Policy Paper

EPG

DECARBONISING ROMANIA'S INDUSTRY

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About EPG:

Energy Policy Group (EPG) is an independent think-tank, specialised in energy and climate policies. Founded in 2014, the association gathers experts who are working together in international research projects. In its work, EPG has a regional focus on Eastern Europe and the Black Sea Basin. Still, EPG's research remains highly focused on the larger context of European policies and of global trends, in its endeavour to promote a constructive dialogue on decarbonisation among decision makers and the larger audience.

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Executive summary

Under the ambitious framework of the European Green Deal, the need for deep industrial decarbonisation has been increasing in urgency. Emissions cuts in energy and resource-intensive manufacturing sectors are key to mitigate climate change, as well as to ensure competitiveness in a progressively low-carbon world. This is particularly important for Romania, where despite a trend of recent deindustrialisation industry contributes more to the economy, employment, and national greenhouse gas (GHG) emissions than the EU average.

The steel, cement and chemicals manufacturing sectors are central to Romania's economy. Operational facilities in these sectors consume significant amounts of electricity, natural gas, and water, as well as specific feedstocks such as coking coal, steel scrap, and limestone. The production landscape is dynamic, with some facilities closing and others reopening or planning to increase their production. Against this background, the challenge of decarbonisation is significant: for national emissions to reach net zero by 2050, Romania's industry will need to reduce its energy consumption in half, undergo massive electrification and a switch to hydrogen and biomass, improve material efficiency, and implement carbon capture and storage.

Despite the size of this challenge, which is enhanced by the lack of coordinated action in Romania, there are sizeable opportunities for industrial decarbonisation, not least the economic importance of heavy industry and Romania's potential for large-scale renewable energy and clean hydrogen production. Establishing a national strategy for industrial decarbonisation, accompanied by an appropriate financial framework and clear institutional responsibilities, are the first steps to enable the rollout of deep industrial decarbonisation. Investment in research and development (R&D) must also be strengthened, and large-scale infrastructure for hydrogen and carbon dioxide (CO_2) transport must be supported by national authorities. Implementing these actions will ensure that Romanian industry can keep up with the accelerating move to low-carbon manufacturing, as well as developing new value chains and business opportunities fit for the future.

Industrial decarbonisation in the EU

The challenge of decarbonising the EU's manufacturing industries has been garnering progressively more attention in recent years. With the launch of the European Green Deal and the bloc's commitment to net zero greenhouse gas (GHG) emissions by 2050, the associated Fit for 55 package and later the RePowerEU plan, the curbing of emissions from EU manufacturing has entered the spotlight. The difficulty of reducing emissions from certain manufacturing industries, termed by some "hard-to-abate" emissions, adds to the debate on balancing policy push and market pull instruments. Given the plethora of production processes, decarbonising the EU industry is not a straightforward process, as it relies on simultaneously capital- and infrastructure-intensive investments in electrification, hydrogen and carbon capture and storage. Energy and material efficiency, circularity and material substitution are equally important in decreasing the carbon footprint of industry.

Industrial decarbonisation has been underpinned by EU policy for several decades. The Emissions Trading System (EU ETS), the EU's cap-and-trade carbon market, has covered carbon dioxide (CO_2) emissions from energy-intensive industries[1] since its start in 2005 (LIFE ETX, 2021). Under successive revisions of the ETS, the cap of available emissions allowances has decreased, and the number of free allowances, reserved for industries considered to be at risk of carbon leakage (mostly heavy industry), has also declined. However, a relative oversupply of free allowances still remains (LIFE ETX, 2021), which has prompted the EU to rebase the cap on total emissions under the system, as well as to decide on a complete phase-out of free allowances by 2034, and in parallel set up a Carbon Border Adjustment Mechanism to protect EU industry from having to compete with cheaper industrial products manufactured in territories with no comparable carbon price (Noerr, 2022).

The rapid elimination of free allowances brings great urgency to the decarbonisation of Europe's industry, particularly given that, to date, the EU ETS mostly failed to send the correct signals for investment in deep industrial cuts in emissions. For the phase-out of free allowances to generate rapid industrial decarbonisation, sufficient financial resources must be mobilised in due course to avoid disorganised closures or suspensions of industrial activity.

In this sense, funding instruments such as the Innovation Fund are key to enable investments in deep decarbonisation. This Fund has awarded substantial grants to large-scale industrial decarbonisation projects, including carbon capture and storage (CCS), low-carbon fuels production, and green hydrogen. Other European initiatives aim to incentivize demand for low-carbon products by implementing product standards: the Ecodesign for Sustainable Products regulation (ESPR) and the

[1] In Phase 1, iron and steel plants, oil refineries, and producers of cement, glass, lime, ceramics, pulp and paper were covered. In Phase 3 (starting from 2013), aluminium, petrochemicals, non-ferrous and ferrous metal processors, ammonia and various chemicals were added (LIFE ETX, 2021).

Construction Products regulation (CPR), two recent proposals currently in negotiations, may target specific products, including intermediary industrial products such as steel and glass, with performance standards. Yet other initiatives aim to incentivise buyers of intermediate or final products to shift their demand towards "green" products: voluntary procurement initiatives and upcoming regulations on buildings and vehicles, alongside a burgeoning interest for low-carbon product standards, are aimed at launching large-scale procurement of green products. Finally, the EU itself stimulates strategic interest in technologies which can support industrial decarbonisation: for example, the Green Industrial Plan for Net Zero (see below) commits to enabling cross-border infrastructure for hydrogen and the development of a European "hydrogen backbone".

Aside from the decarbonisation challenge, EU manufacturing is also in focus due to recent geopolitical events, most prominently the invasion of Ukraine by Russia, which has forced a rethink of current supply chain dependencies and reinforced concerns around the need for increased EU self-sufficiency. Today, products of high technology intensity,[2] such as motor vehicles, machinery and equipment, and chemicals, contribute significantly to the value of sold industrial production, and over half of the bloc's imports are metals, minerals and rubber, particularly metalliferous ores and scrap metals (Eurostat, 2022). The strengthening of domestic supply chains has thus become a crucial point in the EU's future planning (European Commission, 2022).

The push for a low-carbon, competitive and secure EU manufacturing industry has most recently been concretised in the proposal for a Green Deal Industrial Plan for Net Zero (European Commission, 2023). This Plan sets the stage for a suite of regulatory and financial measures and aims to strengthen domestic value chains, increase the security of supply of critical raw materials, and enable increased financing for low-emissions industries. In particular, the Plan charts the path for a Net-Zero Industry Act, which would support the rollout of key decarbonisation technologies for industry, as well as measures to incentivize demand for low-carbon industrial products.

The rapidly unfolding pressure on EU industry will be felt in all Member States, particular in countries such as Romania, where industry represents a higher share of total economic output than the EU average. In this report, we present the current state of industry in Romania and the opportunities and challenges for deep decarbonisation. The focus of the paper is on energy-intensive manufacturing industries: the production of iron, steel and steel products, cement, and chemicals (including fertilizers). The report also touches on the petroleum refining, lime, glass, paper and pulp and ceramics industries. These are not analysed in depth and will form the topic of forthcoming research by EPG.

[2] Technology intensity is widely-used descriptor used to reflect the R&D intensity of a particular industry. High technology intensity industries include the production of chemicals and motor vehicles; medium-technology intensity industries include basic metals and non-metallic products manufacturing, and low-technology intensity industries include furniture, textiles, and food and beverage productions (OECD, 2016).

Romania's industrial manufacturing landscape

Recent history of Romania's industry

Romania was industrialised relatively recently, with its earliest industrial production taking off after its independence in the late 19th century. Prior to this, the Romanian economy was mainly agricultural, despite significant raw material resources including oil, natural gas, iron ore and coal. Oil production and refining emerged as the key driver of the incipient industrialization of the economy, alongside the expansion of metalworking, food production and textile manufacturing (European Route of Industrial Heritage, n.d.). After World War I, the joining with Romania of the industrialized Transylvania and Banat regions led to further industrial growth, with an expansion of petrochemicals production and heavy machinery manufacturing and the emergence of the building materials industry.[3]

After World War II and the rise of the Iron Curtain, all existing industrial facilities were nationalized. Moreover, a state-driven rapid industrialization strategy was pursued, with a focus on heavy industry, including oil refining, power production, steel, and chemicals manufacturing. Between 1960 and 1989, the number of industrial enterprises in Romania grew by 27%, and the average installed power per enterprise ballooned from just under 2 MW to 18.1 MW. Employment in industry rose from 1.2 million in 1960 to approximately 3.7 million in 1989. In the iron and steel sector, the number of producers nearly doubled, and steel output increased from 1.8 Mt in 1960 to nearly 15 Mt in 1987 (Chivu, et al., 2016). Machine building, metalworking and chemicals enterprises also saw a dramatic growth in the number of enterprises,[4] and many industry sectors (including fertilizers, heavy machinery and cement) reached their historical production maxima in the 1980s (Chivu, et al., 2016).

Romania's emerging heavy industry consumed huge amounts of energy and raw materials, and by the time the Soviet Union collapsed in December 1989, its remarkable growth in production had forced the country to import basic raw materials, including iron ore and oil, to supply its oversized industrial enterprises (European Route of Industrial Heritage, n.d.). After the end of the Soviet Union and the downfall of Romania's communist regime, Romania's economy transitioned from centrally planned to free-market, burdened with a large number of communist-era industrial facilities built on an ideology of national self-sufficiency rather than economic competitiveness. State ownership of industrial facilities was gradually withdrawn, and regulations were introduced to enable commercial company activity. The necessary economic reforms and transition measures were implemented in stages, with little long-term thinking and often not informed by adequate analysis (Chivu, 2019).

[3] This growth was driven by the pooling of energy and raw material resources, the joining to Romania of larger industrial enterprises in Transylvania and Banat, and the launch of a larger domestic market for manufactured goods (Chivu, 2019).

