REPORT

Energising industry

The Road to Clean and Competitive Production

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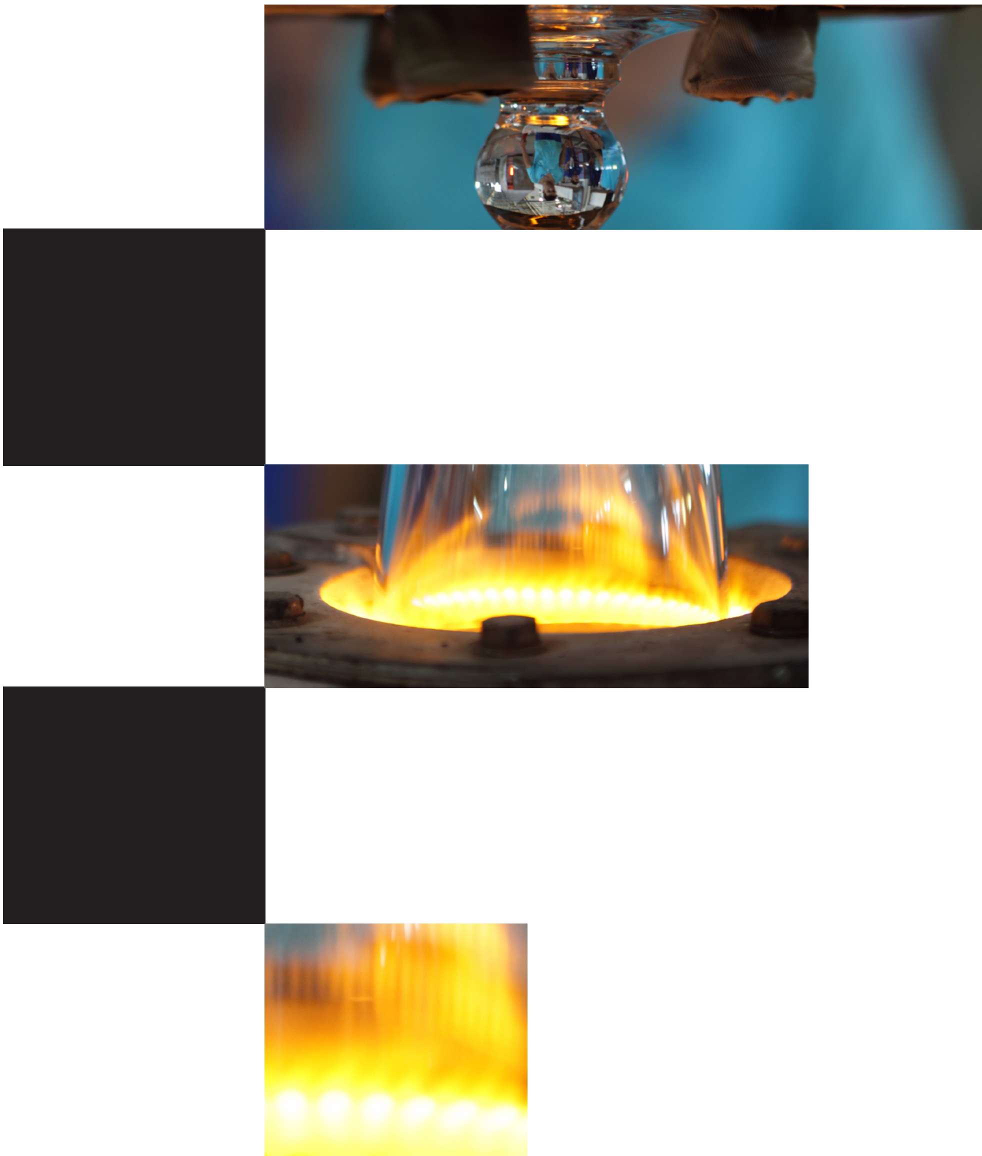
Warsaw 2025



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Summary

Polish industry has no alternative: it must embark on a path of rapid transition away from fossil fuels combustion. Maintaining production based on coal and gas means high costs and increasing dependence on imports, which threatens companies' competitiveness. Decarbonisation of industry is therefore necessary to maintain the European Union's position in the global market and build its resilience to economic, political and military risks.

As indicated by the Clean Industrial Deal, published in February 2025, lowering energy costs will be key to keeping European industry competitive. In the long term, this will be ensured by decarbonising the power sector, in the shorter term by reducing the regulatory burden, lowering energy taxes and reforming the natural gas market.

The diversity of Europe's industry means it is necessary to implement technologies tailored to the specific needs of each industry. Some of the low-carbon technologies for hard to abate sectors (e.g. SMR – small modular [nuclear] reactors) are still in the development stage or only allow transformation of selected processes (e.g. CCS – Carbon Capture and Storage). Therefore, the fastest way to transform the industry is to directly electrify processes based on low- and medium-temperature heat.

Electrification of some industries, especially processing that requires heat up to 200°C, is a low hanging fruit. At the same time, this is the optimal path toward climate neutrality for the sector. Electricity is the easiest energy carrier to decarbonise, and direct electrification technologies – heat pumps, electric and electrode boilers – are reliable, mature and scalable. Moreover, well-planned and executed industrial electrification can support the decarbonisation of the power sector (a process called sector coupling). In this context, it will be particularly important to ensure that the industry's consumption and production of electricity is flexible so that it makes maximum use of the available energy from RES (Renewable Energy Sources). The manufacturing industry can build flexibility through electricity and heat storage and diversification of heat sources – for example, through hybrid systems composed of heat pump and combined heat and power generation engine.

However, in order for industrial electrification to be cost-effective and actually contribute to the reduction of greenhouse gas emissions, the rapid development of RES installations is required. For this purpose, it will be necessary to:

- speed up administrative procedures (permitting),
- streamline grid connection procedures,
- revise cable pooling and direct line regulations,
- optimise the tariff system to encourage effective cooperation with the power system.

