RESOURCE USE IN POLAND IN 2019

CHALLENGES AND OPPORTUNITIES

Technical Report: ENG-TR.014

ISSN: 2633-6839

RESOURCE USE IN POLAND IN 2019

CHALLENGES AND OPPORTUNITIES

Jonathan M Cullen, José M.C. Azevedo,
Karla Cervantes Barrón, Michal Piotr Drewniok

Resource Efficiency Collective – www.refficeincy.org

Cite as:

Cullen J.M., Azevedo J.C, Cervantes Barrón K., Drewniok M.P. (2021) Resource Use in Poland in 2019: Challenges and Opportunities, Technical Report ENG-TR.014, University of Cambridge, ISSN 2633-6839, 2021

The project was co-funded by the National Center for Research and Development as part of the first competition for projects open under the Strategic Program of Scientific Research and Development "Social and economic development of Poland in the conditions of globalizing markets" GOSPOSTRATEG, agreement. oto-GOZ project 1/387784/24/NCBR/2019.

ZUZYCIE ZASOBÓW W POLSCE W 2019

WYZWANIA I MOŻLIWOŚCI

Raport Techniczny nr ENG-TR.014

Projekt współfinansowany przez Narodowe Centrum Badań i Rozwoju w ramach I konkursu na projekty otwarte w ramach Strategicznego programu badań naukowych i prac rozwojowych „Społeczny i gospodarczy rozwój Polski w warunkach globalizujących się rynków” GOSPOSTRATEG

ISSN: 2633-6839

CONTENTS

EXECUTIVE SUMMARY

The report provides an analysis of resource use by selected sectors in Polish industry in 2019, including materials, energy and energy materials, biomass, and water. The research constructs resource flow analyses for the sectors using data from Statistics Poland (Główny Urząd Statystyczny, GUS).

Energy and material use in this report covers the following sectors:

I. General overview
- Agriculture, forestry and fishing,
- Manufacturing,
- Construction,
- Mining and quarrying,
- Electricity, gas, steam and air conditioning supply,
- Water supply; sewage, waste management and remediation activities,
- Transportation and storage.
- Information and communication (when the data is available);
- Other consumption (other than manufacturing, electricity and water supply, construction, transportation, information and communication) – this group is non-NACE but appeared in national material use statistics;

II. More detailed analysis:
- Mining and quarrying,
- Manufacture of metals and metal products,
- Bioproducts and non-metallic mineral products,
- Plastic, rubber and chemical products,
- Construction,
- Information and communication and Transportation and storage.

The analysis in this report covers 2,286.4 PJ (petajoules) of direct energy use in Poland in 2019, representing 65% of the national direct energy use of 3,356.7 PJ. The largest energy intensive sector in Poland in 2019 is the Manufacturing sector with a direct use of 1,023.7 PJ (29% of national direct energy use) followed by Transportation and storage with direct use of 997.8 PJ (28% of national direct energy use). The total mass of the energy materials input to these sectors is 101.3 Mt (million tonnes), 59% of which are solid fossil fuels, including hard coal, lignite and other types of coal (59.8 Mt). More than 90% of the Solid fossil fuels are used for electricity and heat generation (53.9 Mt), with a share of 93% and 7% respectively. The losses from electricity production are 58% and 15% from heat production. The second largest energy input by mass relates to Oil and petroleum products (24%, 24.4 Mt), 90% of which is used directly in the Transportations and storage sector.

The industrial sectors consume 76.2 Mt of materials, including non-metallic minerals (32%), metals (31%), biomass (23%) and other (14%). Manufacturing consumes the largest share of materials, at 64%, followed by Other consumption (30%) and the Construction sector (5%). The largest share of materials used in the Manufacturing sector are non-metallic materials and metals, with shares of 32% and 31% respectively, followed by products from wood (14%) and paper and

paper board (8%). The sectors consume 6,278.5 million m^3 of water, with 68% provided for the national economy and population. 5,525.1 million m^3 is used in electricity, gas, steam and air conditioning supply and 10% in the Manufacturing sector.

Across the analysed sectors, the most consumed materials in 2019 are:

- water – 6,278 Mt, with most used electricity generation,
- lignite – 31 Mt, with most used for electricity generation,
- steam coal – 27 Mt, with 70% used for electricity generation,
- oil and petroleum products – 24 Mt, with 92% used for transportation,
- Portland cement – 20 Mt, with 98% used in construction,
- steel products – 18 Mt, with 72% used to manufacture other products.