[4] Machine-building and metalworking grew by 70% in number of enterprises and 900% in average installed power, and chemicals producers increased by 56% in number and 1100% in average installed power.

After 1989, many of Romania's large industrial enterprises reduced their capacities or closed, driven not least by their inefficiency as well as by the post-1989 economic decline, leading to a trend of deindustrialisation. Between 1993 and 2003, liquid steel production capacities nearly halved and significant steel processing capacities were closed, leading to an overall reduction in crude steel production by 46%, and in semi-finished steel products by 61% (Commission of the European Communities, 2005). Hot rolling capacities were closed, particularly independent rollers (45% decline, compared to 11% in integrated steel mills). Siderurgica Hunedoara (now ArcelorMittal), saw its liquid steel production fall to barely 10% of pre-1989 levels by 2002. Many steel producers which are currently operational were bailed out through state aid: between 2003 and 2010, Romanian steel producers received a little over $1 billion in state aid, mostly directed towards debt write-offs and penalty restructuring (Government of Romania, 2004).

The cement and chemicals sectors saw similar declining trends after 1989. The production of cement in Romania halved between 1989 and 2000 alone, with the industry operating at only 29% capacity in 2001 (Manoleli, et al., 2002). Over this period, Romania's 10 cement plants were gradually privatised, and their production scaled down, reaching a total output of 6.1 Mt of cement in 2001. Today, Romania's 7 clinker production plants are owned by multinational conglomerates HeidelbergCement, Holcim and CRH,[5] which invested in additional production capacity at these plants following their acquisition.[6]. These plants now have a total cement production capacity of 16 Mt, and after a temporary drop in output around the financial crisis, Romania's cement production stood at 8 Mt in 2016 (Consiliul Concurenței România, 2019).

The chemicals industry also shrank, with many oil refineries and petrochemicals plants having closed (Botea, 2020), followed by a more recent wave of shut-downs or suspensions of production at fertilizer plants and organic chemicals producers over the last decade, partially driven by energy prices (Vasiliu, 2022). Due to the intrinsic dependence of major chemicals manufacturing processes on natural gas, most prominently nitrogen-based fertilizer production, the landscape of chemicals manufacturing is still dynamic in Romania. At the same time, many chemicals production plants owned by the Interagro group have been embroiled in financial issues and, in some cases, in serious environmental pollution concerns.

Romania's industry has also undergone fragmentation, with large industrial enterprises making way for small and medium companies; by 2017 92.6% of industrial companies had fewer than 50 employees, whereas at the end of 1989 the average number of employees in an industrial enterprise was over 1,700 (Chivu, 2019). However, from 1996 onwards a consolidation tendency emerged, particularly in the oil and coking coal sectors, as well as the manufacturing industries. The entry of foreign companies

[5] After 2001, the cement plants at Turda, Targu Jiu and Corbu (with an aggregated capacity of 3.3 Mt) were closed and transformed into grinding stations.

[6] For example, HeidelbergCement's investments in 2008-2009 led to a doubling of total production capacity of their plants at Taşca, Fieni and Chișcădaga (Harabagiu, n.d.).

such as ArcelorMittal and cement companies into Romania, has been ongoing since the 1990s, leading to a significant growth in the share of foreign capital in the industrial sector (Chivu, 2019).

The gradual decrease in Romania's industrial output since 1989 has been additionally punctuated by pressure from external crises. The 2008 financial crisis led to significant reductions in output of the mining, metallurgical and non-metallic mineral sectors, with job losses highest in mining and extraction. In the wake of this crisis, the Romanian authorities implemented in-depth restructuring in certain sectors, and the manufacturing industry underwent some consolidation (Chivu, 2019). As with many countries, the Covid-19-related crisis and restrictions led to a fall in output, with heavy industry shrinking by nearly 30% in the second trimester of 2020 alone. This decline in production has mostly rebounded. Finally, the effects of the Russian invasion of Ukraine have placed significant strain on Romania's large industrial consumers of natural gas, some of which had already been struggling due to high energy prices.

Over the last three decades, these changes in the energy-intensive sectors of Romania's industry have fundamentally altered the industrial landscape. Despite these trends broadly indicative of deindustrialisation, Romania's industry is still a significant contributor to both the national economy and national GHG emissions, and continues to face structural challenges such as economy-level low labour productivity (Herman, 2020), and vulnerabilities to input costs, such as energy. The following section describes the current state of Romania's industry and its major industrial producers.

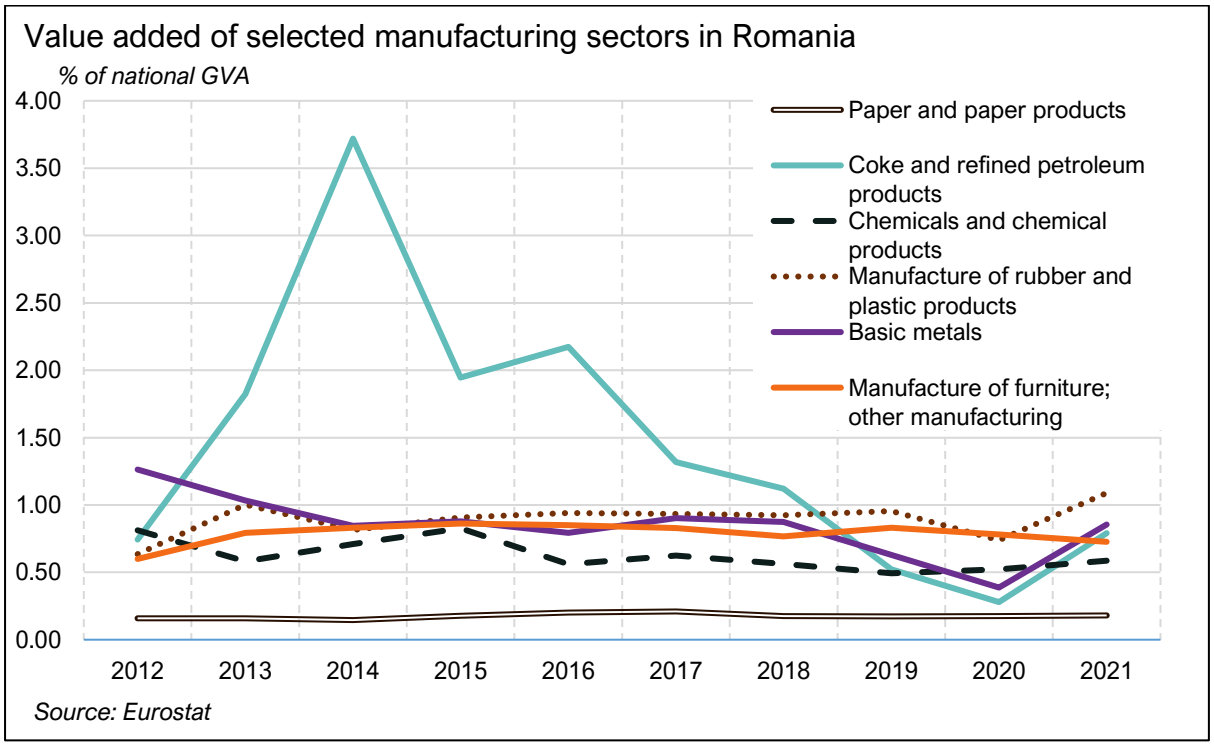
Industrial manufacturing in Romania today

Economic contribution and employment

As an upper-middle-income industrial country in Central and Eastern Europe, (CEE) the Romanian economy still reflects the legacy of its communist era. Industry (including construction) contributes 18.3% to national gross value added (GVA), 11% more than the EU average in 2021 (Eurostat, 2023). However, the value added of industry to the Romanian economy has stagnated since 2000 and is now below average among middle-income countries as a percentage of GDP (World Bank, 2023). The value added and competitiveness of specific manufacturing sectors have also changed (

Figure 1). The manufacturing of steel, cement, and glass, which are products of medium technology intensity, has decreased in value added (IAP, 2023), as a proportion of national GVA (Eurostat, 2023). At the same time, some manufacturing sectors of higher technology intensity (such as automotive and machinery manufacturing), but also medium (rubber and plastics) and lower technological intensities (furniture) have increased, and today are the most important manufacturing contributors to the Romanian economy, aside from food and drink manufacturing.

Figure 1. Contribution to national gross value added (GVA) of manufacturing industries in Romania. (Eurostat, 2023).



The most drastic decrease in value added over the last decade is in basic metals manufacturing (70% decrease in value added, significantly higher than the EU average of 23.4% decrease), as well as in coke and refined petroleum products and fabricated metals manufacturing.[7] The decrease in value added of these sectors was generally accompanied by decreases in production, although production increased for some products such as alloyed steel produced in EAFs and hot-rolled bars and heavy sections (Eurostat, 2022). Production of fertilizers also decreased; even before the recent energy price crisis, which has forced closures in Romanian fertilizer plants, production of ammonia and urea had declined by 20-30%.

In terms of industry competitiveness, Romanian exports have also seen a shift which broadly reflects the trends in GVA. In general, the share of Romania's low- and middle-technology intensity products in total manufactured exports has been decreasing year-on-year since 1995, being replaced by the high-tech manufacturing that made up 62% of manufacturing exports in 2020. Romania's trade balance for manufactured goods is currently in deficit, whereas in 1995 the country was a net exporter of middle-technology intensity products (IAP, 2023).

Romania's industry employed nearly 1.2 million people in 2021, around a fifth of the total active workforce. The automotive, food and drink, textiles, rubber and plastics and

[7] Fabricated metals manufacturing decreased in value added by 52% decrease, significantly higher than the EU average decrease of 5.7%. The decline in value added from coke and refined petroleum products was similar to that at EU level.

fabricated metal products sectors are the most important industrial employers in Romania. Of the energy-intensive manufacturers of intermediate products, the largest employers are in the sectors of cement, lime, and glass (48,237 employees), metallurgy (29,131), and chemicals (24,414). The largest companies in terms of personnel in these sectors are Liberty Galați (4,987 employees, nearly one-sixth of Romania's metallurgical industry, in 2021), aluminium producer Alro (2,479 employees in 2021), and Chimcomplex (1,919 employees in 2021).