Glossary of terms

Cable pooling	a mechanism that allows more than one electricity generator to share grid connection infrastructure
CID	Clean Industrial Deal
CCS	carbon capture and storage
EED	Energy Efficiency Directive
NECP	National Energy and Climate Plan
NPS	National Power System
NZIA	Net-Zero Industry Act
PPA	Power Purchase Agreement; a PPA is a long-term agreement for the supply of electricity, usually between a power generator and a power consumer
Industry	industry as defined by Eurostat, i.e. activities in Polish Classification of Activities (PKD) 2007 including sections B (Mining and quarrying), C (Manufacturing) and F (Construction)
Manufacturing	activities in Polish Classification of Activities (PKD) 2007 including section C (Manufacturing)
RED III	Renewable Energy Directive 2023/2413
RFNBO	Renewable Fuels of Non-Biogenic Origin; liquid and gaseous fuels produced from renewable sources other than biomass (i.e. wind, solar, hydroelectric, or geothermal energy)
SMR	Small Modular Reactor

1. Why should we wait no more with decarbonising the industry?

1.1. Competitiveness

Rising energy costs, due to the EU's limited access to its own resources, are making the industry increasingly dependent on the price of imported fossil fuels. Meanwhile, the EU's global competitors – especially those with their own oil and gas resources – are gaining cost advantages and strengthening their position an increasing number of markets.

Independence from fossil fuel imports is the key to solving this problem. The transformation toward zero-carbon energy sources decides the "to be or not to be" for European industry. For this reason, decarbonisation is still a priority for European policymakers and an important pillar of the European Commission's new initiatives, such as the Competitiveness Compass for the EU[1] and the Clean Industrial Deal[2] (which is discussed in more detail in section 2.2.).

In the coming years, competition will no longer be limited to price race. Competition in product emissivity is also gaining importance. In the European Union, demand for products and intermediates with a low carbon footprint will grow rapidly. The reason is not only the increasing awareness of customers, but also the new obligations for manufacturing companies to report their environmental footprint.

As of the beginning of 2024, the Corporate Sustainability Reporting Directive (CSRD) is in effect[3]. Under its terms, companies employing more than 500 people must report their environmental and social impacts in detail as early as 2025. From 2026, the obligation will apply to companies with more than 250 employees, and from 2027 to listed companies with more than 10 employees. This means that corporations will start looking for suppliers and subcontractors demonstrating low-emission performance of their products.

Under the CID, the European Commission also plans to support the use of non-cost criteria in public procurement, including climate impacts. In the coming years, therefore, we can expect to see an increasing preference for the use of zero-carbon steel or cement in publicly funded infrastructure projects in Europe.

Importantly, the carbon footprint competition extends beyond the EU. China – a leader in investing in new RES and nuclear power capacity[4] – is already exporting more and more products made with zero-carbon energy to Europe. At the same time, production based on fossil fuels is maintained to satisfy domestic market needs.

1 Click here to access the Commission's communication on the Compass.

2 Click here to access the Commission's communication on the CID.

3 Directive is available here.

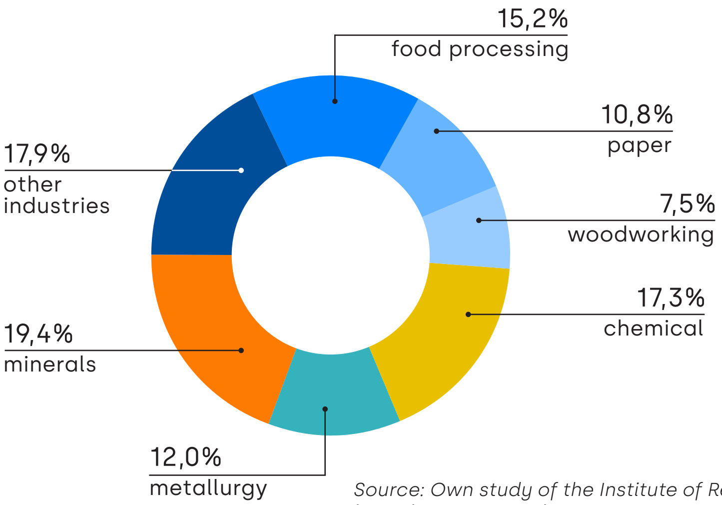
4 In 2023, China installed more than 300 GW of new RES capacity and accounted for about 60% of global renewable growth. More information can be found here.

Polish context

Maintaining industrial competitiveness is crucial for Poland – industry is one of the cornerstones of the national economy. In 2023, the manufacturing industry alone provided jobs for more than 2.5 million employees, accounting for 22.8% of all full-time jobs in Poland. A year earlier, the sector's marketed production amounted to nearly 2 trillion PLN and gross value added to more than half a trillion, equivalent to nearly one-fifth of the total value added in the Polish economy[5].

Polish industry is distinguished by a large share of energy-intensive sectors that are extremely sensitive to fluctuations in energy prices. Only three industries – chemicals, minerals and metallurgy – account for nearly half of the total energy consumption of domestic industry (see Figure 1.). These are the industries that are most at risk of losing competitiveness if a cost-optimal decarbonisation path is not set.

Figure 1 Share of individual industries in final energy consumption in Poland in 2023



Source: Own study of the Institute of Reforms based on Eurostat data.