STRESZCZENIE

Niniejszy raport przedstawia analizę zużycia materiałów, przepływy materiałów i energii dla wybranych działów gospodarki w Polsce w 2019 r. Zakres obejmuje metale, produktu wytworzone z minerałów niemetalicznych, materiały energetyczne (paliwa), biomasę, wodę oraz inne materiały. Niniejsza analiza została wykonana w oparciu o dane statystyczne Głównego Urzędu Statystycznego (GUS, Statistics Poland), w szczególności zawarte w analizach statycznych „Gospodarka materiałowa w 2019 r.", „Rocznik Statystyczny Przemysłu – 2020 r." oraz „Gospodarka paliwowo-energetyczna w latach 2018 i 2019".

Niniejszy raport zakresem obejmuje następujące działy wg. statystycznej klasyfikacji działalności gospodarczych w Unii Europejskiej (NACE Rev. 2):

I. Przegląd ogólny przez następujące sektory:

- Rolnictwo, leśnictwo, łowiectwo i rybactwo,
- Przetwórstwo przemysłowe,
- Budownictwo,
- Górnictwo i wydobywanie,
- Wytwarzanie i zaopatrywanie w energię elektryczną, gaz, parę wodną i powietrze do układów klimatyzacyjnych,
- Dostawa wody; gospodarowanie ściekami i odpadami oraz działalność związana z rekultywacją,
- Transport i gospodarka magazynowa,
- Informacja i komunikacja (w przypadku dostępności danych);
- Pozostała konsumpcja (nie zawarta w powyższych grupach) – ta grupa nie ma bezpośredniego odpowiednika w klasyfikacji NACE, jednak występuje w statystykach materiałowych;

II. Bardziej szczegółowa analiza wykonana została dla sektorów:

- Górnictwo i wydobywanie
- Produkcja metali i wyrobów z metali
- Produkcja artykułów spożywczych, wyrobów tytoniowych, skór i wyrobów skórzanych, mebli, papieru i wyrobów z papiery oraz wyrobów mineralnych surowców niemetalicznych,
- Produkcja plastiku, gumy oraz produktów chemicznych,
- Budownictwo
- Informacja i komunikacja - działalność wydawnicza oraz Transport in gospodarka magazynowa

Niniejszy raport obejmuje 2 286,4 PJ bezpośredniego zużycia energii, 65% całkowitego bezpośredniego zużycia energii w Polsce w 2019, wynoszącego 3 356,7 PJ. Sektory chrakteryzujące się najwyższym zużyciem energii bezpośredniej są Przetwórstwo przemysłowe (1 023,7 PJ, 29% całkowitego bezpośredniego zużycia energii) oraz Transport i gospodarka magazynowa (997,8 PJ, 29% całkowitego bezpośredniego zużycia energii). Konsumpcja materiałów energetycznych (paliw) w analizowanych sektorach wyniosła 101,3 mln t, z których

59% to stałe paliwa kopalne taki jak węgiel kamienny czy węgiel brunatny. 91% stałych paliw kopalnych (53,9 mln t) wykorzystywanych jest do produkcji energii elektrycznej i ciepła z podziałem odpowiednio 93% oraz 7%. Sprawność elektrowni zawodowych w produkcji energii elektrycznej w Polsce pozostaje na poziomie 42%, natomiast 85% w przypadku elektrowni zawodowych produkujących ciepło.

Jedna piąta konsumpcji materiałów energetycznych (paliw) to ropa i produkty naftowe (24,4 mln t). 90% tych paliw jest używane w sektorze Transport i gospodarka magazynowa.

Zużycie materiałów w analizowanych sektorach wyniosło 76,2 mln t. 32% to niemetaliczne produkty mineralne, 31% metale, 23% biomasa oraz 14% inne materiały. Sektor o największym użyciu materiałów jest Przetwórstwo przemysłowe (64%), Pozostała konsumpcja (30%) i Budownictwo (5%).

Materiałami, które miały największy udział w sektorze Przetwórstwo przemysłowe miały niemetaliczne materiały mineralne oraz metale odpowiednio 32% oraz 31%, jak również produkty z drewna (14%) oraz papier i tektura (8%).

Konsumpcja wody w analizowanych sektorach wyniosła 6 278,5 mln t. Odpowiada to za 68% całkowitej konsumpcji wody w Polsce w 2019. 88% wody w analizowanych sektorach używana była do wytwarzania energii elektrycznej w sektorze Wytwarzanie i zaopatrywanie w energię elektryczną, gaz, parę wodną i powietrze do układów klimatyzacyjnych; 10% natomiast w sektorze Przetwórstwo przemysłowe.