While the total number of employees in Romania has increased slightly since 2008, the number of those employed in manufacturing industries declined by 12%. The steepest declines were in the mining sector, particularly in fossil fuel extraction, but some manufacturing industries also saw significant declines, mostly in line with GVA trends: coke and refined petroleum products manufacturing (73% decrease), metallurgy (41%) and chemicals manufacturing (34% decrease).[8] On the other hand, the manufacturing of rubber, plastics, and paper products, and sectors of higher technology intensity, increased their workforce by 23%-50% over the same period (Institutul Național de Statistică, 2023).

Emissions

GHG emissions from Romania's industrial sector declined between 1990 and 2019, primarily due to the gradual closing or downscaling of extremely energy- and resource-intensive industrial facilities (Figure 2, Figure 3). The CO_2 intensity of manufacturing has also decreased since 2000 but remains above the EU average (0.28 kg CO_2/constant 2015 US dollar, compared to 0.16) (IAP, 2023). In 2020, emissions generated by Romania's manufacturing and construction industries amounted to 25.4 Mt of CO_2 emissions, or 34.2% of total CO_2 emissions (excluding land-use, land-use change and forestry, LULUCF). The share of national emissions contributed by emissions from fuel combustion in manufacturing and construction has decreased by a third since 1990. This is broadly in line with the decrease in Romania's economy-wide emissions, and indicative of a general trend to switch away from carbon-intensive fuels. However, the share of industrial process and product use (IPPU) emissions, which are emitted during the manufacturing processes themselves, has stagnated.

Despite this decline in emissions, Romania's industry still contributes a higher overall share of total national emissions compared to the EU average. CO_2 emissions from fuel combustion for manufacturing industries and construction made up nearly 20% of national emissions,[9] compared to 15.2% at EU level, mainly driven by cement, lime and glass (4.9% of all CO_2 emissions in 2020) and chemicals (4.9% of all CO_2 emissions). IPPU emissions in Romania also contribute more to national CO_2 emissions than the EU average (14.4% of in 2020, compared to 8.3%), driven by cement, iron and steel,

[8] Liberty Galați saw a decrease in number of employees from nearly 28,000 in 2000 to just over 11,000 in 2009, to 5,081 today (Territorial Just Transition Plan for Galați county).

[9] The statistics for fuel combustion in manufacturing industries do not include scope 2 emissions arising from the use of electricity or thermal energy purchased from the national grid or a third party (IPCC, 2006).

and ammonia production. IPPU emissions from ammonia production make up 99% of IPPU emissions in Romania's chemicals industry, compared to 45% at EU level.

Figure 2. Emissions from the combustion of fuels in Romania's manufacturing industries (including fuels combusted for generating electricity or heat for own use) (Eurostat, 2022).[10]

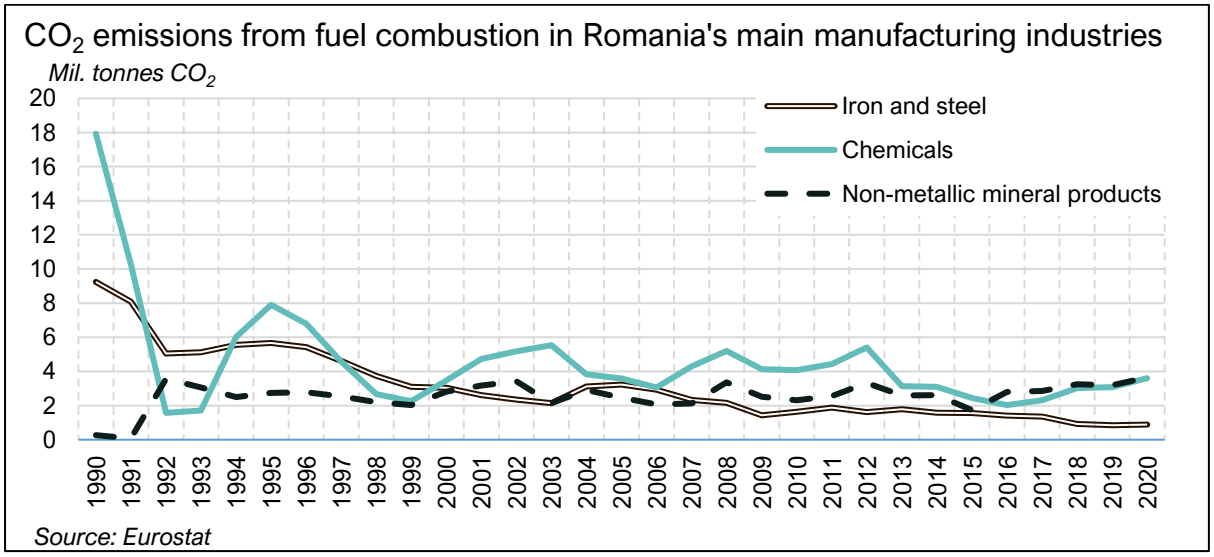
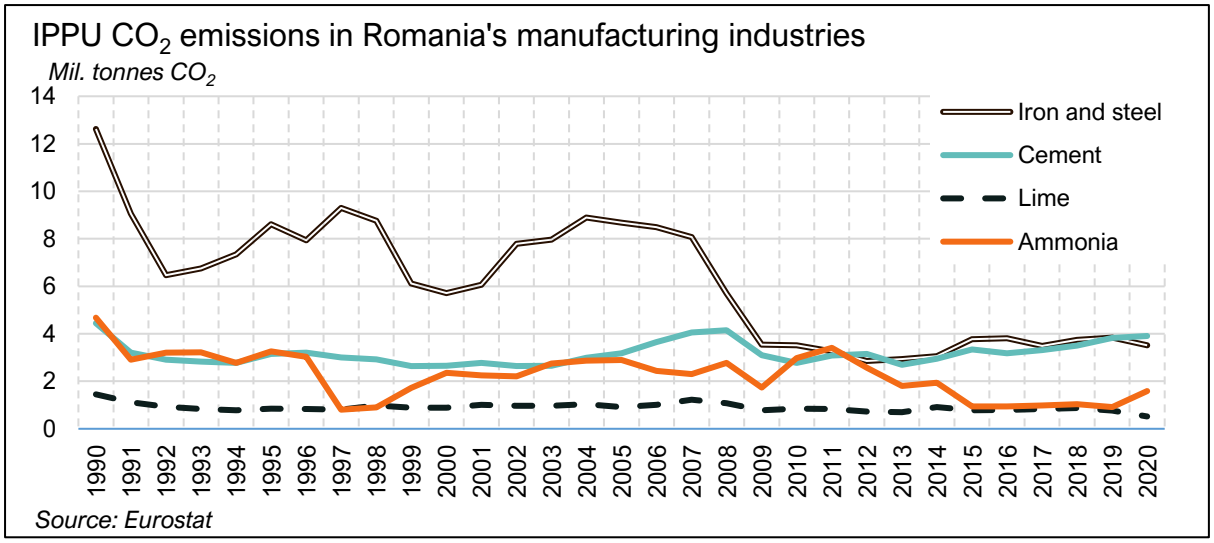


Figure 3. IPPU emissions from Romania's manufacturing industries (Eurostat, 2022).[11]



Romania's industrial landscape has changed fundamentally in the last 30 years, primarily on a trend of progressive deindustrialisation, but maintaining a higher-than-EU-average contribution of industrial manufacturing to the economy and to national emissions. This is broadly similar to other countries in the CEE region; for example, the production of non-metallic mineral products (which includes cement, lime, and glass) makes up a higher-than-average share of emissions in most CEE countries (Eurostat,

[10] Non-metallic mineral products comprise cement, lime, ceramics, and glass (European Commission, 2023). Pulp and paper and non-ferrous metal manufacturing are not shown, as their aggregated emissions were consistently less than 1% of national CO_2 emissions.

[11] Aluminium, ferroalloys and glass production emissions are not shown, as their aggregated contribution was consistently less than 1% of national CO_2 emissions.

2022). There are some differences in the carbon footprint of industry within the region: Hungary and the Czech Republic both have lower CO_2 emissions per unit value added from their industries than Romania, while Bulgaria's are significantly higher (IAP, 2023). However, the situation of industry in Romania and CEE is dynamic, and the trend of deindustrialisation may be partially reversed with the reopening of facilities and investments in new technologies. In the following sections, we review Romania's main industrial producers and the changes they may undergo in the near future.

Romania's main industrial producers

Today, the largest industrial emitter in Romania is the Liberty Galați integrated steelworks, with nearly 4.4 Mt CO_2-eq reported in 2021 under the EU ETS. Nineteen other industrial emitters had verified emissions over 100,000 tonnes of CO_2-eq in 2021. The second-largest emitter is Azomureș, Romania's main fertilizer producer, with 1.3 Mt CO_2-eq emitted in 2021, followed by Romania's cement and aluminium producers, the Petrobrazi, Ploiești and Năvodari oil refineries, three lime production plants, the Chimcomplex chemicals production plant at Râmnicu-Vâlcea, and the Saint-Gobain glass production facility (Table 1).

