*

*** CIPACK center – Parco Area delle Scienze 181/A, 43124, Parma (Italy), (mariavittoria.rizzo@unipr.it, giovannipaolo.tancredi@unipr.it)*

Abstract: Encouraging patterns of consumption and production that are sustainable is a crucial imperative for the future. This involves utilizing Earth's resources efficiently, minimizing greenhouse gas emissions, and disconnecting economic growth from environmental degradation. The increase in the consumption of goods and services led to an increase in direct and indirect energy consumption and greenhouse gas production by industries. Recently the European Union has fixed the target of reduction of greenhouse gas emissions to 55% before 2055 (fit for 55). As far as the Italian context is concerned, these emissions are mainly related to household consumptions, mobility and in significant amount to the industrial activities (28.2%in 2022 according to Eurostat statistics). The latter, often referred as to "hardly to abate" emissions are not equally distributed in the Italian area, being the majority located in the northern part of Italy. This study aims to demonstrate how relevant such emissions are in specific areas and the real perspectives of reduction in 10 years, based on the ongoing activities and commitment and the most relevant technologies in this regard. The Italian data will be compared with those available at a European level and other relevant geographical areas such as the United States.

Keywords: Environmental impacts, Industry, Emissions, Italy.

1.Introduction

According to the data published in 2021 by the Italian Trade and Investment Agency, Italy is the third largest economy in the Eurozone and the second largest manufacturer in Europe (Ministry of Enterprises and Made in Italy, 2024). As part of the G7, the group of the seven world-leading developed countries (Canada, France, Germany, Italy, Japan, the United Kingdom, the United States), its commitment in the climate action is of crucial importance, since economic development and wealth growth must go hand in hand with a reduction in greenhouse gases (GHG) emissions, so to keep the increase in the global temperature below 2°C above pre-industrial levels, as established by the Paris Agreement. GHG emissions monitoring plays a fundamental role in appropriately establishing reduction strategies to meet European targets: for this reason, the Institute for Environmental Protection and Research (ISPRA), on behalf of the Ministry of the Environment and Protection of Land and Sea, has been nominated as responsible for the preparation and annual updating of the Italian GHG inventory. As reported in the most recent National Inventory Report (ISPRA, 2023), the energy sector was responsible for the 79.7% of the national GHG emissions in the 2021. Since the contribution of the energy sector includes the emissions from the combustion of fuels both in power plants to produce electricity and in the industrial plants to fuel the industrial processes, the focus on the industrial sector represents the key for identifying the major hotspots in the Italian scenario. Italy has a florid industrial sector, which includes a mix of small and medium-sized enterprises, and an increasingly innovative technology sector. Italy has embraced the European framework of Industry 4.0 in 2016 (Ciaschini, et al., 2022) to enhance productivity and competitiveness. Its industries cover a wide range of sectors: automotive, machinery, food, fashion, cosmetic and pharmaceutical are some of the most profitable according to the data reported in the second edition of the publication "Excellence: Italian Main Industrial Sectors" (Ministry of Foreign Affairs and International Cooperation, 2021). Referring to the Trade Performance Index updated to 2019, Italy is the world's second most competitive country in the manufacturing sectors and, since nowadays competitiveness is also played out on environmental sustainability, the monitoring of the environmental performance, including GHG emissions, is essential. Therefore, the present study aims at exploring the current trend of GHG emissions within the Italian industrial sector, making projections to 2030 according to the available data.

2.Literature review

The scientific literature is replete not only with climatology studies, which emphasise the urgency, importance, and seriousness of the climate situation (IPCC, 2023), but also with review studies analysing the state of the art of