5 Statistics Poland. The data refers to the manufacturing sector only.

1.2. Political and military risks

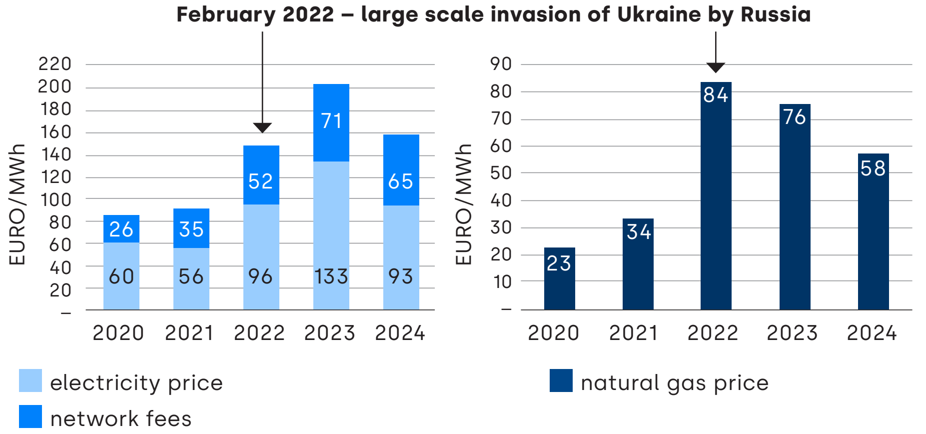
Global rivalry is accelerating, going beyond the economic sphere and turning into a clash of powers. With the start of Donald Trump's second presidency, the U.S. has drastically tightened its trade policies, implementing high tariffs on goods from China and elsewhere. If tensions escalate, Europe's access to key raw materials and technologies could be significantly reduced.

In the new, uncertain global environment, cutting of the fossil fuels is becoming a strategic path to strengthening the EU's economic stability. An interruption of oil or gas supplies has immediate and serious consequences for the industry. Meanwhile, any potential reduction in imports of components such as photovoltaic panels or parts of wind turbines would not immediately disrupt the operation of existing installations.

In addition, the energy system, which relies heavily on centralised sources of power and heat generation, is extremely vulnerable to armed attacks, as Russia's invasion of Ukraine has demonstrated – strikes against large-scale energy infrastructure have become a regular feature of modern warfare. An industry powered by distributed energy sources, independent of fossil fuel supplies, provides a higher level of security and allows it to maintain strategic production capacity despite rising political tensions.

An example of the impact of external shocks on gas and energy prices

Electricity and natural gas prices for industry [Reform Institute's own compilation based on Eurostat data]



The scale of the impact of the political situation in Europe on the industry was demonstrated by the energy crisis following Russia's large-scale invasion of Ukraine in February 2022 and the earlier manipulation of gas prices. Following these developments, the price of natural gas for Polish industry increased by 146% between 2021 and 2022. In turn, the price of electricity for industrial consumers in 2023 exceeded twice the level before the invasion began.

Spikes in electricity and natural gas prices have caused many Polish companies to reduce production. Among other things, mineral fertiliser production has suffered, decreasing by 20% in 2022[6]. The crude steel industry (down 12% and 13% y-o-y) and the cement industry (down 1% and 12% y-o-y) also saw declines in output between 2022 and 2023[7].

The hardest hit were energy-intensive industries, which were forced to reduce energy consumption by more than 20%[8]. As a result, industrial electricity consumption in 2023 fell to its lowest level since 2010[9].

The significant share of natural gas and electricity in the structure of energy consumption by Polish industry (24% and 29% respectively[10]) means that the sector remains under strong pressure from risks related to the geopolitical situation affecting commodity price fluctuations.

1.3. An opportunity for economic development

The decarbonisation of industry is creating a window of opportunity for European clean tech manufacturers. On the one hand, this will increase security of supply and keep capital in the EU, on the other hand, it will generate new jobs and support the development of local companies.

For example, the European Union is now a leader in heat pump production, with nearly 300 plants providing about 170,000 jobs[11]. However, there are areas where the dominance of European manufacturers is weakening – as in the wind industry[12] – or where the market has already been taken over by non-EU competitors, as is the case with photovoltaic panels from China[13].

Opportunities for future development of European zero-carbon technologies are particularly high in early-stage markets that require systemic innovation and a stable regulatory environment. Deep industrial decarbonisation leading to qualitative changes in production processes is one such promising area.

6 Click here to access more information on this topic from the Ministry of Agriculture and Rural Development of Poland.

7 Click here to access more information on this topic from Statistics Poland.

8 According to Eurostat data, total final energy consumption for the chemical, mineral and metallurgical industries fell from 99 TWh in 2021 to 78 TWh in 2023.

9 Both in percentage and absolute terms.

10 Averaged 2013-2023 data for final energy consumption based on Eurostat data.

11 See the map of production plants located in the EU here.

12 More information on this topic is available here.

13 More information on this topic is available here.

1.4. Duration of the investment process

Investments in replacing heat sources or building one's own RES installations are complex undertakings and require careful timing of the process of obtaining the relevant administrative approvals and permits, incurring capital expenditures (CAPEX), and readiness for operating expenditures (OPEX) change.

Many companies are holding back decisions to begin decarbonisation efforts, hoping that the profitability of such investments will increase (e.g. as energy prices rise). However, delaying this process until the cost of fuel or CO_2 emission allowances rises significantly could expose these companies to years of high operating costs associated with using outdated heat sources.

Decarbonisation investments, especially for large projects are also time-consuming[14]. This includes administrative formalities (obtaining connection permits, an environmental decision, a construction permit), as well as the selection of a technology supplier, contractors and performing the construction. By waiting until the "last minute" to invest, industrial plants risk having their energy costs remain high for a long time if the price of CO_2 allowances or fuels rises suddenly.

14 E.g. currently 5-7 years for onshore wind power plants.

Moreover, the extended implementation time of decarbonisation investments is becoming a key challenge in the face of the enormity of industry modernisation needs. Accumulating multiple investment projects at one time can result in:

- overloading the administration responsible for processing applications, which affects the quality and speed of processing;
- extended component delivery times due to production constraints at suppliers, potentially resulting in further price increases;
- increased problems in accessing the connection capacity in the power system;
- the options of obtaining financial support for investment.