Dla analizowanych sektorów, najbardziej używanymi materiałami były:

- woda – 6 278 mln t, w większości używana do produkcji energii elektrycznej,
- węgiel brunatny – 31 mln t, w większości używany do produkcji energii elektrycznej,
- węgiel kamienny – 27 mln t, z którego 70% używane jest do produkcji energii elektrycznej,
- ropa i produkty naftowe – 24 mln t, z których 92% używana jest w transporcie,
- cement portlandzki – 20 mln t, z którego 98% docelowo używana jest w budownictwie,
- produkty stalowe – 18 mln t, z których 72% używane jest do produkcji kolejnych produktów stalowych.

MATERIAL AND ENERGY USE IN POLAND – OVERVIEW

The use of biomass, fossil energy and metal ores has remained relatively constant over the last two-decades, while non-metallic minerals have roughly doubled in use, as shown in Figure 1. By 2019, Domestic material consumption (DMC) which represents all materials, had reached 668 Mt [1]. The DMC per captia for Poland sits at 17.6 tonnes per person, which approximately 20% higher than in Germany, 25% higher than in all EU-28 countries and more than 50% higher than in the UK (Figure 2).

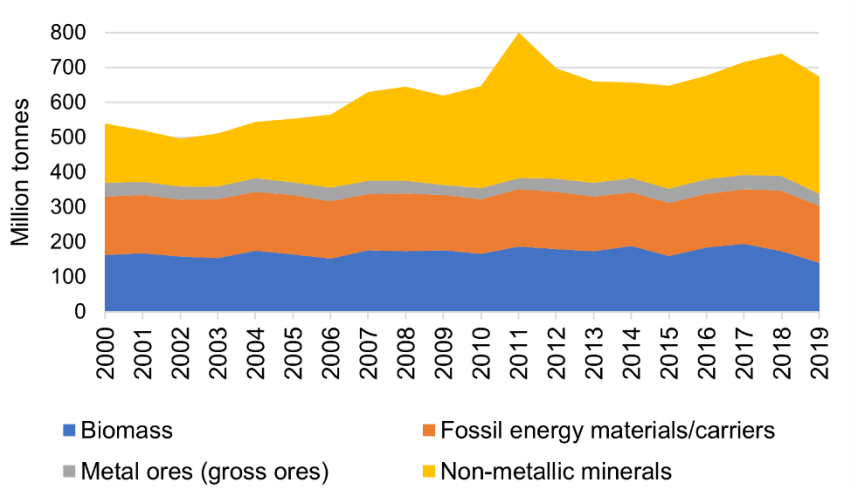


Figure 1 – Domestic material consumption in Poland [1]

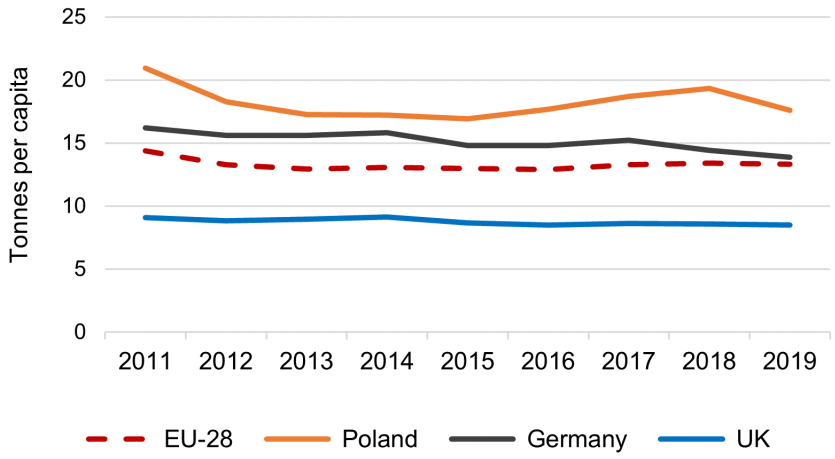


Figure 2 – Domestic material consumption per capita [1]