industrial-related greenhouse gas emissions from the past. First of all, researchers analysed the main drivers of greenhouse gas emissions. A structural decomposition analysis, based on the global input-output database from 1995 to 2009 in 40 countries, found that among the main drivers of GHG emissions the rapid global economic growth is crucial, showing also a relationship between the growth of greenhouse gas emissions and the gross output of countries (Liu, et al., 2019). Moreover, developing countries – China and India in particular – have been high emitters of CO_2 and CH_4: in the last year, an increase of both fossil fuel emissions in Asia, caused by its industrial expansion, as well as AFOLU emissions, due to deforestation related to agricultural practices in Latin America and Africa, have been recorded (Lamb, et al., 2021). Finally, the researchers emphasise how energy efficiency and technological innovation can contribute to decreasing emissions: a literature review from 1990 to 2018, observed a moderate decarbonisation of the energy systems in Europe and North America thanks to the reduction of fuel consumption and the increase of renewable energies (Lamb, et al., 2021). However, the EU's 2030 targets also call for a reduction in emissions from agriculture. In 2018, they were reduced by only 2% from 2005, deriving mainly from enteric fermentation (45%), agricultural soils (37.8%) and manure management (14.7%) and finally from liming (1.4%), urea application (1%) and burning of agricultural residues (0.1%) (Mielcarek-Bochenska & Rzeznik, 2021). Based on these analyses, researchers report that EU countries should do more to achieve the greenhouse gas emission reduction target of the Paris Agreement (Liobikienè & Butkus, 2017).

Some more recent studies focus on Italy, addressing their attention on its technological innovations (Ciaschini, et al., 2022) and sustainability research. For instance, Arbolino et al. combined multidimensional data analysis using a Hierarchical Cluster Analysis based on the Principal Component Analysis and a Swot Analysis to compare industrial sustainability reached in the Italian regions in 2015 (Arbolino, et al., 2018). Their results highlighted that the environmental performance is geographically different from northern-central regions and southern-insular ones. The first ones registered well-educated human resources, a high incidence of environmental certifications and labels and environmental infrastructure, project and energy endowment. The latter achieved low rates of education, inefficient public administration in managing sustainability investments, reporting many weaknesses in their structures. Based on these results, it is reiterated that observing the average of a country's results is not sufficient to best describe the specific situations of each region or province, but only gives an overview of the overall state of the art.
Some other studies address the problem of monitoring emissions at a global level. Minx et al. compiled a new dataset of global coverage on anthropogenic GHG emissions for 1970–2018 and assessed the related uncertainties thorough both statistical analysis and comparison with the different global emissions inventories (Minx, et al., 2021). Zheng et al. reviewed the global emissions profiles and dynamics of the G7 and BRICS countries finding that the EU member states obtained the best results in terms of decarbonization trends and were the best players in climate change mitigation. On the contrary, Russia, US and Canada showed the worst performance (Zheng, et al., 2019).

3. Materials and methods

To provide an overview of the contribution of the Italian industry to national GHG emissions, the data relating to national and sectoral emissions, obtained from national and European reports, were analysed. The presence of disintegrated data poorly addressed in scientific literature, have made comparison and re-elaboration necessary. The data were reprocessed to investigate the aspects of interest according to the purpose of the research. The main results are presented in section 4 and then discussed in section 5.

4. Results

In the latest version of the National Inventory Report, the national GHG emissions are divided between the following sectors: energy (fuel combustion and fugitives from oil and gas), industrial processes, agriculture, waste and Land-Use Change and Forestry (LULUCF) sector. The latter plays a key role in the removal of GHG from the atmosphere and, for this reason, the total GHG emissions are reported both including and excluding the contribution of LULUCF sector. Table 1 reports the total national GHG emissions without LULUCF, expressed in kt CO_2 eq, and Figure 1 shows the emissions trend between 1990, taken as the base year, and 2021. After an increase in the emissions accounted in the period from 1990 till 2005, a decrease was detected starting from that year. For the energy sector, such