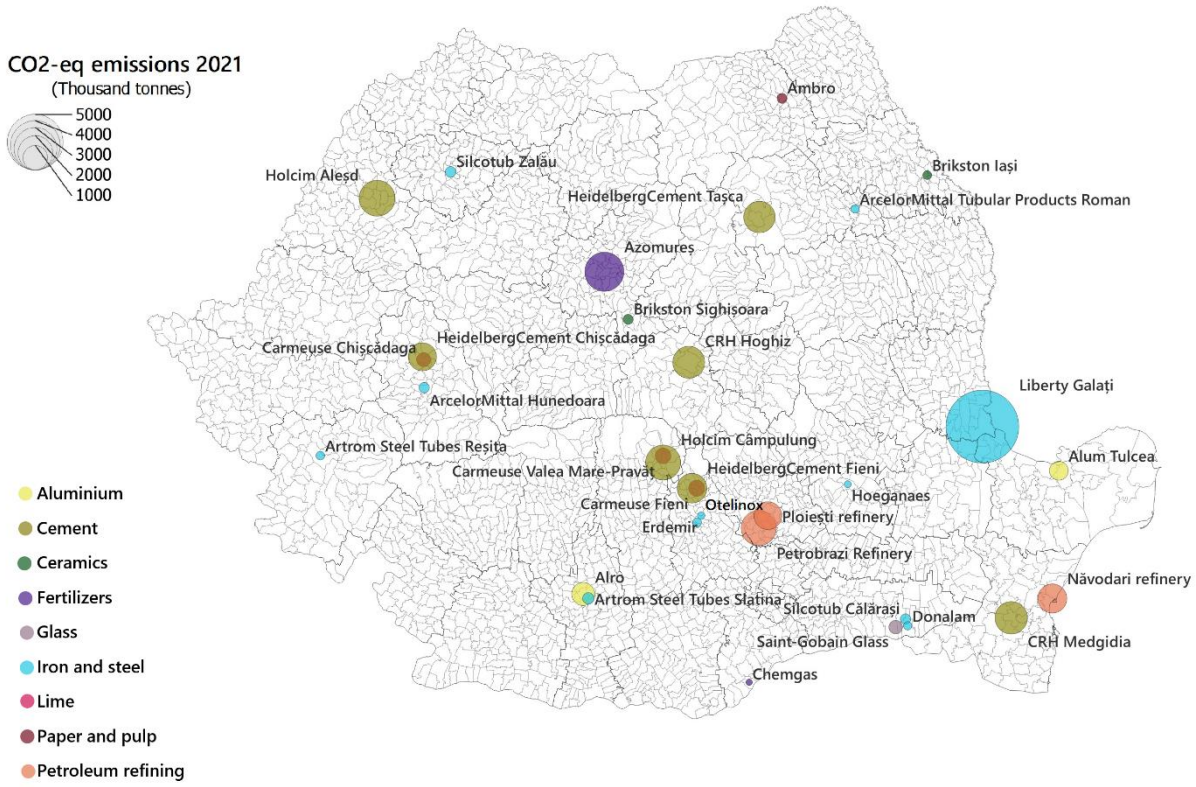
Table 1. Romania's largest industrial emitters. Source: (European Commission, 2023).

Installation	Industry	Emissions in 2021 (t CO_2-eq)
Liberty Galați	Iron and steel	4,394,990
Azomureș	Fertilizers	1,308,070
Holcim - Aleșd	Cement	1,096,758
OMV Petrom - Petrobrazi refinery	Oil refining	1,052,362
Holcim - Câmpulung	Cement	1,042,156
CRH Ciment - Medgidia	Cement	888,902
CRH Ciment - Hoghiz	Cement	861,851
HeidelbergCement - Tașca	Cement	832,087
HeidelbergCement - Fieni	Cement	733,688
Rompetrol – Năvodari refinery	Oil refining	702,940
HeidelbergCement - Chișcădaga	Cement	655,166
Petrotel-Lukoil - Ploiești refinery	Oil refining	637,122
Alro (primary production)	Aluminum	398,480
Alum Tulcea	Aluminum	261,745
Carmeuse - Fieni	Lime	177,459
Carmeuse - Câmpulung	Lime	165,678
Carmeuse - Chișcădaga	Lime	122,568
Chimcomplex - Râmnicu-Vâlcea	Chemicals	116,232
Saint-Gobain Glass - Călărași	Glass	110,775

Romania's major industrial manufacturing sites are located across the country, but several regions display a clustering of producers (Figure 4**)**. Among these are the Prahova and Dâmbovița counties in southern Romania (the OMV Petrom Petrobrazi refinery, and the HeidelbergCement plant and Carmeuse lime plant at Fieni) and the southern Dobrogea region on the Black Sea coast (the CRH cement plant at Medgidia, the Celco lime plant at Corbu and the Rompetrol refinery at Năvodari). Liberty Galați is not geographically close to other producers, but benefits from port access to the

Danube River, Romania's most important waterway. However, some emitters are relatively isolated from other large industrial sites, for example the cement plants at Aleșd and Tașca.

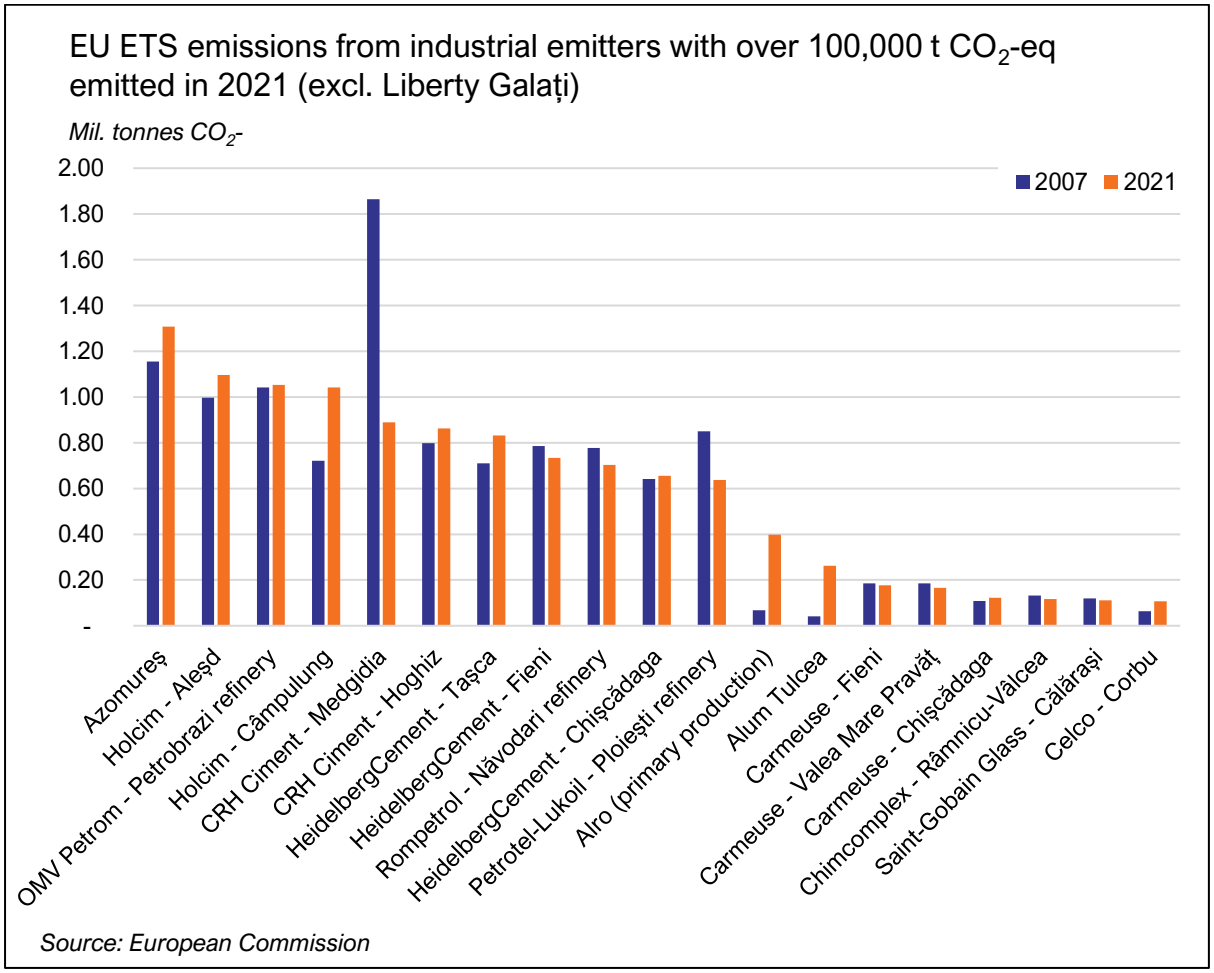
Figure 4. Industrial facilities in Romania with emissions over 100,000 tonnes CO_2-eq in 2021 under the EU ETS. Source: EPG own work, based on (European Commission, 2023).



Over the past 15 years, most of the large industrial emitters shown in Table 1 slightly increased their emissions, with the a few notable exceptions (Figure 5). In the following section, we present a more in-depth analysis of major producers in the steel (production and processing), cement and chemicals industries. It is worth noting the aluminium production sector, which is not discussed in this report, but which saw a significant increase in emissions between 2007 and 2021. This is primarily due to the restarting of Alum Tulcea, Romania's only alumina producer, after closure for maintenance and modernisation until 2008. Following the restart, Alum Tulcea increased its supply of alumina to Alro Slatina, Romania's only aluminium manufacturer. Combined with the merger of Alro Slatina with Alprom (potentially leading to a revision of emissions reporting), these events led to an increase in combined emissions of Alro and Alum from 128,500 tonnes CO_2-eq in 2007 to 656,000 tonnes by 2013 and 680,000 tonnes in 2021. Another noteworthy observation is for the Chimcomplex Onești platform for chemicals production, which more than doubled its emissions between 2007 and 2021 to reach 65,500 tonnes CO_2-eq by 2021 (not

shown in Figure 5 which only displays sources which emitted over 100,000 tonnes CO_2-eq in 2021).

Figure 5. Emissions reported under the EU ETS for industrial producers with over 100,000 tonnes CO_2-eq emitted in 2021 (European Commission, 2023). Liberty Galați is excluded for visualization purposes.



Source: European Commission

In the following section, we conduct a more in-depth analysis of installations in the steel, cement, and chemicals industries. In the chemicals industry, we focus on the production of fertilizers and bulk chemicals, with the petrochemical and oil refining industries remaining out of the scope of this report. For the steel industry, we analyse both steel production and processing (i.e., the manufacturing of finished steel products such as pipes).