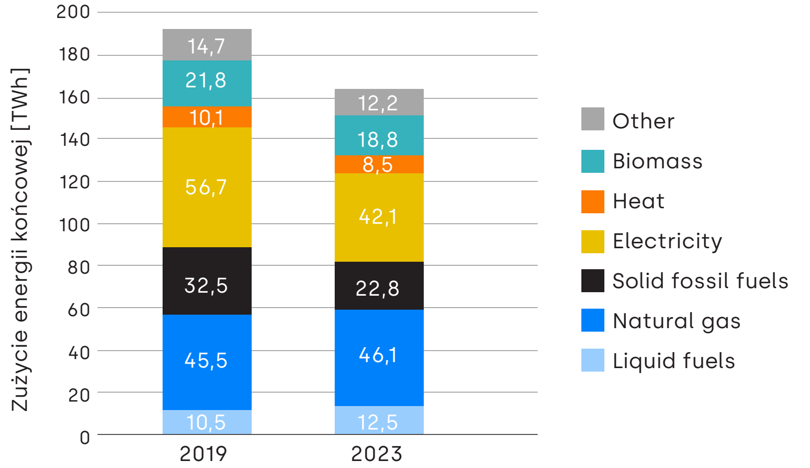
There are numerous benefits to spreading out decarbonisation investments over time:

- it enables the development of the European zero-emission market and systematically builds its competitiveness;
- it will better align the pace of expansion of generation sources and transmission and distribution networks;
- will facilitate ongoing analysis of barriers to industry decarbonisation and implementation of changes in the regulatory environment.

How much energy used in industry awaits decarbonisation

Industry accounts for about **22.4%** of Poland's final energy consumption and **22.8%** of the country's direct CO_2 emissions[15]. Annual demand for all energy carriers in the industry ranges from 160 TWh to 190 TWh. That is comparable to the country's total electricity consumption. More than half of the energy used in industry comes from fossil fuels combustion[16], mainly coal and gas. The domestic industry therefore faces a huge investment challenge in decarbonisation – and there is no more time for further delays.

Figure 3 Final energy consumption in industry in Poland [Reform Institute based on Eurostat]



15 Data averaged for the period 2013-2023 based on Eurostat.

16 57.4% in 2023.

2. European regulatory framework for the industry

2.1. Main framework and regulatory mechanisms

The European Union is consistently pursuing a long-term strategy to build a modern, competitive and climate-neutral economy by 2050. A milestone on this path is to reduce greenhouse gas emissions by 55% by 2030 (relative to 1990)[17]. This goal cannot be achieved without the active participation of the industrial sector.

European Emission Trading System

The main tool for reducing emissions in industry is the EU ETS, which has been in operation since 2005 under Directive 2003/87/EC[18]. The EU ETS is a market-based mechanism that encourages companies to reduce emissions and, over time, to fully decarbonise. Under the EU ETS, large power and industrial installations (with a capacity of more than 20 MW) must buy CO_2 emission allowances on the market and then redeem them, thereby accounting for environmental pollution generated by their own operations. The pool of available allowances is shrinking year by year, raising their price and encouraging emission reductions[19].

Starting in 2027, the ETS will be expanded to include, among other things, smaller power and industrial installations (less than 20 MW), under the so-called EU ETS2. Under ETS2, the obligation to purchase and redeem allowances will fall on fuel suppliers, not end users. In practice, however, industrial customers covered by ETS 2 will feel this in the form of higher fuel prices, to which the cost of purchasing allowances by fuel suppliers will be added[20].

The EU regulations assume that by 2030, emissions in the ETS sectors (large-scale industry and power generation) will decrease by 62% (relative to 2005)[21]. For the remaining sectors (the so-called non-ETS), the emission reduction is to be at least 40%.[22]

According to the draft National Energy and Climate Plan (NECP)[23] from October 2024, Poland's contribution to the reduction targets in the ETS and non-ETS sectors may amount to 49.4% and 18.2%, respectively[24]. National reduction targets will not be met without industrial decarbonisation.

Reducing emissions in industry, as in other areas of the economy, should be based primarily on increasing energy efficiency and the share of renewable energy sources.

17 The EU target defined in the European Climate Law 2021/1119 can be found here.

18 Directive 2003/87/EC is available here.

19 More information on this topic can be found here.

20 Amendment to the Directive 2023/959/EC which establishes the ETS2 system is available here.

21 Click here to access a simple explanation of the target in the Council's communication is available here.

22 The target set out in Regulation (EU) 2023/857 on binding annual greenhouse gas emission reductions here.

23 The draft NECP from October 2024 submitted for public consultation is available here.

24 At the same time, a binding target has already been set for Poland to reduce emissions in non-ETS sectors by 17.7% compared to 2005.

Development of RES energy

The revised RED III directive (Renewable Energy Directive)[25] increased the EU target for the share of renewables in the energy mix to 42.5% in 2030 (with an ambition to reach 45%)[26]. For industry, this translates into an obligation to increase the share of RES in final energy consumption by at least 1.6% per year by 2030.

The RED III directive also sets targets for non-biological renewable fuels (RFNBO)[27], including green hydrogen. By 2030, it should account for at least 42% among the fuels used in industry (for both energy and non-energy purposes), and by 2035 the share should rise to 60%.

Energy efficiency

Although there are no sectoral energy efficiency targets for industry, without its involvement it will not be possible to achieve the EU's ambitions.

In accordance with the revised EED (Energy Efficiency Directive)[28], energy consumption across the European Union is expected to fall by at least 11.7% by 2030.

For Poland, this means a 12.8% reduction in final energy consumption and a 14.4% reduction in primary energy consumption[29]. Meanwhile, the projections in the draft NECP assume only a 4.6% reduction in final energy and 13.6% in primary energy. This large gap between the target and projected final energy consumption (14.4% vs. 4.6%) could be bridged by taking additional measures in the industry, such as greater use of high-efficiency heat pumps.