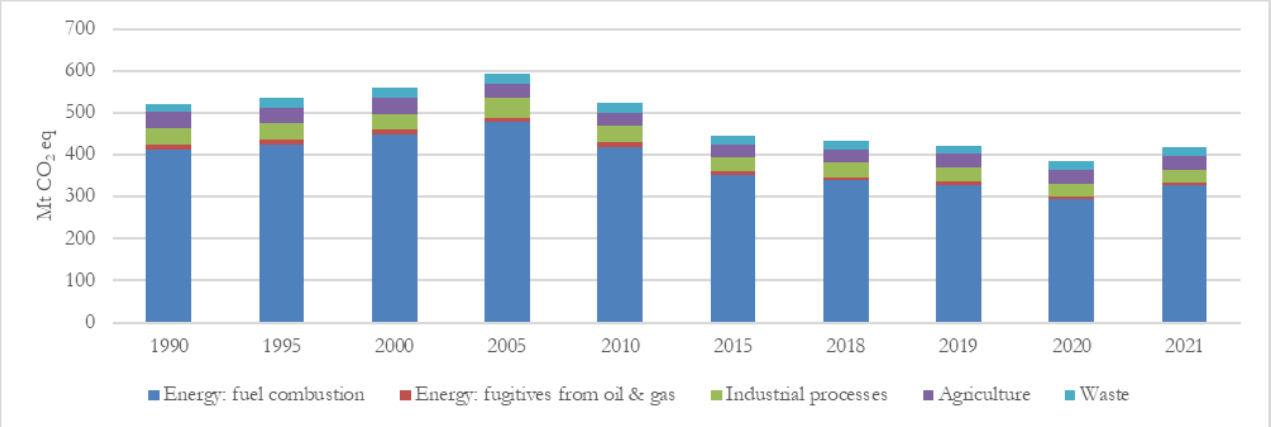

Figure 1: Emission trends by source category (kt CO_2 eq) – data taken from ISPRA

decrease is attributable to the implementation of European policies in favour of the use of renewable sources and the implementation in the same year of the Emission Trading Scheme (EU ETS), which further pushed the replacement of petrol products (ISPRA, 2022). As far as the industrial processes are concerned the decrease of GHG emissions is attributed to the downsizing of the production of minerals, in particular cement, and to the implementation of emissions abatement technologies in the chemical industry, especially in the production of nitric acid and adipic acid. For agriculture the decrease is mainly due to the reduction of CH_4 emissions from enteric fermentation and to the reduction of the use of nitrogen fertilizers (ISPRA, 2022). The waste sector, although having a marginal contribution to the total national GHG emissions (between 4% and 5%), showed a slight increase from 2015 to 2021, due to solid waste disposal (ISPRA, 2022).

Figure 1 also shows the contribution of each sector to the total GHG emissions. Over time the energy sector has maintained the highest contribution, which is always over 75%, and reaches a peak in years 2005 and 2010. Being the energy sector a wide sector, which also includes emissions from the combustion of fuels for the operation of the manufacturing and construction industries, as well as mobile combustion in vehicles for transport purposes, it is useful to separate the emissions to identify the total contribution of the Italian industry, considering both the direct emissions from processes and the indirect emissions from fuel combustion.

For this purpose, it is useful to make a comparison of the ISPRA data with those reported in the Emissions Database for Global Atmospheric Research (EDGAR) version 8.0, a global database on anthropogenic GHG emissions developed by the Joint Research Centre of the European Commission (JRC). It independently estimates what is reported by European Member States or Parties under the United Nations Framework Convention on Climate Change (UNFCCC), using international statistics and a methodology in line with the latest IPCC guidelines.

The total emissions values are updated to 2022, while in the most recent ISPRA report the data stop at 2021. Looking at the total value in kt of CO_2 eq, reported in Table 1, it can be noticed that, compared to ISPRA data, the emissions are underestimated by a few percentage points. The difference between the two emission values increases as the years increase, reaching 6% in 2021, as represented in the graph in Figure 2. However, the same trend is recorded over the years with a peak set in 2005. The EDGAR database reports the contribution of the following sources of emissions: agriculture, buildings, fuel exploitation, industrial combustion, power industry, processes, transport, and waste.

Table 1: Total GHG emissions (without LULUCF) taken from ISPRA and Total GHG emissions taken from EDGAR v. 0.8 database

	Total GHG emissions (without LULUCF) [Mt CO_2 eq]	**Total GHG emissions [Mt CO_2 eq]**
1990	521.48	513.74
1995	535.654	522.31
2000	559.977	545.78
2005	594.198	580.43
2010	523.465	417.57
2015	445.736	405.33
2018	433.629	367.41
2019	422.276	392.96
2020	384.971	394.75
2021	417.591	513.74
2022	-	522.31
Source	ISPRA	EDGAR v. 0.8 database

The highest contribution is that of the power industries which is around 24%. In second place after power industries there are the transports, followed by buildings. The contribution of industrial combustion is around 8% in the years following 2015 and has undergone a notable decrease compared to the base year (1990) in which its the contribution stood at 14.4%. The values of the percentage contributions of each sector are shown in Figure 3. By combining the emission data from industrial combustion and processes, it is possible to estimate the total share of emissions associated with the Italian industry. Such share represents the 16.6% in 2022 as shown in Figure 4.