Steel production and processing

Despite its decline in recent decades, Romania still has a significant industry of steel production and processing. The largest steel producer is Liberty Galați, Romania's only primary steel producer and its largest point-source emitter. First opened in 1966, the Liberty Galați plant is one of Romania's largest industrial complexes, a major employer, and included in the Territorial Just Transition Plan for the Galați region. It uses a blast

furnace-basic oxygen furnace (BF-BOF) process, and in 2021 it produced 2.35 Mt of liquid steel and 3.51 Mt of finished products,[12] emitted 4.39 Mt CO_2-eq and received 3.14 million free allowances under the EU ETS (ANPM, 2021). Its emissions have fallen by 54% since 2007 (from 9.75 Mt to 4.4 Mt), mostly due to a significant reduction in production capacity: between 1993 and 2021, its liquid steel production capacity fell from 10.15 Mt/year to 4.17 Mt/year and its finished products capacity from 11 Mt/year to 6.49 Mt/year.[13]

Table 2. Finished products production capacities and outputs for steel producers in Romania. Excludes Ductil Steel Oțelu Roșu for which no data was available. The most recent year of available data is always used. Source: data from annual environmental reports, environmental permitting documentation, and companies' own statements.[14]

Installation	Finished products	Production capacity (finished products) (tonnes/year)	Output (finished products) (tonnes/year)	Year
Liberty Galați	Sheets, strip, and other products	6,490,000	3,510,000	2020
ArcelorMittal Hunedoara	Rolled products, blooms	400,000	181,729	2021
Silcotub Călărași	Blooms and billet	535,000	317,073	2018
Artrom Steel Tubes Reșița	Continuous cast products	464,000	251,492	2021
COS Târgoviște	Rolled products, semi-finished products	281,825	146,741	2019
SC SMR SA Balș (closed)	Wheels, axles, and other rolling stock	87,000	Unknown	Unknown

Aside from Liberty Galați, Romania has four other operational steel producers, all of which are secondary steel producers using electric arc furnaces (EAFs): Silcotub Călărași (formerly Donasid), ArcelorMittal Hunedoara (formerly Siderurgia Hunedoara), Artrom Steel Tubes Reșița (formerly TMK Reșița) and COS Târgoviște (reopened in 2022).[15] They each produced between 195,000 and 600,000 tonnes of liquid steel in 2021,[16] with the largest volumes produced at Silcotub Călărași (601,809 tonnes), and emitted between 26,000 and 48,800 tonnes CO_2-eq in 2021.[17] Significant decreases in emissions have occurred for ArcelorMittal Hunedoara and Artrom Steel Tubes Reșița, due to the conversion of their blast furnace-open hearth processes to EAF processes. This conversion led to a significant reduction in liquid steel production

[12] In this year, one of Liberty's heavy plate rolling mills with a capacity of 1.2 Mt/year had been temporarily shut since 2013 (Liberty Galați, 2022).
[13] The utilization rate of Liberty Galati's finished product capacity was 83% in 2010 and 54% in 2021, likely linked to the suspension of activity at one of its heavy plate rolling mills (see footnote 10).
[14] Final products are not necessarily finished products; in some cases, the final products are semi-finished products such as blooms and billet, which are further processed at separate steel mills (this is the case for Silcotub Călărași and Artrom Steel Tubes Reșița; ArcelorMittal Hunedoara has its own steel mill, but also sends semi-finished products to ArcelorMittal Tubular Products Roman, for pipe production). No data was available for Ductil Steel Oțelu Roșu.
[15] Hoeganaes Buzău (formerly Ductil Iron Powder) also has an EAF; however, the plant is not considered to be a steel producer, as the melted scrap is atomised and used for the production of iron powders.
[16] COS Târgoviște produced 293,000 tonnes of liquid steel in 2019, the most recent year of available data.
[17] It should be noted that COS Târgoviște resumed operations in 2022, and EU ETS emissions data is available most recently for 2021. Before ceasing operations, it emitted between 40,000 and 50,000 tonnes of CO_2-eq in the 2013-2018 period.

capacities at these two plants,[18] and emissions decreased steeply to a 2009 minimum around the financial crisis. On the other hand, emissions at Silcotub Călărași increased by nearly 50% between 2007 and 2021, associated with an increase in steel production[19].

In addition to the currently operational steel production plants, it is worth mentioning the Ductil Steel plant at Oțelu Roșu and SC SMR Balș. The former, whose emissions dropped from 18,000 in 2007 to zero in 2017, has been closed due to the plant's poor energy performance and long transport distance to the associated processing plant in Buzău (AMEC, 2017). SMR SA Balș, an integrated EAF steel producer making wheels, axles and rolling stock, emitted 47,000 tonnes of CO_2-eq in 2007 and recorded no emissions from 2017 onwards. The plant has been gradually demolished, and the space may now be relaunched as an industrial park (Eveniment de Olt, 2021).

The consumption of resources at Romania's steel plants is mostly aligned with the processes they use and their production levels. In absolute terms, the largest consumer of energy in Romania's steel sector was of course Liberty Galați: in 2017, it consumed 865 GWh of electricity (second only to aluminium producer Alro of the large emitters included in this report), 199 million m^3 of natural gas and 2.8 billion m^3 of blast furnace gas. It also used over 3.8 million tonnes of iron ore and 1.4 million tonnes of coking coal in for sintering and pig iron production. Its entire coking coal requirement is currently met by imports from India and Poland, after it replaced its Russian coking coal imports (300,000 tonnes) with alternative sources (Liberty Steel, 2022).

Given their small relative sizes, EAF producers had much lower resource consumptions than Liberty Galați. Among them, producers with integrated steel mills (ArcelorMittal Hunedoara and COS Târgoviște) had higher water and natural gas consumptions than Silcotub Călărași and Artrom Steel Tubes Reșița, which shipped their semi-finished products to separate rolling mills (Table 3). At the same time, Silcotub Călărași had the highest consumption of electricity, coal, and scrap steel, in line with its large production volumes relative to other producers. Silcotub Călărași is also the most efficient EAF at using scrap steel for liquid steel production (1.05 tonne/tonne, compared to ArcelorMittal Hunedoara with 1.28).

It is worth noting that some steelmakers, such as Liberty Galați, also produce hydrogen for their own consumption purposes, as does metallurgical powders producer Hoeganaes. In 2017 Hoeganaes used 65 tonnes of hydrogen per tonne of finished metallurgical powder for thermochemical treatment, with the excess being burned and vented into the atmosphere (ANPM, 2018).

[18] Liquid steel capacity at ArcelorMittal Hunedoara decreased from 3.8 Mt to 0.935 Mt between 1993 and 2003, and at Artrom Steel Tubes Reșița it decreased from 1.05 Mt to 0.45 Mt in the same time period (Commission of the European Communities, 2005)

[19] By the end of 2018, steel production had risen to 523,000 tonnes, and by 2021 was over 600,000 tonnes (Pană, 2019).

Table 3. Consumption of water, energy and raw materials for steel producers in Romania. Excludes Ductil Steel Oțelu Roșu for which no data was available. The most recent year of data is always used. Source: data from annual environmental reports, environmental permitting documentation, and companies' own statements.

Installation	Water consumption (thousand m^3/year)	Electricity consumption (GWh/year)	Natural gas consumption (thousand m^3/year)	Coal consumption (tonnes/year)	Consumption of main iron-bearing raw material (tonnes/year)	Year
Liberty Galați	Unknown[20]	865.1	199,042	1,574,861[21]	3,881,496 (iron ore)	2017
ArcelorMittal Hunedoara	19,626	182	17,158	4,040[22]	254,063 (scrap and ferro-alloys)	2021
Silcotub Călărași	531.55	302.2	6,876	9,969[23]	646,731 (scrap and pig iron)	2021
TMK- Reșița	1,348	194.94	4,324	4,730[24]	303,199 (ferrous materials and ferro-alloys)	2021
COS Târgoviște	3,744	219.57	14,070	Unknown	349,194 (scrap and ferro-alloys)	2019
SC SMR SA Balș (closed)	Unknown[25]	41.7	2,497	904.3[26]	47,081 (scrap and ferro-alloys)	2007

Connected to steel production, the steel processing industry is present in Romania both in integrated steel mills (Liberty Galați, ArcelorMittal Hunedoara, and COS Târgoviște), as well as in independent processing plants. Steel and ferroalloy processing into pipes, profiles and rolled products contributed 1.1% to Romania's GVA in 2021, and employed nearly 83,500 people (Institutul Național de Statistică, 2023). While integrated steel mills dominate the market, some independent steel processing plants remain active: Oțelinox, Donalam Călărași, Erdemir, ArcelorMittal Tubular Products Roman, Silcotub Zalău and Artrom Steel Tubes Slatina. The latter three plants receive their steel inputs (e.g., billet, blooms, and other continuous cast products) from their corresponding EAF steel producers (ArcelorMittal Hunedoara[27], Silcotub Călărași, and Artrom Stel Tubes Reșița, respectively). The parent group of Donalam, Beltrame Group, recently purchased some of the steel production assets of COS Târgoviște ahead of this facility's production restart in 2022.

Of the six active standalone steel processors in Romania, three produced steel pipes (ArcelorMittal Tubular Products Roman, Artrom Steel Tubes Slatina and Silcotub Zalău), and the remainder produced rolled steel products, including electrotechnical strips (Erdemir) (Table 4). These six plants emitted between 15,000 and 68,500 tonnes of CO_2-eq in 2021, with pipe producers appearing to generate more emissions per

[20] For Liberty Galati, only the total water requirement was available: 46.8 million m^3/year. The water requirement is generally higher than actual water consumption for industrial plants, and is a theoretical quantity generally cited for obtaining authorizations for water extraction to supply the plants.
[21] Coking coal and anthracite.
[22] Petcoke.
[23] Anthracite.
[24] Petcoke and mixes for slag foaming.
[25] Only the total water requirement was available: 66,800 m^3/year.
[26] Petcoke and graphite dust.
[27] ArcelorMittal Roman also receives raw material from ArcelorMittal Ostrava and ArcelorMittal Warsawa (ArcelorMittal, n.d.).

tonne than manufacturers of other products. The emissions of ArcelorMittal Roman dropped by 82% between 2007 and 2021, associated with a significant reduction in the output of finished products after 2015, while those of Silcotub Zalău increased by 73% over the same period, possibly linked to its addition of a new production line for piping used in oil and gas production (OCTG line) (Vrabie, 2013).