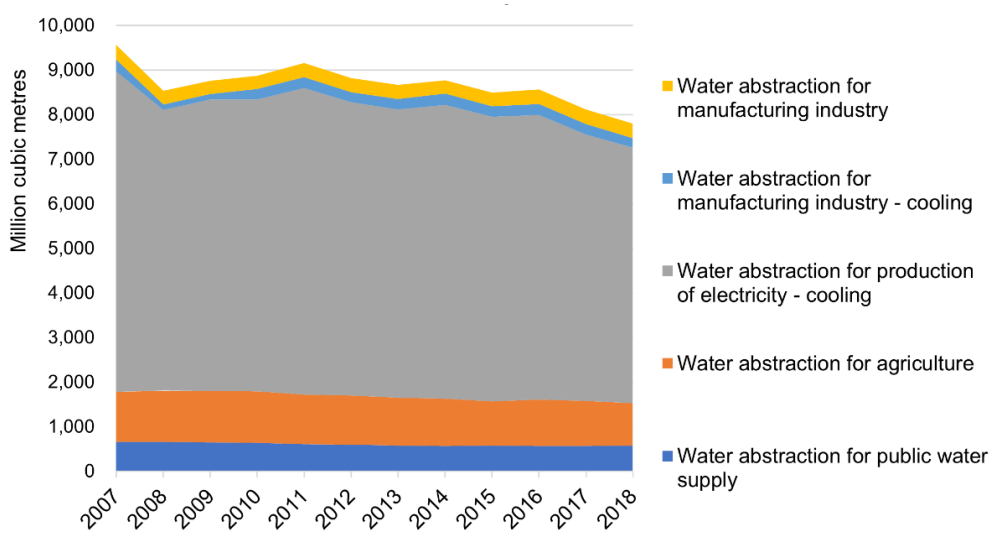


Figure 3 – Water abstracted by sector of use [2]

The total gross water abstraction[1] in Poland in 2018 is 7,825 million m^3. Approximately 73% of the abstracted water in Poland is used for cooling in electricity production. Manufacturing (production and cooling) represents approximately 7%. A similar share is abstracted for public water supply [2] (Figure 3).

The mining sector produces one third of all waste in Poland in 2018, followed by manufacturing and water supply sector with shares of 17% and 14% respectively. The construction sector is responsible for 10% of all waste generation in Poland [3] (Figure 4).

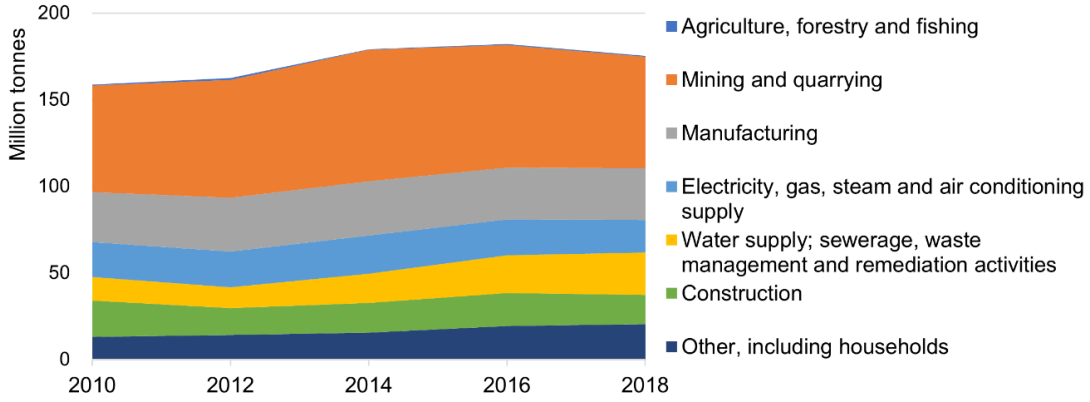


Figure 4 – Generation of waste by sector [3]

[1] *Water abstracted by economic units engaged in collection, purification and distribution of water (including desalting of sea water to produce water as the principal product of interest), water that is used to absorb and remove heat in the course of processes for the generation of electricity.*