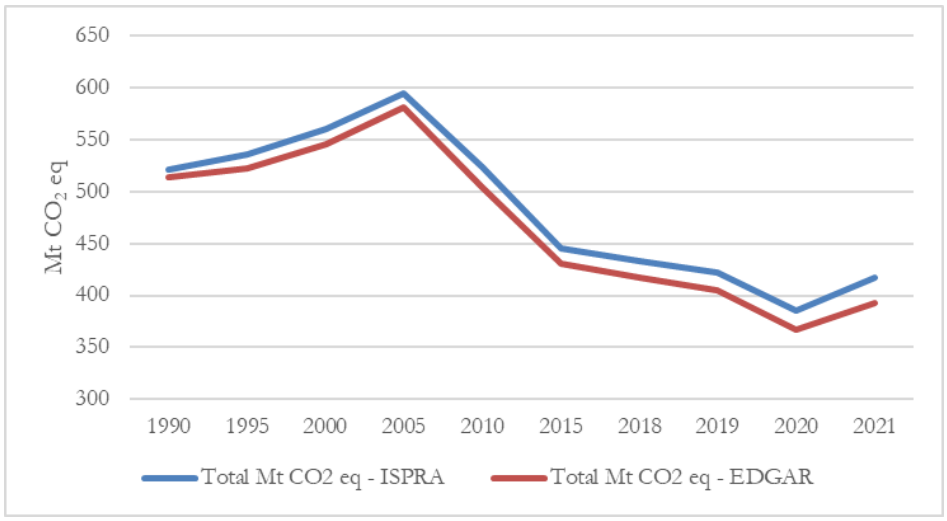

Figure 2: Deviation of total GHG values for Italy reported by the two different sources (ISPRA and EDGAR)

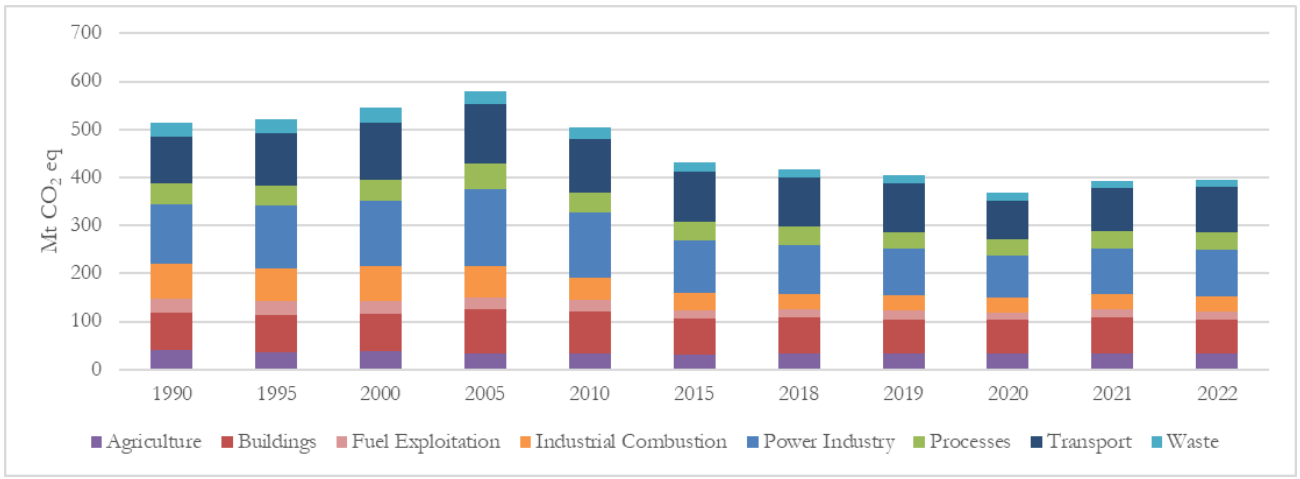

Figure 3: Emission trends by source category (Mt CO_2 eq)- Data taken from EDGAR v. 8.0 database