In addition to the currently operational steel processing plants, it is worth mentioning Ductil Steel Buzău, the processing plant of the Ductil Steel plant at Oțelu Roșu, which bankrupted in 2021. In 2011, the plant had emitted 32,000 tonnes of CO_2-eq. Industria Sârmei Câmpia Turzii, with verified emissions of 55,600 tonnes in 2007, used to be an integrated EAF steel producer (producing nearly 220,000 tonnes of liquid steel in 2002, and cast-iron products as well as bars and wire), but from 2009 appeared to cease its steel production activities and move to processing billet into steel wire and other finished products. It is also currently bankrupt.

Table 4. Finished products production capacities and outputs for steel processing plants in Romania. The most recent year of available data is always used. Source: data from annual environmental reports, environmental permitting documentation, and companies' own statements.

Installation	Finished products	Production capacity (finished products)	Output (finished products)	Year
Oțelinox Târgoviște	Rolled bands	Unknown	92,823 tonnes/year	2016
SC Donalam SRL, Călărași	Rolled products and heavy profiles	450,000 tonnes/year	162,026 tonnes/year	2021
ArcelorMittal Tubular Products Roman	Pipes	180,000 tonnes/year	63,146 tonnes/year	2021
Erdemir, Târgoviște	Electrotechnical strips	150,000 tonnes/year	75,000 tonnes/year	2019
Silcotub, Zalău	Pipes	Varies[28]	165,309 tonnes/year	2016
Artrom Steel Tubes, Slatina	Pipes	248,000 tonnes/year	187,667 tonnes/year	2019
Industria Sârmei Câmpia Turzii (closed)	Wire	80 tonnes/hour	15,845 tonnes/year	2013[29]
Ductil Steel, Buzău (closed)	Rolled products	504,504 tonnes/year	220,980 tonnes/year	2019

It is difficult to compare resource consumption between steel processing plants, as data is rarely available for the same year for more than two plants. Nevertheless, it is worth pointing out ArcelorMittal Tubular Products Roman, which consumed the most water in absolute terms out of all steel processors with available data, and Silcotub Zalău and Artrom Steel Tubes Slatina, which had the largest absolute consumptions of electricity, natural gas and input steel products in the most recent year of available data (2016 and 2019, respectively) (Table 5). Their electricity consumption is, of course, much smaller than steel producers (Table 3) (with Hoeaganes being an exception), and their natural gas consumption is larger than all EAF steel producers. In fact, all steel processors consumed more natural gas than all EAF steel producers except ArcelorMittal Hunedoara and COS Târgoviște. According to environmental

[28] Hot rolling capacity: 260,000 tonnes/year; drawn pipes capacity: 90,000 tonnes/year; production of pup-joint accessories: 1,000 tonnes/year.
[29] The quoted capacity is from 2016; the production output is from 2013.

reporting data, Oțelinox and Erdemir consumed hydrogen in their steel processing activities: Erdemir used 675,000 m^3 of hydrogen in 2019.

Table 5. Consumption of water, energy and raw materials for steel processors in Romania. The most recent year of available data is always used. Source: data from annual environmental reports, environmental permitting documentation, and companies' own statements

Installation	Water consumption (thousand m^3/year)	Electricity consumption (GWh/year)	Natural gas consumption (thousand m^3/year)	Consumption of main steel-bearing raw material (t/year)	Year
Oțelinox Târgoviște	Unknown[30]	45	17,000	70,000 (hot-rolled bands)[31]	2017
SC Donalam SRL, Călărași	87.3	33.75	11,809	166,917 (blooms)	2021
ArcelorMittal Tubular Products Roman	5,972	30.36	11,256	175,765 (billet and ingots)	2021
Erdemir, Târgoviște	173	35.53	7,646	82,500 (hot-rolled bands)	2019
Silcotub, Zalău	Unknown[32]	98.4	25,044	192,957 (billet)	2016
Artrom Steel Tubes, Slatina	636	60.3	32,884	229,109 (billet)	2019
Industria Sârmei Câmpia Turzii (closed)	353	6.5	1,530	Unknown	2016
Ductil Steel, Buzău (closed)	186	28.3	8,555	138,128 (billet)	2019

The picture of steel production and processing is likely to be dynamic over the coming decade, with many historically large and energy-intensive facilities hoping to relaunch their operations in economically challenging times. As mentioned above, COS Târgoviște resumed its operations in June 2022 (at low capacity) and its owners announced plans to upgrade the plant and increase production (Banila, 2022). On the other hand, the Ductil Steel facilities at Oțelu Roșu and Buzău have been demolished and are unlikely to resume operations. Active production capacities and outputs could also change: Liberty Galați is planning to increase its production output to 4 Mt/year of liquid steel (Liberty Steel, 2021), and in early 2023, the Artrom Steel Tubes facilities at Reșița and Slatina were acquired by Hefestos Capital, in a move that investors hope will relaunch its modernization and development programmes (Economedia, 2023).

These potential changes have implications both for local economies and workforces, but also for pressure on resources (e.g., natural gas, and scrap steel for EAF producers, as further detailed in the final section of this report). Pressure on water resources should also not be neglected in the context of climate change, although higher-quality data is required to assess the impact on water resources of different steel production and processing facilities. Hydrogen production and consumption may also become a topic of consideration by steelmakers, given the broad interest in hydrogen as a decarbonisation solution for industry. Of course, external factors will always affect planned changes, particularly in the context of the ongoing energy crisis: as an example, in 2019, Tenaris Silcotub said that its planned investment into its

[30] Only the total water requirement was available: 1.52 million m^3/year.
[31] It is not clear if this is the capacity or actual consumption of hot-rolled steel bands.
[32] Only the total water requirement was available: 597,000 m^3/year.

Călărași steel mill was being challenged by high electricity prices (Pană, 2019), and previous development plans at Artrom Steel Tubes Reșița had stagnated during the Covid-19 crisis and the Russian invasion of Ukraine.

Cement production

Romania's seven operational plants for clinker and cement production are owned by HeidelbergCement (plants at Tașca, Fieni and Chișcădaga), Holcim (plants at Aleșd and Câmpulung) and CRH (through subsidiary Romcim, with plants at Medgidia and Hoghiz). These plants, which are relatively scattered and often co-located with lime producers (Figure 4) are important emitters and consumers of energy and raw materials. Their emissions ranged between 832,000 and 1.3 million tonnes of CO_2-eq, in general correlated with production volumes where these were available (4 out of 7 plants, Table 6) and reported emissions per tonne of cement were generally comparable, ranging from 0.58 at Holcim Câmpulung to 0.71 at CRH Medgidia.

Table 6. Cement production capacities and outputs for cement plants in Romania. The most recent year of available data is always used. Source: data from annual environmental reports, environmental permitting documentation, and companies' own statements.[33]

Installation	Production capacity (cement)	Output (cement)	Year
HeidelbergCement, Fieni	2,500,000 tonnes/year	Confidential	2021
HeidelbergCement, Chișcădaga	1,650,000 tonnes/year	1,096,000 t/year	2019
HeidelbergCement, Tașca	3,000,000 tonnes/year	Confidential	2020
Holcim, Aleșd	Unknown	1,822,628 t/year	2021
Holcim, Câmpulung	Unknown	1,803,254 t/year	2020
CRH Ciment, Medgidia	800 tonnes/hour	1,320,488 t/year	2019[34]
CRH Ciment, Hoghiz	4,100 tonnes/day	Unknown	2018

In contrast to the steel sector, emissions from cement producers have generally remained stable over the 2007-2021 period, with several exceptions. The Holcim Câmpulung plant increased its emissions by 44% in line with the addition of a new clinker production line in 2008, resulting in an increase in production capacity of nearly 250%.[35] Holcim is currently planning to further expand its existing production capacities (Financial Intelligence, 2022). On the other hand, emissions from CRH Medgidia decreased by half in just three years (2007-2010), stretching into a longer-term decline in production, from 1.8 Mt in 2001 to 1.3 Mt in 2019. Whereas the decline in steel-generated emissions is partially attributable to technological conversion, this is less the case for cement production: it had switched from wet to dry kilns and added pre-calcining units before 2008, and waste co-incineration to substitute fossil fuel use

[33] For the Holcim plants, there was no official production capacity data for cement, only for clinker. An estimate of cement production capacity was calculated based on clinker production capacity and output, and cement output, leading to ~2.3 Mt cement production capacity for the Aleșd plant and 2.5 Mt production capacity for the Câmpulung plant.

[34] For this facility, production capacity figures are from 2016, while output figures are from 2019.

[35] Holcim's cement plant at Câmpulung, with emissions increasing from 722,000 tonnes in 2007 to just over 1 Mt in 2021, increased its cement production capacity by nearly 250% with the introduction of a new clinker production line in 2008.

occurs at all cement plants. This co-incineration is unabated and some controversy has surrounded the use of imported waste for this purpose (EURACTIV, 2020).

There was little reliable data on water consumption by cement producers, with most environmental reports quoting the "water requirement" (the theoretical quantity needed for an industrial process) rather than the actual consumption. Cement producers are significant electricity consumers, albeit less so than large steel and chemicals plants. For the two plants where waste use for co-incineration was available (CRH Medgidia and Holcim Câmpulung), it appeared correlated to production volumes (0.08 and 0.09 tonnes per tonne of cement produced, respectively) (Table 7). There was very little data available for natural gas, coal and pet coke consumption.