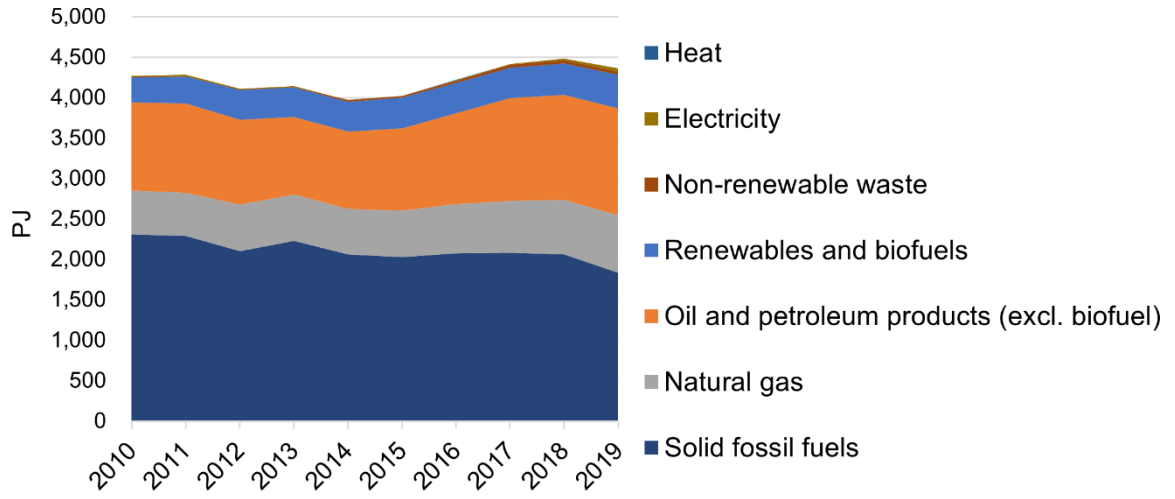


Figure 5 – Primary energy use in Poland by fuel, in PJ (petajoules) [4]

The total primary energy use[2] in Poland in 2019 is to 4,405.8 PJ [5] (Figure 5). From 2010 to 2019, total energy use in Poland increased for crude oil, natural gas, renewable energy and other carriers, while use of hard coal and lignite decreased. In 2019, the share of hard coal is37.0%, lignite 9.1%, crude oil 26.3%, natural gas 16.1%, renewable energy carriers 9.3%, with the remaining 2.2% is delivered from electricity and heat. Losses of energy during conversion and transformations total 818.8 PJ, leaving 3,550.8 PJ [5] available for direct energy use as refined fuels, electricity and heat.

The industrial sector, which includes manufacturing, mining and quarrying, electricity and water supply, is the largest user of direct energy use with a share of 34.6% as seen in Figure 6. The transport sector is the second largest direct energy user, with a share of 28.1% in 2019 including fuel use in private passenger cars. In 2019, households consume 21.7% of energy, agriculture 4.5%, construction 1.7% and other consumers 9.4%.

Figure 7 shows that oil products are the most important energy carriers of direct energy with a share of 33.3%, followed by Electricity with a share of 16.7%, Natural Gas at 16.1%, and Hard Coal at 10.7%. The share of heat amounts to 8.0%, renewable energy carriers 6.4% and other carriers (mainly metallurgical coke and industrial gases) 8.8% (Figure 7)[5].

[2] *Total energy use includes the supply of all energy commodities to the domestic market (or its sector), corrected (up or down) with the stock change figure. This corresponds closely to the international concept of "Total Primary Energy Supply" .*

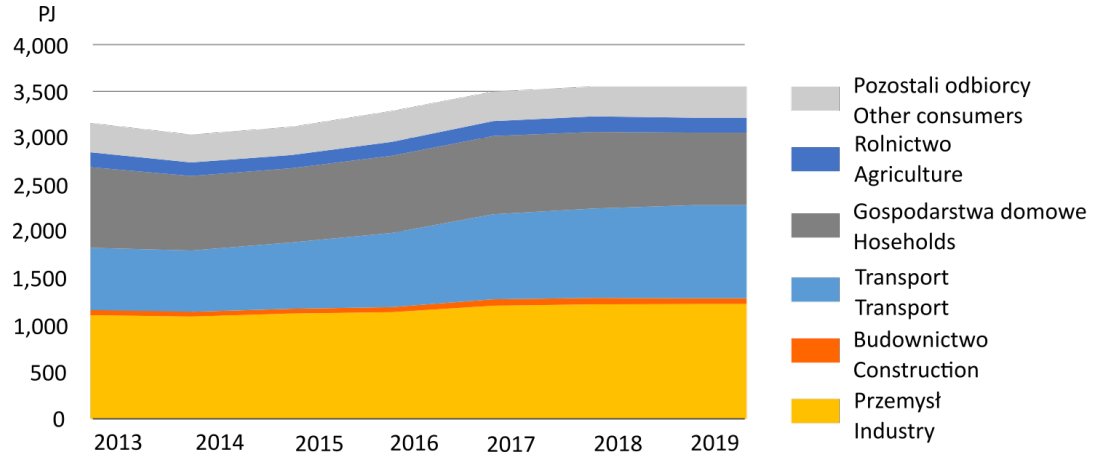


Figure 6 – Direct energy use by sectors [5]