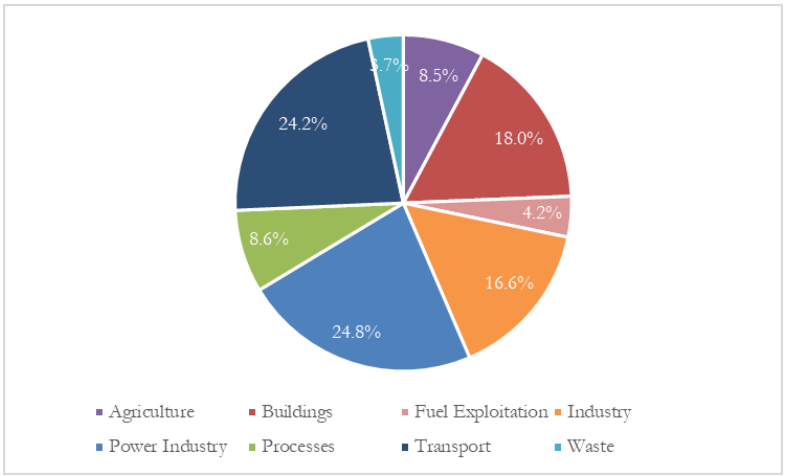

Figure 4: Contribution of each sector to the total national GHG emissions in 2022

5. Discussion

From the analysis and processing of the emission data obtained from the various databases it was possible to identify the share of GHG attributable to the industrial sector. Observing the trend in the period from 1990 to 2022, it can be pointed out that the industrial sector has reduced its emissions by 44% from the base year, in which its contribution to the national GHG emissions was 22.6%. Once the emissions of the industrial sector and the reduction profile have been identified, it is interesting to understand which are the areas where the major emitting industries are located. Furthermore, it is useful to compare Italian data with those of other countries, for example the USA, which represents one of the countries with the worst environmental performance according to Zheng, et al., and to make projections of improvement on the basis of the long-term Italian strategy for climate neutrality.

5.1 Distribution of industrial emissions within the Italian territory

The number of industrial plants reported in the European Pollutant Release and Transfer Register (PRTR) was 4028 in 2020, of which 3040 located in Northern Italy, 519 in the Centre, 465 in the south (including the islands) and 4 in the sea referring to off-shore platforms. It must be noted that the emissions are declared only when the level of emissions is above certain thresholds and are caused by one of the 65 activities listed in Annex I of Regulation (EC) No. 166/2006 by. Therefore, the available data on emissions does not cover the entire range of Italian industries, which counts over 400.000 industries, but only those that fall within the following sectors, indicated in the regulation mentioned previously: energy activities, metal production and processing, mineral products industry, chemical industry, waste and wastewater management, production and processing of wood pulp and paper, intensive livestock farming and animal and vegetable products from the food and beverage sector. The Italian region with the highest number of factories is Lombardy with 1375 factories followed by Emilia-Romagna and Veneto with 587 and 445 factories respectively (Bernetti, et al., 2020). The different activities contribute in a different way to GHG emissions and, starting from the data reported in the PRTR, Sechi et al. identified ten industrial clusters responsible for the majority of the hard-to-abate emissions. Eight out of ten are located in the North of Italy, one in the Centre and one in the South. However, the only cluster in southern Italy, located in the Taranto area, was identified as the largest emitter (Sechi, et al., 2022). Each cluster includes at least two installations within a defined distance radius and cover the following activities: production of pig iron and steel, cement production, lime production, glass manufacturing, ceramic manufacturing and paper production. The majority of these industries rely on high-temperature processes that currently depend on fossil fuels, making it difficult to switch to renewable energy sources. Industries can intervene to reduce their emissions by adopting various techniques: the first known as "end of pipe" act downstream of the production process and involve the use of systems for treating emissions into the atmosphere, water waste purification systems and systems for optimal waste management. The latter are instead preventive techniques that are applied upstream of the process to reduce downstream emissions. According to 2016 data, the Italian industry prefers the first approach since approximately 66.5% of investments for the reduction of emissions are for end-of-pipe technologies (Bernetti et al.,2020). In the 2016 ISPRA report related to the industrial sector, environmental performance indicators are used to define the positive or negative trend in the carbon dioxide emissions intensity, and the specific emissions of production processes (Bernetti et al.,2020). As regards the first indicator, a negative trend is highlighted only for the paper industry, which also shows a static situation in specific process emissions. As far as the second indicator is concerned, a general static trend has been outlined. Such situation extends to the chemical, steel, mineral and non-ferrous metal industries, in addition to the paper industry. The trend of the indicators show that the Italian industry focuses lot on efficiency, but still has a long way to go in the shift to the use of greener resources.