When it comes to raw materials, of the plants which provided reliable data, the largest absolute consumption of limestone, clay and marls was Holcim Aleșd (2.4 Mt total consumption) (Table 7). Holcim Câmpulung used the least of these materials per tonne of cement produced, while also using the highest absolute amount of slag, a commonly used substitute for clinker in the production of composite cements (145,450 tonnes). The largest consumers of ash (another material substitute) were the CRH plants at Medgidia (99,100 tonnes in 2019) and at Hoghiz (81,900 tonnes in 2017).

Table 7. Consumption of water, energy and raw materials for cement plants in Romania. The most recent year of available data is always used. Source: data from annual environmental reports, environmental permitting documentation, and companies' own statements.[36]

Installation	Electricity (MWh/year)	Natural gas (,000 m^3/year)	Coal and pet coke (t/year)	Co-incinerated waste (t/year)	Limestone, clay, marls (t/year)	Year
HeidelbergCement, Fieni	Confidential	Confidential	Unknown	47,096	Confidential	2021
HeidelbergCement, Chișcădaga	120,560	Unknown	Unknown	Unknown	1,346,989	2019
Holcim, Aleșd	187,730	Unknown	110,186	101,658[37]	2,395,893	2021
Holcim, Câmpulung	81,146	1,738	89,851	143,027[38]	2,395,030	2020
CRH Ciment, Medgidia	155,504	387	Unknown	96,928	1,808,076	2019
CRH Ciment, Hoghiz	120,845	Unknown	Unknown	64,000	1,461,969	2017

[36] For the HeidelbergCement Chișcădaga, Holcim Alesd and Holcim Câmpulung plants, electricity consumption was calculated from their specific electricity consumption (110, 103 and 45 kWh/tonne, respectively). HeidelbergCement Tașca did not have any publicly available data.
[37] Shredded solid waste only; other consumption data for co-incinerated waste is not available.
[38] Shredded solid waste only; other consumption data for co-incinerated waste is not available.

Chemicals production

The chemicals production sector is dominated by Azomureș and Chimcomplex. Azomureș, a producer of fertilizers, is Romania's largest chemicals producer (

Table 8) and the second-largest industrial emitter in Romania. Based in the Just Transition region of Mureș, it has 60-year history of production, using the steam

Installation	Main final products	Production capacity (final products) (t/year)	Output (final products) (t/year)	Year
Azomureș	Nitrogen-based fertilizers (including NPK) and melamine	1,985,572	813,201	2021
Chimcomplex Râmnicu Vâlcea	Chlorinated products, biocides, polyols	1,437,295	1,300,341	2021
Chimcomplex Onești	Chlorinated products, inorganic chlorides, biocides, alkylamines	672,711	462,955	2021
Ciech Soda (suspended)	Soda ash and derivatives	615,390	Unknown	2018
Viromet Victoria (closed)	Methyl alcohol, formaldehyde, and resins	260,360	49,144	2018
Chemgas Slobozia (closed)	Nitrogen-based fertilizers	1,220,000	94,840	2019
Donau Chem (closed)	Nitrogen-based fertilizers	1,370,000	Unknown	2021
Amurco Bacău (closed)	Urea, food-grade sodium bicarbonate	421,500	Unknown	2011
GHCL Upsom (closed)	Heavy soda ash	200,000	Unknown	2006

methane reforming and Haber-Bosch processes to produce ammonia. Most of this ammonia is used to produce nitrogen-based fertilizers, including NPK fertilizers, which Azomureș is the only producer of in Romania. The facility was recently faced with multiple temporary closures due to high natural gas prices and is currently not operational since June 2022 (Stanciu, 2023). This series of temporary closures has led to emissions of 1.3 Mt CO_2-eq in 2021, its lowest levels since 2010.

Chimcomplex operates two platforms for the production of bulk chemicals at Râmnicu-Vâlcea and Onești. Both platforms use brine electrolysis to produce a range of finite products, including chlorinated products and biocides, and the Râmnicu-Vâlcea platform is also a significant consumer of natural gas as a raw material. Production volumes and emissions under the EU ETS were much higher at Râmnicu-Vâlcea than at Onești in 2021 (

Installation	Main final products	Production capacity (final products) (t/year)	Output (final products) (t/year)	Year

Azomureș	Nitrogen-based fertilizers (including NPK) and melamine	1,985,572	813,201	2021
Chimcomplex Râmnicu Vâlcea	Chlorinated products, biocides, polyols	1,437,295	1,300,341	2021
Chimcomplex Onești	Chlorinated products, inorganic chlorides, biocides, alkylamines	672,711	462,955	2021
Ciech Soda (suspended)	Soda ash and derivatives	615,390	Unknown	2018
Viromet Victoria (closed)	Methyl alcohol, formaldehyde, and resins	260,360	49,144	2018
Chemgas Slobozia (closed)	Nitrogen-based fertilizers	1,220,000	94,840	2019
Donau Chem (closed)	Nitrogen-based fertilizers	1,370,000	Unknown	2021
Amurco Bacău (closed)	Urea, food-grade sodium bicarbonate	421,500	Unknown	2011
GHCL Upsom (closed)	Heavy soda ash	200,000	Unknown	2006

Table 8), although the differences in production processes at the two plants (which have common but also different finished products) mean that emissions per tonne of finished product are higher at Onești than at Râmnicu-Vâlcea. As mentioned earlier in this report, the Chimcomplex Onești platform more than doubled its emissions between 2007 and 2021, while the platform at Râmnicu-Vâlcea saw a reduction of around 11.5%.

Several other important chemicals plants are temporarily or permanently closed. These include three bankrupted fertilizer plants (Donau Chem, a former huge natural gas consumer which emitted over 860,000 tonnes of CO_2-eq in 2014, Amurco, which emitted 530,000 tonnes in 2012, and Chemgas, which emitted 612,000 tonnes in 2020), methanol and derivatives producer Viromet, and soda ash producer GHCL Upsom. Ciech Soda, another soda ash producer, has suspended its operations due to issues with steam supply. In general, these defunct or suspended plants were primarily shut due to issues with the supply of utilities or the accumulation of debts. Some of the plants have also been at the heart of environmental issues, including transborder air pollution (Donau Chem) and of large-scale legal action. Although petrochemicals production is not covered in this report, it is worth also noting the Arpechim oil refinery, one of Romania's largest during the communist regime. This plant, which employed 8,000 people before 1990, was shut in 2011 due to lack of economic viability. Following a failed attempt to revive the plant, the decision was taken to demolish it in 2020 (Adevărul, 2020).

Table 8. Finished products production capacities and outputs for chemicals plants in Romania. The most recent year of available data is always used. Source: data from annual environmental reports, environmental permitting documentation, and companies' own statements.

Installation	Main final products	Production capacity (final products) (t/year)	Output (final products) (t/year)	Year
Azomureș[39]	Nitrogen-based fertilizers (including NPK) and melamine[40]	1,985,572	813,201	2021
Chimcomplex Râmnicu Vâlcea	Chlorinated products, biocides, polyols	1,437,295	1,300,341	2021
Chimcomplex Onești[41]	Chlorinated products, inorganic chlorides, biocides, alkylamines	672,711	462,955	2021
Ciech Soda (suspended)	Soda ash and derivatives	615,390	Unknown	2018
Viromet Victoria (closed)[42]	Methyl alcohol, formaldehyde, and resins	260,360	49,144	2018
Chemgas Slobozia (closed)	Nitrogen-based fertilizers	1,220,000	94,840	2019
Donau Chem (closed)	Nitrogen-based fertilizers	1,370,000	Unknown	2021
Amurco Bacău (closed)	Urea, food-grade sodium bicarbonate	421,500	Unknown	2011
GHCL Upsom (closed)	Heavy soda ash	200,000	Unknown	2006

Romania's chemicals producers are major consumers of natural gas as an energy source and feedstock, and significant consumers of water and electricity (Table 9). Azomureș was the largest industrial consumer of natural gas in Romania. The Chimcomplex Râmnicu-Vâlcea platform was the second-largest electricity consumer of the large emitters in the steel, cement, and chemicals sectors, after Liberty Galați. It is closely followed by Azomureș in 2021 and Donau Chem in 2014. Other important raw materials used in Romania's chemicals sector are brine and limestone, used by both Chimcomplex platforms and by soda ash producer Ciech Soda. Water consumption data was oftentimes inconsistently reported, but Ciech Soda stood out as a significant water consumer, with a higher water consumption than Azomureș in the most recent year of available data.

[39] The production capacities and output for Azomureș include those of ammonium nitrate, which is partially consumed internally to produce urea. However, it is produced in the same installation as nitrocalcar and the capacity and output of the two products is not differentiated.
[40] Melamine is a widely used organic compound in the manufacture of plastics.
[41] The production capacities and output of Chimcomplex Onești exclude the inactive installations and those used in "campaigns" (for which details of the number of operating months per year are not provided), as well as soda flakes for which production data is not available, but includes all intermediary products, including hydrogen, which were not disaggregated to indicate the shares of own use versus export.
[42] For Viromet Victoria, the output volume is calculated based on the cited specific gas consumption; in 2021, the company had zero methanol production.