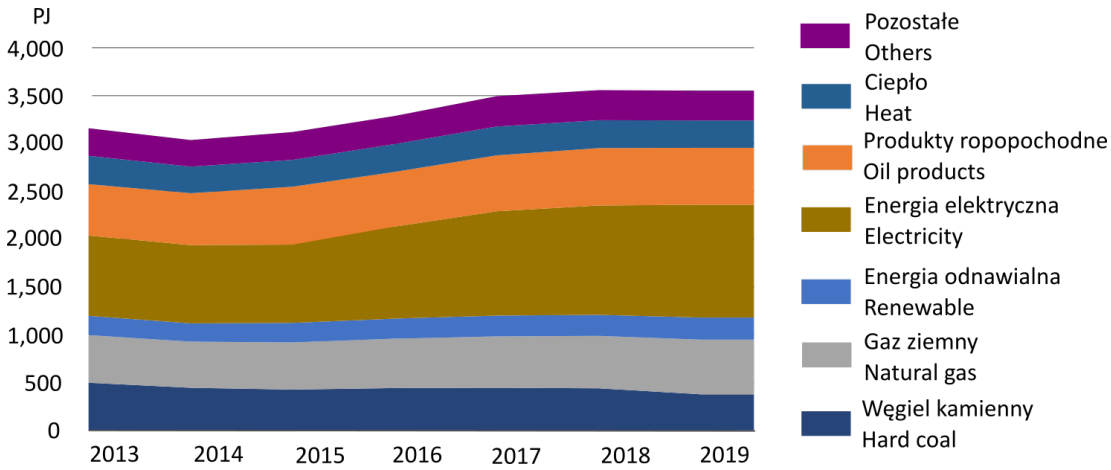


Figure 7 – Direct energy use by energy carriers [5]

EMISSIONS IN POLAND - OVERVIEW

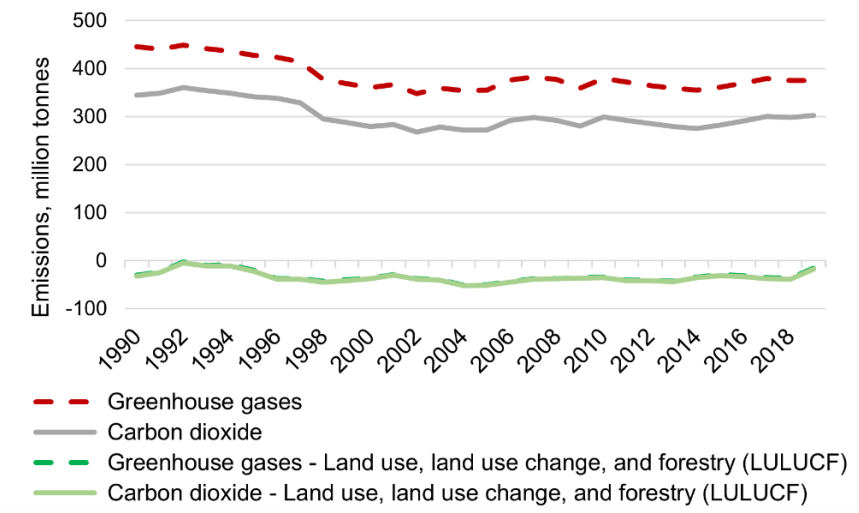


Figure 8 – Territorial emissions in Poland [6]

Poland's territorial greenhouse gas (GHG) emissions in 2019 are 375.7 $MtCO_{2e}$, with 80% from carbon dioxide emissions (CO_2) [6] (Figure 8). Compared to 1990 levels, GHG emission in 2019 are 16% lower with CO_2 reduced by 12%. In 2019, 63% of CO_2 emissions result from coal combustion, followed by oil combustion at 26% (Figure 9). Almost a half of all CO_2 emissions (49%) can be attributed to electricity and heat production, with transport making up a further 21%. CO_2 emissions from Residential and commercial and public services sector are 14% of the total in 2019 (Figure 10). Emissions from transport show a threefold increase from 1990 to 2018.