5.2 Comparison with the United States

Based on data taken form EDGAR, a further comparative analysis of GHG emission by sector for the United States and Italy, from 1970 to 2022, show several key patterns and contrast between the two countries. As shown in Figure 5, for the year 2022, in the transportation sector the USA has consistently shown a higher emission expressed in Mt CO_2 eq than Italy over the period, reflecting a greater influence of the heavy-duty vehicles usage and reliance on personal vehicles. Notable observations for Italy's contribution to emissions from agriculture stands at 7.5%, which is slightly higher than the 6.2% seen in the United States. In the buildings sector, the gap between the two countries is more pronounced, with Italy contributing 16.8% compared to the United States' 9.6%. The United States has a substantially higher contribution in the fuel exploitation sector, with 9.9%, compared to Italy's 4.6%. For industrial combustion, the two countries exhibit more similarity, with Italy contributing 10.3% and the United States 7.6%. A significant divergence appears in the power industry sector, where the United States leads with 31.3%, while Italy contributes 25.1%. In terms of processes, Italy's emissions are moderately higher, at 8.7%, while the United States contributes 5.9%. The transport sector reveals a minor difference, with Italy at 22.4% and the United States at 26.6%. In the waste sector, Italy's emissions are substantially higher at 4.7% compared to the United States' 2.8%. These data illustrate that while both countries share similar major contributing sectors to greenhouse gas emissions, such as power industry, transport, and buildings, there are significant disparities in certain sectors.

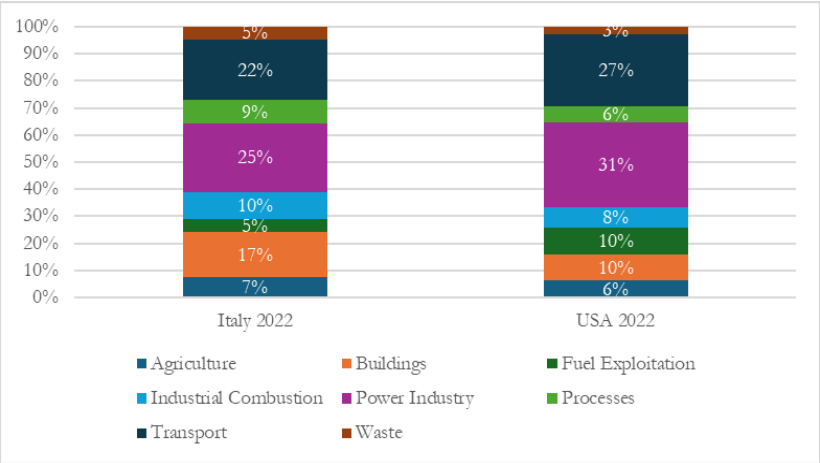

Figure 5: GHG by sector year 2022 United States-Italy

The data reported in the databases consulted refer to emissions resulting from production and do not include those based on consumption, incorporated into imported goods. This is a type of emission that the European Union is trying to reduce through the Carbon Border Adjustment Regulation (CBAM), which obliges importers to purchase CBAM certificates for each ton of equivalent CO_2 incorporated into the imported goods. Through a price mechanism, Europe is thus trying to combat the phenomenon of carbon leakage. Consumption-based emissions are calculated by subtracting from production-based emissions those incorporated in exported goods and adding those incorporated in imported goods. In terms of net CO_2 imports, the US are the largest net importers, meaning that they import more CO_2 emissions embedded in goods than it exports. Italy, while also being a net importer of emissions, has a smaller scale of imports compared to the US (Ritchie, 2019). Per-capita consumption-based CO_2 emissions reached 16,5 tons and 7,3 tons respectively for US and Italy in 2021. The per-capita evaluation allows a fair comparison of the performance of the two countries. When the CBAM becomes operational in January 2026, a further improvement is expected for European countries.