2.2. New EU plan for industry – Clean Industrial Deal

Although the directions for decarbonisation of the electricity, heating or transportation sectors have been relatively well defined in EU regulations, an equally clear vision for industry has so far been lacking. The sector's energy transformation has been a bottleneck on the road to EU climate neutrality.

The problem of the industry's heavy dependence on fossil fuels became apparent in 2021-2024 during the energy crisis, triggered, among other things, by Russia's aggression against Ukraine. Spikes in fuel and electricity prices have forced the European Union to seek systemic solutions to protect domestic industry.

The first step in creating a European industrial policy was the Net-Zero Industry Act, abbreviated NZIA[30], adopted in 2024. It is intended to provide a framework for the development of Europe's clean tech sector. The document identifies key technologies, such as RES, heat pumps and energy storage, to be prioritised for access to EU funding or regulatory support. The goal is for the EU to produce at least 40% of the zero-carbon technologies it needs on its own by 2030.

Another boost came from the so-called Draghi Report[31], which stressed the need to support European industry in the decarbonisation process by increasing access to cheap and clean energy. Among the recommendations leading to regaining the competitiveness of European industry were the development of renewable energy sources to electrify production processes, better integration of EU energy markets (including expansion of interconnector capacity) and greater investment in innovation.

25 The current version of Directive 2023/2413 (RED) is available here.

26 As a contribution to the new EU-wide target, in the draft updated NECP, Poland has declared to achieve a 32.6% share of RES in gross final energy consumption by 2030.

27 Examples of RFNBO are green hydrogen and green ammonia.

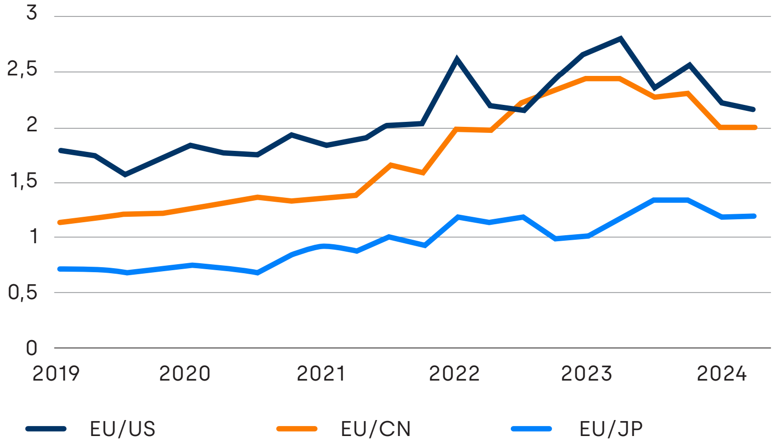
28 The full text of the Directive is available here.

29 For Poland, the indicative national contribution to reducing primary energy consumption should be at 14.4% compared to the forecast in the PRIMES 2020 scenario (i.e. primary energy consumption should be reduced to 79.9 Mtoe). In turn, the indicative contribution in terms of reducing final energy consumption should be at 12.8% (i.e. final energy consumption should be reduced to 58.5 Mtoe). More information can be found here.

30 The Regulation 2023/0081 is available here.

31 The Draghi Report is available here.

Figure 4 Retail electricity price index for industry on world markets



Ratios of industrial retail electricity prices in global markets (European Commission estimations) (A ratio of more than 1 means that EU prices are higher than those of the corresponding non-EU country)

The conclusions of the Draghi report are reflected in the European Commission's 2025 **Competitiveness Compass,** published in January[32]. The document presents strategic directions for building the competitiveness of the EU economy. Among other things, it points to the need to develop innovation in the process of decarbonising all sectors and to combine decarbonisation policies with industrial and commercial ones. Building European clean tech sector and increasing independence (particularly in terms of fossil fuel imports and zero-carbon technologies) will be supported by measures aimed at simplification of administrative procedures, better use of the EU market and increased investment in innovation. It is also important to develop the competence of human resources.

In the wake of the Competitiveness Compass, on February 26, 2025, the European Commission published **the Clean Industrial Deal**[33], hereafter called CID. It is a strategy to decarbonise and increase industrial competitiveness.

A key element of the Clean Industrial Deal is lowering energy prices. In the long term, the sector is expected to reduce production costs by becoming less dependent on fossil fuels and implementing carbon-neutral solutions for industrial heat production. The role of the European clean tech sector is crucial here – these are EU manufacturers that are expected to supply components and installations for a significant portion of the decarbonisation projects being implemented in Europe in the future. Ensuring demand for these products is a priority. At the same time, the technological and resource independence of the European Union is to be strengthened by building a circular economy, including the development of recycling technologies and material substitution.

The CID also identifies measures to reduce the cost of energy purchases in the shorter term. They include reducing regulatory burdens, increasing incentives for industrial customers to enter into direct agreements with RES suppliers (PPAs), and reducing energy taxes.

The **Affordable Energy Action Plan**[34], accompanying the publication of CID, identifies eight necessary actions:

1. Reducing electricity bills for all consumers – by reducing taxes and optimising network charges.

32 Click here to access the Commission's communication on the Compass.

33 The Commission's communication on the Pact can be found here.

34 The content of the Plan is available here.

2. Lowering the cost of power generation – through better integration of markets, as well as increasing the role of RES and flexibility.
3. Improving the operation of the gas market – through, among other things, joint purchases of imported gas and better supervision of the market.
4. Improving energy efficiency – including by updating energy labels and financing efficiency measures in industry.
5. Finalising single EU energy market – through better market, infrastructure and regulatory integration.
6. Introducing tripartite agreements for energy sales – in order for the public sector to secure agreements between generators and energy consumers.
7. Guaranteeing stability of energy prices – in response to threats from natural disasters, political and military risks as well as deliberate actions of third parties.
8. Increasing resilience to abrupt price fluctuations – by, among other things, using incentives to reduce energy consumption at particularly critical times.