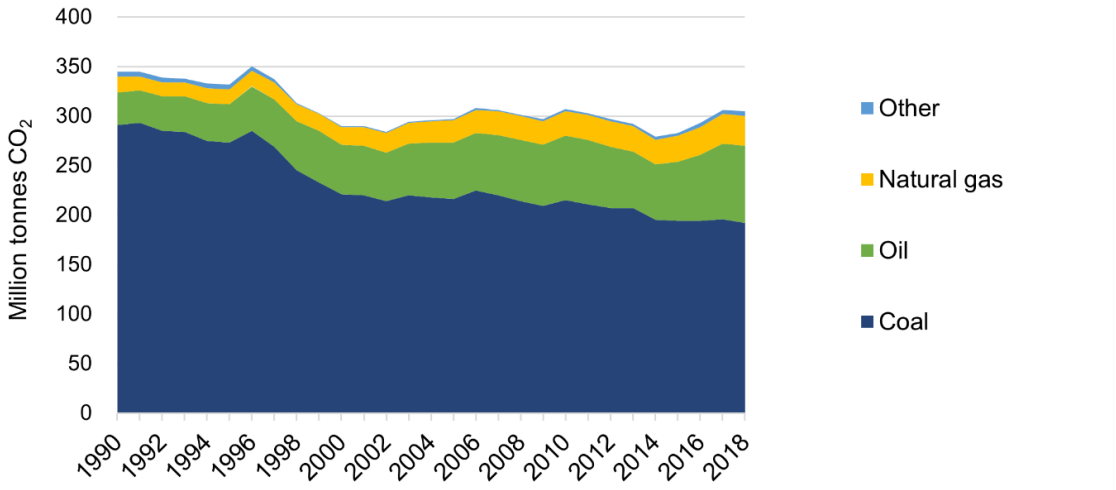


Figure 9 – Carbon dioxide emissions by source [6]

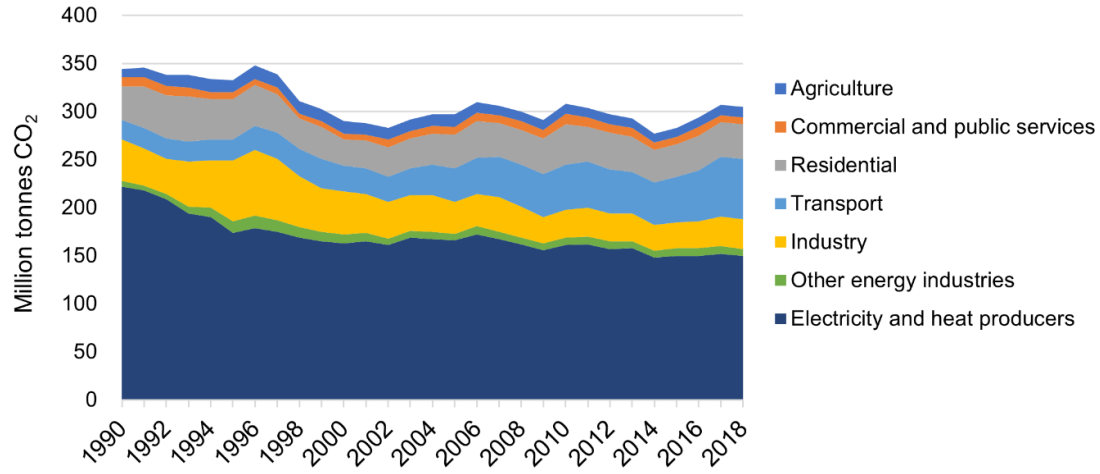


Figure 10 – Carbon dioxide emissions by sector [6]

Long term EU strategy is to become climate-neutral by 2050 – an economy with net-zero greenhouse gas emissions, and to reduce its greenhouse gas emissions by at least 55% by 2030 from 1990 levels. Poland also has agreed to hit the 2050 carbon neutral target. During COP26 in Glasgow (4 November 2021), Poland has committed to phase out coal-fired power generation by 2040, placing emphasis on offshore wind and nuclear energy. Even if the Polish government still intends to produce energy from coal until 2049, reduction of emissions from burning fossil fuels will need to accelerate rapidly in the coming years, if Poland is to meet the EU climate strategy.

MATERIAL AND ENERGY FLOW DIAGRAMS - METHODOLOGY

For this study, energy and material flows are visualised in the form of Sankey diagrams [7] where material and energy flows are traced from material and energy sources, through to the end use sectors. The width of each flow indicates the magnitude of the resource flow, measured in mass (Mt) or energy (TJ) units. Visualising Poland's resource use in this way allows the scale of resource flows to be compared side by side, and indicates where actions might be taken to improve the efficiency of resource use.

The industrial sector has the largest share in direct energy use (34.6%) in 2019, from activities such as manufacturing, mining and quarrying, electricity and water supply. The transport sector is the second largest user of energy (28.1%), with households using 21.7%, agriculture 4.5%, construction 1.7% and other consumers 9.4% (Figure 11).