5.3 The Italian Long-Term Strategy for Climate Neutrality

In order to achieve climate neutrality at a national level, Italy has developed the Italian Long-Term Strategy. This strategy consists of four main points. The first point focuses on the International and European Framework. The Paris Agreement and the Regulation on the Governance of the Energy Union establish emission reduction targets for 2050. The European Commission has proposed decarbonization pathways to achieve emissions reduction between 80% and 100% compared to 1990 levels. Then, the strategy declares the will to achieve climate neutrality by 2050, with emissions offset by CO_2 absorption and the use of carbon capture and utilization technologies. Based on the Integrated National Energy and Climate Plan (INECP), it forecasts a reduction in emissions by approximately 17% between 1990 and 2018, from 516 to 428 million tonnes of CO_2 equivalent. Objectives for 2030 include the growth of renewable sources and improvements in energy efficiency. Achieving climate neutrality by 2050 requires a radical change in the energy mix, an increase in absorptions provided by forested areas, and potentially the use of Carbon, Capture and Storage (CCS) – Carbon, Capture and Utilization (CCU) forms. CCS technology allows for the capture of carbon dioxide emitted by industrial and power plants and its safe storage, for example, in underground geological formations, to prevent it from entering the atmosphere and contributing to the greenhouse effect. CCU technology involves capturing carbon dioxide for subsequent use in various processes, such as the production of synthetic fuels or the synthesis of chemical products, thus transforming CO_2 from waste to a resource. The total number CCUS projects in Europe amounts to 72, which corresponds to around 80 $MtCO_2$/year stored by 2030 (IOGP, 2023). Current CCS challenges, in addition to cost, involve long-term isolation from the atmosphere and ensuring that elements of capture, transport and storage pose no other risks to human health or ecosystems (European Commission, 2021). One of the major controversies related to CCUS technologies concerns the relationship with the fossil fuel supply chain given that most of the captured CO_2 is used to facilitate the extraction of hydrocarbons. Thus, burdens would be attributed to future generations associated both with the management of the risks of stored CO_2 and the costs of decommissioning the fossil fuel supply chain infrastructures (WWF, 2021). Another fundamental target is the decarbonization. The Decarbonization Scenario was developed as a supporting tool to outline the combinations, synergies and criticalities of potential levers that can be activated to achieve climate neutrality by 2050. This pathway requires a shift in Italy's energy paradigm, with investments in clean technologies, infrastructure, and lifestyle changes. It involves increasing the use of renewable energies and energy efficiency across various sectors, including industry and residential areas. As regards the transition to renewable sources, the total renewable power capacity in the EU27 increased from 371093 MW in 2015 to 641478 in 2023. Italy contributes to the total renewable power capacity of the EU27 with 65157 MW, standing out

as one of the best performing countries in Europe and showing a rate of increase of 23% compared to 2015 (IRENA, 2024). These points outline an ambitious and complex pathway toward decarbonization, necessitating concerted efforts both nationally and internationally for a sustainable and responsible energy transition.

6. Conclusions

Nowadays, many activities and discussions are focused on sustainability, but only a few associations and research institutes have clearly outlined the national origin of the environmental impact. Among the several indicators, certainly the global warming potential was the most assessed. Based on the data collected and discussed in this article, the influence of industry turns out to be relevant, despite being, especially in Europe, one of the sectors that in last years has improved its environmental performance the most. Europe, from this point of view, performed better than the United States, in particular as far as the energy transition is concerned, but more and more will have to be planned and implemented in the coming years to tend towards the desired carbon neutrality condition. No discussions about the Asian countries have been made, due to the lack of consistent and reliable data coming from those countries, which, however, will be those that will have to act the most in the coming decades to reduce their greenhouse gases emissions.