Table 9. Consumption of water, energy and raw materials for chemicals plants in Romania. No data was available for Amurco. The most recent year of available data is always used. Source: data from annual environmental reports, environmental permitting documentation, and companies' own statements.[43]

Installation	Water (,000 m^3/year)	Electricity (MWh/year)	Natural gas (combustion) (,000 m^3/year)	Natural gas (raw material) (,000 m^3/year)	Year
Azomureș	8,231	367,623	445,146	296,357[44]	2021
Chimcomplex Râmnicu Vâlcea	3,156	102,096 (2021)	32,230	Unknown	2022
Chimcomplex Onești	Unknown[45]	394,731	56,485	57,948	2021
Ciech Soda (suspended)	11,559	95,226	1,700	n/a	2018
Viromet Victoria (closed)	1,006[46]	8,499	25,434		2018
Chemgas Slobozia (closed)	1,563	23,270	58,983	55,339	2019
Donau Chem (closed)	15,455	262,800	435,688		2014
GHCL Upsom (closed)	Unknown	Unknown	8,000 m^3/month	n/a	Unclear

It is worth highlighting the hydrogen and methanol production capabilities, and carbon capture capabilities, of Romania's chemicals sector. Although public data is sparse, environmental reports show a production of 1,170 tonnes of hydrogen from brine electrolysis at Chimcomplex Onești in 2018, and a consumption of 10,720 tonnes of hydrogen at Chimcomplex Râmnicu-Vâlcea in 2021[47]. Although not covered in this report, Romania's refineries are also significant hydrogen producers, particularly the Petrobrazi, Năvodari and Ploiești refineries. Viromet produced 216,000 tonnes of methanol in 2016, at 90% of its production capacity. Finally, Azomureș captures and uses some of its emitted CO_2 for the production of urea, while Chimcomplex Râmicu Vâlcea consumed 22,000 tonnes of its own emitted CO_2 in 2021.

Romania's chemicals sector is dynamic, given its high dependence on natural gas, as well as the potential for new business lines for hydrogen and low-carbon products. Following a dip in 2008, production at Azomureș rebounded, generating a peak of emissions in 2018, after which rising natural gas prices caused a decrease in production. The substitution of natural gas as an input or an acceptable natural gas price could lead to another rebound in production. Chimcomplex is also planning to increase its polyols and propylene oxide production capacities at Râmnicu-Vâlcea (Vasiliu & Pâslaru, 2022), (Oancea, 2022). Ciech Soda is exploring the construction of its own CHP to resume operations (Energy Industry Review, 2021). Interagro, the parent company of Donau Chem, Amurco and Chemgas, is in judicial reorganization, with many of its operations suspended. In some cases, the closure of facilities was driven by questionable management practices, and it would not be surprising for these plants to reopen under the right judicial conditions and dependent on the trajectory of natural gas prices. Nonetheless, significant investments would be needed for this to happen.

[43] For Viromet Victoria and Donau Chem, data was only available for total natural gas consumption.
[44] The data on consumption of natural gas as a raw material is for ammonia production only.
[45] Only the authorized volume of water is cited (28.5 million m^3 in 2021).
[46] The water intake includes supply to the facility's two micro-hydropower plants, which provided sufficient electricity to cover nearly three-quarters of the company's electricity demand in 2016 (2,070 MWh of 2,809 MWh).
[47] It is not clear how much is produced by the company and how much is imported to the platform.

The future of Romania's industry

The landscape of steel, cement and chemicals manufacturing in Romania has changed substantially over the last three decades. Although on a progressive trend of deindustrialisation, the Romanian manufacturing industry is still a major contributor to the national economy, employment and emissions. The sectors analysed in this report (steel, cement and chemicals manufacturing) each exhibit their own characteristics and challenges, but the common challenges of heavy dependence on energy and key natural resources place technological transformation, demand management, and new processes at the head of Romania's industrial future.

Romania's industry needs to undergo a deep transformation for the national economy to reach net zero emissions by 2050 and meet EU targets. In a balanced scenario, the penetration of technologies such as hydrogen-based direct reduction of iron (DRI) in steelmaking, the use of alternative fuels (including electrification and zero-carbon hydrogen and biomass use), material efficiency and substitution (particularly in the cement and construction industries, respectively) and the use of carbon capture must all play a significant role in Romania's industry (Energy Policy Group, 2022). This would lead to a drastic decrease in emissions from the cement, ceramics and steel industries, coupled with an increased demand for wood as a material substitute, and hence higher emissions from wood production (not covered in this report). Implementation of these measures would bring the total energy demand of Romania's industry to half of 2015 values by 2050 and reduce its GHG emissions to 2.67 Mt CO_2-eq per year, equivalent to just over half of the current emissions of Liberty Steel Galați.

This transformation of Romania's industry is beginning to emerge in the investment plans of major industrial producers. Some have submitted applications for funding renewable energy projects, committed to investing in carbon capture and storage or utilization, and elaborated plans for transitioning to low-carbon processes. These plans align on three major directions for deep industrial decarbonisation: electrification and the use of renewable electricity, the use of hydrogen, and carbon capture. Demand management will also play a role in reducing resource consumption and encouraging low-carbon production.

However, while investments in these directions could shift the resource consumption landscape and generate new value chains, their planning is fragmented as Romania currently has no roadmap for industrial decarbonisation. This is particularly challenging given the declining number of new investment cycles before 2050 and the scale of the transformation that must be achieved. Reaching net zero emissions by 2050 in the balanced scenario requires a massive reduction in natural gas consumption by industry, driven by the electrification of low-temperature industrial heat production, and the use of clean hydrogen and biomethane. At the same time, under this scenario industry must capture and store 1.16 Mt of its CO_2 emissions yearly by 2030, reaching 3 Mt CO_2 per year by 2050 (Energy Policy Group, 2022). Today, however, most

hydrogen produced in Romania is through the emissions-intensive steam methane reforming process, and there are no large-scale carbon capture and storage projects.

The scale of Romania's industrial decarbonisation challenge is therefore significant, but certain characteristics of the Romanian industrial sector may create or enhance existing opportunities for meeting this challenge. Firstly, as shown in this report, industrial manufacturing sectors are important contributors to the Romanian economy, and as such benefit from public and institutional buy-in to modernising industrial production, particularly if the alternative is the closure of facilities. Secondly, six counties in Romania[48] will benefit from funding under the Just Transition Mechanism, including those which are home to Liberty Steel Galați, Azomureș, and the OMV Petrom Petrobrazi refinery. While this funding is likely to be mostly directed towards social safeguards for employees of carbon-intensive industries, they are an important driver for rethinking local economies and developing new businesses, including in industrial hubs.

Thirdly, the significant potential of Romania for renewable energy (including offshore wind in the Black Sea (Energy Policy Group, 2023)), hydrogen production and natural gas production can propel large-scale fuel switching to support industry decarbonisation. Large-scale wind and solar energy projects can reduce the carbon intensity of Romania's grid, propagate the benefits of reduced scope 2 emissions to industrial facilities looking to electrify, and enable the production of green hydrogen. Hydrogen production can help not only decarbonise Romanian industry, but also generate new business opportunities for existing and future industrial facilities (Energy Policy Group, 2021). Finally, Romania has potentially significant geological CO_2 storage capacities: 514 Mt in onshore hydrocarbon deposits only (PwC, 2022), and likely more in deep saline aquifers. Both types of storage sites are oftentimes situated close to heavy industry facilities. A market could also be developed for utilizing captured CO_2 – however, a thorough life-cycle assessment must be performed on the envisaged utilisation pathways.[49]

To make the most of these opportunities and drive industrial decarbonisation at scale and at pace, several actions must be taken at national level. Firstly, Romania must implement **a national strategy for industrial decarbonisation.** Deep emissions reductions in industry are currently not discussed in an integrated manner and are not the concrete responsibility of any public institution. In some cases, the approach to funding industrial decarbonisation technologies is unclear – for example, financing from the EU Modernization Fund has been directed towards energy efficiency in industry, including enabling carbon capture (Government of Romania, 2022) (despite carbon capture incurring an energy penalty, and not contributing to energy efficiency). The revision of the National Energy and Climate Plan (NECP) and publication of its

[48] These six counties are Gorj, Dolj, Mures, Galati, Prahova and Hunedoara.

[49] Different CCU pathways result in the re-release of CO_2 over different timescales – e.g., concrete curing releases CO_2 in 10-100 years, while chemical fuels result in re-release CO_2 in less than 6 months (Berstad, et al., 2021)

Long-Term Strategy for climate neutrality (both expected in 2023) can act as a launchpad for establishing a national industrial decarbonisation strategy for Romania.

A national strategy for industrial decarbonisation must be accompanied by a **comprehensive framework for financing**, including more proactivity on supporting applications for large-scale EU funding, such as the Innovation Fund,[50] and an analysis of the potential for using EU ETS revenues to fund industrial decarbonisation. Financing frameworks should also seek to stimulate private finance, tapping into the potential of products such as loan guarantees or models such as public-private partnerships for driving large-scale industrial decarbonisation. Following an economy-wide approach to industrial decarbonisation, **sector-specific decarbonisation strategies** can help address the inherent differences in decarbonisation pathways between major industrial sectors. These should incentivize the deployment of solutions on a "ladder" basis, providing support based on emissions reduction potential. Strategies for the deployment of specific technologies, such as hydrogen or CCS, can further support R&D, funding, and infrastructure for deploying these capital-intensive solutions. **Clarifying institutional responsibility** for implementing industrial decarbonisation strategies will also be key, with the Ministry of Economy likely playing a central role, and coordinating with the Ministries of Energy and Environment.

Other enablers of industrial decarbonisation **are R&D, stakeholder cooperation and enabling infrastructure**. Fostering R&D by financing pilot and demonstration projects can help to propel industrial decarbonisation, benefitting from Romania's numerous research institutions and universities with specialization in science and engineering. However, funding for R&D must be significantly boosted to enable this. Stakeholder cooperation, particularly in the case of pursuing low-carbon industrial hubs, is key to exchange knowledge, build resilient partnerships, and aggregate demand for relevant resources and infrastructure. Finally, investments in reinforcement of the power grid and in major infrastructure for hydrogen and CO_2 transport and storage are key to accelerate the implementation of decarbonisation technologies, but also to ensure that industrial emitters who are more "isolated" from industrial hubs (Figure 4) are able to access solutions such as hydrogen and CCS in a cost-effective way.

[50] To date, Romania, has not made any applications to the Innovation Fund. Multiple industry-focused projects have been awarded Innovation Fund funding in the CEE region, including a project to capture CO_2 emissions from a cement plant in Bulgaria and store them in the western Black Sea.

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