By the end of 2025, the Commission plans to publish further documents that will set pathways for industry decarbonisation, such as:

- The draft **Industrial Decarbonisation Accelerator Act** – scheduled for release in Q4 2025 will introduce:
  - elements of qualitative evaluation to private and public tenders, promoting the use of EU goods;
  - voluntary carbon intensity label for industrial products (for steel in 2025, and later for cement);
  - simplified and harmonised carbon accounting methods.
- **Recommendation on energy taxation** – announced for Q4 2025
- **Electrification Action Plan** (Q1 2026)
- **European Grids Package** (Q1 2026)

3. The special role of electrification in the decarbonisation of industry

3.1. Why is industrial decarbonisation such a challenge?

Decarbonising the industry poses several significant challenges:

- Industry consumes a lot of energy, and in a relatively constant way over time. Therefore, the cost of energy has a significant impact on the profitability of production.
- Industries, especially low-margin ones, are very sensitive to the price of energy. Manufacturers need to keep manufacturing costs under control to avoid losing the market to imports.

Additional impediments are technical and technological barriers, such as:

- the need for high-pressure and/or high-temperature process heat (e.g. in metallurgy), which precludes the use of certain technologies, such as heat pumps;
- consumption of fossil fuels as raw materials in chemical processes, which requires the development of synthetic fuel technologies;
- process CO_2 emissions, such as in cement production, which requires carbon capture and storage technology (CCS).

The barriers listed above make some industrial greenhouse gas emissions hard to abate. For such industries, it is necessary to develop customised solutions and develop new advanced technologies. In Poland, such hard to abate sectors include cement production, the chemical and petrochemical industries, and steel production[35].

3.2. Technology portfolio for industry

EU regulations (including the Net-Zero Industry Act[36]) have identified key zero-carbon technologies for decarbonisation. Below we describe their characteristics and limitations.

The importance of electrification is growing in all industries, as electricity is the easiest to decarbonise through the use of RES, primarily photovoltaic and wind installations.

Nuclear technologies

Nuclear power generation, including in the form of SMRs microreactors can provide stable heat and power production for industry. The constant energy production profile of nuclear reactors matches well with the constant energy demand of most industries. Nuclear technologies can also provide process heat with high temperature parameters.

35 More information on this topic can be found here.

36 Regulation 2024/1735 is available here.

However, the use of these technologies has limitations. First, because SMR and micro-reactor technologies are currently only at the early stage of commercial implementation globally, and the horizon for their availability in Poland is not clear. Second, the solutions are tailored for large industrial plants – commercial SMR projects currently under development reach capacities in the 70-300 MWe range. Although in the context of nuclear power such reactors are referred to as "small" (compared to the capacity of classic nuclear units), such demand characterises only energy-intensive industries.

Carbon Capture and Storage/Utilisation technologies (CCS/CCU)

CCS/CCU technologies (Carbon Capture and Storage/Utilisation) are also targeting large industrial plants and are just entering their first large-scale deployments in Europe[37].

Priority for funding projects using CCS/CCU should be given to those industries where carbon dioxide is a by-product of the technological process. In such hard to abate sectors, simply switching to clean energy carriers will not eliminate CO_2 emissions. In Poland, the challenge is primarily related to cement plants.

The use of CCS/CCU reduces the technological complexity of the process, operational costs and uncertainty regarding the pace and scale of development of CO_2 transmission and storage infrastructure.

37 More about the progress in technology development in Europe here.

Hydrogen

The technology to produce green hydrogen (from RES-powered electrolysers) is already commercially available. However, green hydrogen is not widely used due to high production costs (relative to grey hydrogen produced by steam reforming of natural gas) and lack of adequate production and transmission infrastructure. Nonetheless, the role of this fuel will grow, both because of EU targets and the high added value of green hydrogen as a "closing" element in an energy and fuel system with a large share of renewable sources.

Although the combustion of green hydrogen makes it possible to achieve high temperature, the efficiency of such solutions is lower than that of producing heat directly from electricity. A key barrier to the widespread use of green hydrogen in industry is the difficulty in the long-distance transportation. The lack of an adequate transmission network forces the transportation of previously compressed or liquefied hydrogen by road, which is energy-intensive and costly.

However, green hydrogen is the future for those industries that need it as a substrate for technological processes. For this reason, green hydrogen in Poland has great potential primarily in the chemical and metallurgical industries.

Biomethane and biogas

Biomethane and biogas production can achieve the lowest unit production costs among the technologies discussed. However, the potential of this technology is limited by the availability of substrates that can be sustainably sourced[38]. Biomethane will play a special role in the integration of weather-dependent RES into the power system, acting as fuel for flexibly operating cogeneration units.

Such sources could be used in industry, but their operation would have to be adapted to the changing demand for electricity in the system. Since process heat demand is continuous and relatively constant (which is difficult to change without interfering with the industrial process itself), biomethane engines for combined heat and power generation would have to cooperate with other energy sources with flexible operation profiles. These could include heat pumps or electrode boilers, which are direct electrification technologies.

38 Care should be taken to provide a regulatory framework that would eliminate the occurrence of such pathological phenomena as the conversion of agricultural crops for food production to crops that are then sold for biogas production.

Biomass

Biomass is currently the main renewable heat source used in Polish industry.

As in the case of biomethane, biomass will not allow full decarbonisation of the industry due to the limited potential for its use in a sustainable manner (the principle of cascading biomass use is particularly relevant here[39]).

Although biomass may currently appear to be competitively priced compared to other technologies, rapidly growing demand from specific sectors moving away from fossil fuels will quickly drive up its prices. So, it is not a technology that will enable cost-effective large-scale decarbonisation of industry.