References

Arbolino, R., Boffardi, R., Lanuzza, F. & Ioppolo, G., 2018. Monitoring and evaluation of regional industrial sustainability: Evidence from Italian regions. *Land Use Policy,* pp. 420-428.

Bernetti, A., De Lauretis, R., Gagna, A. & Mincarini, M., 2020. *Industria.* [Online] Available at: https://www.isprambiente.gov.it/files2020/pubblicazioni/stato-ambiente/annuario-2020/6_Industria_Finale_2019.pdf

Ciaschini, C. et al., 2022. The Industrial Pattern of Italian Regions: A Disaggregated Sectoral Analysis Based on Input–Output Tables. *Economies.*

European Commission, 2021. *Carbon capture, use and storage.* [Online] Available at: https://climate.ec.europa.eu/eu-action/carbon-capture-use-and-storage/overview_en?prefLang=it#barriers

Hannah Ritchie, 2019. *How do CO2 emissions compare when we adjust for trade?.* [Online] Available at: https://ourworldindata.org/consumption-based-co2

IOGP, 2023. *CCUS projects in Europe.* [Online] Available at: https://iogpeurope.org/wp-content/uploads/2022/11/Map-of-EU-CCUS-Projects.pdf

IPCC, 2023. *Sixth Assessment Report.* [Online] Available at: https://www.ipcc.ch/assessment-report/ar6/

IRENA, 2024. *Renewable capacity statistics 2024.* [Online] Available at: https://www.irena.org/Publications/2024/Mar/Renewable-capacity-statistics-2024

ISPRA, 2022. *Italian Greenhouse Ga sInventory 1990-2020 National Inventory Report 2022.* [Online] Available at: https://www.isprambiente.gov.it/files2022/pubblicazioni/rapporti/nir2022_italy_r360.pdf

ISPRA, 2023. *Italian Greenhouse Gas Inventory 1990-2021 National Inventory - Report 2023.* [Online] Available at: https://www.isprambiente.gov.it/files2023/pubblicazioni/rapporti/rapporto_383_2023.pdf

Lamb, W. F. et al., 2021. A review of trends and drivers of greenhouse gas emissions by sector from 1990 to 2018. *Environmental research letters,* 16(7).

Liobikienė, G. & Butkus, M., 2017. The European Union possibilities to achieve targets of Europe 2020 and Paris agreement climate policy. *Renewable Energy,* Volume 106, pp. 298-309.

Liu, D., Guo, X. & Xiao, B., 2019. What causes growth of global greenhouse gas emissions? Evidence from 40 countries. *Science of the Total Environment,* Volume 661, pp. 750-766.

Mielcarek-Bochenska, P. & Rzeznik, W., 2021. Greenhouse Gas Emissions from Agriculture in EU Countries—State and Perspectives. *Atmosphere.*

Ministry of Enterprises and Made in Italy, 2024. *Did you know IT? Italy is industrious.* [Online] Available at: https://www.ice.it/en/invest/did-you-know-it#:~:text=With%20a%20GDP%20of%20over,of%202.71%25%20of%20worldwide%20market.

Ministry of Foreign Affairs and International Cooperation, 2021. *Excellence - italian main productive sectors.* [Online] Available at: https://www.esteri.it/mae/resource/doc/2021/10/eccellenze2021.pdf

Minx, J. C. et al., 2021. A comprehensive and synthetic dataset for global,regional, and national greenhouse gas emissions by sector 1970–2018 with an extension to 201. *Earth System Science Data,* Volume 13.

Sechi, S., Giarola, S. & Leone, P., 2022. Taxonomy for Industrial Cluster Decarbonization: An Analysis for the Italian Hard-to-Abate Industry. *Energies,* 15(22).

WWF, 2021. *Ambiguità, rischi e illusioni della CCS-CCUS.* [Online]. Available at: https://www.wwf.it/uploads/Report-CCS_WWF_def-impaginato-25-ott-def.pdf

Zheng, X. et al., 2019. A review of greenhouse gas emission profiles, dynamics, and climate change mitigation efforts across the key climate change players. *Journal of Cleaner Production,* Volume 234, pp. 1113-1133.