Direct electrification

Direct electrification technologies make it possible to produce heat using electricity. They are versatile in nature, making them applicable to various production processes. Direct electrification technologies include heat pumps, electrode boilers and electric boilers. These technologies are mature, scalable, efficient, and commercially available. When combined with heat storage, electricity storage and/or gas-fired cogeneration engines, they can support demand-supply balancing in the power system.

An additional benefit of properly implemented industrial electrification is the ability to minimise the scale of forced reductions in RES generation for balancing reasons (so called curtailment). Electrification also helps to achieve the synergy of sector coupling[40].

However, direct electrification may face numerous barriers, the biggest of which concerns the availability of RES based electricity. Therefore, it will be crucial to ensure self-production of energy by locating new RES investments close to existing industrial plants. Combined with the possibility of building a direct line by the manufacturer (a dedicated power line that connects a separated generating unit to a separated customer) – must become an integral part of Poland's industrial development strategy. Given the diversity of technological processes in the industry, decarbonisation of this sector will require an individual approach for each plant.

39 Priority in access to biomass (e.g. forest chips and lumber processing waste) should be given to sectors that use it to make new products (e.g. the furniture industry), while biomass combustion for energy purposes should have the lowest priority.

40 Sector coupling involves taking a holistic view of energy needs in search of synergies. The simplest example is combined heat and power generation also known as cogeneration, which uses less energy than generating them separately. There will be many more such synergy opportunities in the future energy system. For example, processes that require a lot of energy with little maintenance like heating or drying can be powered by heat recovery or carried out at a time when plenty of low-cost electricity from RES is available. More information on this topic can be found here.

4. Guidelines for industrial electrification

In building a strategic approach to industrial electrification in Poland, one principle should be followed – electrification should support the decarbonisation of the electric power sector, not hinder it.

First, an electrified industry should be able to match its electricity consumption with the supply of renewable energy as much as possible. In other words, industrial electrification should be based on the available renewable energy.

Secondly, electrification of industry should be implemented without excessive expansion of electricity infrastructure (i.e., transmission grids, distribution networks, new RES capacity), but making efficient use of already available facilities.

Below, we outline three key guidelines for creating a regulatory environment to facilitate electrification for businesses.

1. Energy efficiency first and foremost

Efficiency measures include:

- Increasing the efficiency of technological processes, i.e., minimising energy losses and reducing the temperature of the process heat carrier (where this is applicable without adversely affecting the quality of the process).
- Investing in sources with high heat production efficiency, such as heat pumps with high SCOP[41]. This recommendation is mainly aimed at those industries with low-temperature and medium-temperature (i.e., up to 200°C) heat requirements.

Such measures will reduce the demand for electric power needed to produce process heat in the standard mode of operation (i.e., one in which the primary electrified source operates at nominal capacity to meet the entire heat demand). Such optimisation for the electrified heat sources minimises the need to expand the power infrastructure, and therefore the costs incurred for the energy transition.

2. Flexibility, flexibility and more flexibility

The industry flexibility required to achieve synergy with the power system means:

- Reducing the demand for electric power at times of shortage from RES;
- Increasing demand for electric power to use available green energy during high production from RES (peak production times).

41 SCOP (Seasonal Coefficient of Performance) – the coefficient of heating efficiency, the higher it is, the more efficient the heat pump is.

Flexibility in industrial energy consumption can be achieved in several ways, including:

- **diversification of energy sources and the use of hybrid systems**
  An example is the combination of a heat pump and a cogeneration engine – currently fuelled by natural gas and eventually by biomethane[42]. In such a system, the heat pump operates during hours of high RES production, and at times of green energy shortages (e.g. in the afternoon, when production from photovoltaic sources drops sharply), heat and electricity generation is taken over by a cogeneration engine. Such a hybrid system is attractive because of its fast engine startup, which allows it to adapt to dynamic changes in the power system. In comparison, a biomass boiler, which could theoretically replace a heat pump, requires a long start-up time. Therefore, it should work during periods when RES supply is low for an extended period of time, such as during low wind periods in the winter (so called "dunkenflaute"), when low wind availability translates into low generation from wind sources.

42 Replacing natural gas with biomethane will be linked to the need to reduce natural gas consumption in the Polish economy.

- **energy storage**
  Electricity storage and heat storage cooperating with an electrified source can provide flexibility by adjusting electric power consumption up and down. Short-term storage will be the easiest solution, allowing demand to be balanced within a day. Heat storages cooperating with the electrode boiler may gain in importance, which will allow to manage a part of the surplus green energy during the peak hours of RES generation.

- **adaptation of production processes to the hours of high RES generation**
  It would be most desirable to adjust the production process to consume energy only during hours of high production from RES. However, in most cases this is not possible due to the requirement to maintain continuity of production processes.

3. RES for industry

Industrial electrification will require the construction of new renewable capacity. The strategic solution is to locate new RES capacity as close to consumers as possible, or for industry to invest in its own generation sources. This allows to avoid the transmission of electricity over long distances, thus partially reducing the costs associated with the development of network infrastructure.

Another solution are PPAs (Power Purchase Agreements) with RES power producers. PPAs are concluded between generators and power consumers for a long period of time (mostly 8-10 years in Poland). Such an agreement allows RES power producers to secure a steady level of revenue, which makes it easier to obtain financing and repay loans taken out for the construction of installations. For energy consumers, large industrial plants in particular, this means access to energy from renewable sources at a predictable, stable price. As a result, their resilience to price fluctuations in the wholesale market is increased.

From the perspective of national policymakers (government administration, grid operators, municipal and provincial authorities), it is particularly advantageous to locate new RESs in industrial areas or near large industrial plants. Hybrid installations, combining, for example, photovoltaics, a wind farm and energy storage, will work best in such places. This approach is consistent with the currently implemented regulations for RES Acceleration Areas (RAAS - as stipulated in the REDIII Directive), which should first be designated on brownfield sites with assured electricity collection.

Oława Cluster

An example of the use of RES directly for industry needs is the Oława Energy Cluster, which supplies energy to, among other, a medical products plant[43]. The Cluster includes:

- wind turbines with a total capacity of 21MW;
- double-sided photovoltaic panels with a capacity of 9.3MW, which are located on a structure with a height of 6m, which allows to grow crops under them;
- two energy storage facilities (a total capacity of 12 MWh);
- electrolysers with a total capacity of 5MW;
- hydrogen and methane trigeneration systems (1MW/1.2MWe each).

43 More information on this topic can be found here.

5. What barriers need to be removed?

In order for the industry to make more widespread use of RES electricity, and at the same time improve the competitiveness of its products, a number of systemic barriers must be removed.

5.1. Too high cost of electricity

The primary barrier to electrification of industrial heat is still the high price of electricity. It is the one that has the strongest influence on the profitability of electrification projects. Therefore, concrete changes to the regulatory framework are needed, introduced in consultation with the relevant industries.

The key steps are:

- **identification of industries where heat pumps can be used** (that is, primarily where process heat up to 200°C is used). Heat pumps use up to several times less energy than electric or electrode boilers. Identifying the industries that can be electrified using this technology will allow financial support (e.g. in the form of grants or a contract for difference) to be directed first to where it will be most profitable.
- **introduction of special tariffs for electrode and electric boilers,** which could operate as peak sources, consuming surplus energy from RES. In order to increase the profitability of investments in such sources, it may be necessary, for example, to reduce network charges during hours when the operation of electric boilers helps balance the power system.

In the long term, it is also important to shape the price ratio between electricity and fossil fuels (especially natural gas) in favour of using electricity. In order to achieve a higher level of cost-effectiveness for heat pumps in industry, the ratio of electricity price to fuel price should be 3:1 or less.

Achieving such a ratio is possible through:

- equal taxation of all emission sources regardless of their size – an element of this policy is the upcoming ETS2, which, in addition to buildings and road transport, will also cover the burning of fossil fuels in industrial installations not yet covered by the EU ETS;
- the elimination of direct and non-direct subsidies for fossil fuels, such as subsidies for cogeneration facilities that do not provide flexibility for the power system (i.e., operating in the base), subsidies for the expansion of the gas system, or subsidies for coal mining;
- fair taxation of fossil fuels relative to electricity.

5.2. Financing new projects

Another barrier is the lack of adequate financial support mechanisms. Such assistance is particularly important for technologies that are just entering the market commercially and have high investment costs.

The most favourable solution for the investor are subsidies, which reduce the total cost of investment, as well as loans on preferential terms, also available under business risk conditions. Another solution is favourable-interest commercial loans and debt financing, for example in a form of "green bonds".

To ensure the effective use of national and EU funds for industrial electrification, the competition criteria for projects seeking support should be prepared accordingly. Preference should be given to those solutions that increase the flexibility of electricity consumption from the grid, such as through the integration of electricity storage, heat storage or cogeneration engines.

5.3. Limited availability of green energy for industry

A product made with electricity will have a low carbon footprint only if the energy used to produce it is zero- or low-carbon. In Poland, this is a challenge – the country's power system is one of the most emission-intensive ones in the world. For industry, this means limited access to the green energy needed to decarbonise production processes.

Improved availability of renewable and zero-carbon energy for industry should be achieved in two ways. First, it is necessary to increase the pace of decarbonisation of the entire national power system. Second, investment in the construction of new RES capacity for industry, such as wind and photovoltaic farms on industrial sites or in the immediate vicinity of plants, should be facilitated.

Measures to unlock RES potential in the short term

The government can unlock the potential of RES development to decarbonise the industry in a relatively short period of time. Among the actions needed are:

- **Speeding up procedures for obtaining approvals and permits for RES** (permitting). In this context, it will be particularly important to put in place an appropriate legal framework for Renewable Acceleration Areas and to designate them in a timely manner.
- **Liberalisation of distance criteria for onshore wind farms,** which will allow new installations to be built closer to developments and increase the availability of land for investment.
- **Revision of cable pooling regulations** to allow flexible use of connection capacity by RES installations, industrial consumers and energy storage facilities.
- **Changing direct line regulations,** including an analysis and possible reduction of the "solidarity fee" to make direct line projects more profitable for industry.
- **Introducing mechanisms to limit "blocking" of connection capacity,** such as auctions for grid connection of new RES and energy storage projects.

In parallel, the flexibility of the power system should be increased.

The rapid development of new wind and solar capacity is increasingly capable of balancing demand and supply of electricity in the system. The greater the flexibility of the grid, the faster new renewable sources can be created. Solutions that support increasing system flexibility include:

- **Promotion and introduction of dynamic electricity tariffs** for businesses.
- **Reforming network tariffs,** including the potential for dynamization of network fees.
- **Introduction of tariffs for electric and electrode boilers** that can support balancing of the grid.
- **Supporting research and development of process heat storage** by industry.

6. Summary

Polish industry must reduce direct emissions but also adapt to work with a dynamically changing power system.

Decarbonising the sector is a prerequisite for maintaining competitiveness, reducing dependence on fossil fuel imports, building technological independence and increasing resilience to political and military risks.

Due to the varying technological processes in the various industries, there is no one-size-fits-all scenario for the sector's transformation. Therefore, regulatory policy must support a broad spectrum of zero-carbon technologies. The industry cannot passively wait for the commercialisation of new technological solutions, such as SMR or CCS. On the contrary, it should start decarbonisation today using available direct electrification solutions such as pumps and electrode and electric boilers.

However, the electrification of industrial heat in Poland requires the dynamic development of new RES capacity. It is crucial to achieve synergies between the electrified industry and the power system. This will be made possible by industry investments in flexibility such as energy storage, diversification of power sources, as well as support of the decarbonisation process by regulators and legislators through the creation of a regulatory environment tailored to the needs of the industry, particularly the tariff system.

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