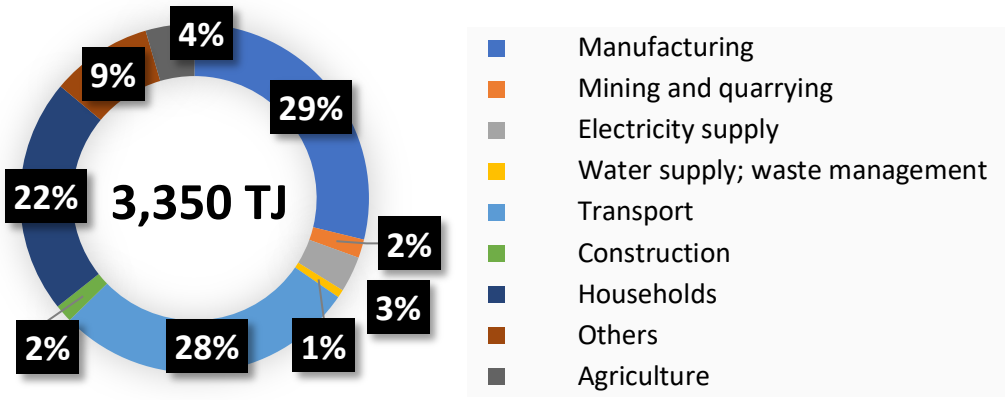


Figure 11 – Shares of direct energy by sectors [5].

For this report, material and energy use in Poland, in 2019, is disaggregated by industry sectors (or departments) taken from the "Statistical Classification of Economic Activities in the European Community (NACE) Rev.2" (Appendix 1 – NACE Sections and Divisions).

Material and energy flows are tracked for selected sectors from the "Materials management in 2019" (Tab)le 4 [8]), and are responsible for 65% of direct energy use in Poland (see Figure 11):

- Agriculture, forestry and fishing (NACE code A)
- Mining and quarrying (NACE code B)
- Manufacturing (NACE code C)
- Electricity, gas, steam and air conditioning supply (NACE code D)
- Water supply; sewage, waste management and remediation activities (NACE code E)
- Construction (NACE code F)

Additional sectors are included from Table 5 [8]

- Transportation and storage (NACE code H)
- Information and communication (NACE code J)
- Other consumption (not specified by the NACE code)

The Energy analysis is based on data from the "Energy statistics in 2018 and 2019" [5]. Results do not include sectors or sub-sectors for which energy data is unavailable, e.g. Printing activities. Energy is not assessed for Other consumption as the boundaries between materials and energy use is unknown.

The classification of biomass, energy materials, metals, non-metallic minerals, other and water is used for presenting the domestic material and energy use in Poland (see Figure 1 and [1]). Energy materials and water are presented as separate figures from biomass, metals, non-metallic minerals, and other due to the different scale of use when measured in mass.

Definitions used in this study

In this report, the following definitions are adopted from [8] and [5]:

Domestic use of materials is the use of materials in the production process for manufacturing manufactured products, semi-finished products and services as well as directly by households, along with losses and natural losses and statistical differences. Use may concern individual materials and is then expressed in natural units or it may concern the sum of all materials and is then expressed in values; the net balance: generated production + imports + the decrease in stocks (at the producer) – exports – the increase in stocks (at the producer) = domestic use

Imports includes goods that have been imported into the territory of Poland regardless of the form of payment. It also includes quasi-transit and does not include imports for processing.

Exports includes goods that have been exported from the territory of Poland regardless of the form of payment. It also includes quasi-transit and does not include exports for processing.

Outcome of water accounts for the sum of the total use of water for own needs, the sale of surplus water as well as water losses in the network.

Direct use (energy) is a sum of all energy commodities, consumed without the further transformation included in the synthetic energy balance. Direct use includes also energy needs of transformations, losses which took place at the consumers and non-energy use (presented in balances separately as part of "direct use").

Non-energy use (energy) includes use of fuels as raw materials for production (e.g. natural gas consumed as raw material to manufacture ammonia, hard coal for electrode production)

Material flow diagrams

The analysis of material flows includes 27 main materials categories from the "Materials management in 2019" [8] as well as water from the "Statistical Yearbook of Industry 2020" [9] (Appendix 2 – Materials in DCU). Where available, the analysis includes materials sub-categories, with 46 different materials analysed overall. Material statistics are converted from various units (e.g. m^2, m^3,) to Mt (million tonnes) using the factors in Appendix 3 – Materials – conversion factors.

Materials are aggregated into biomass, metals, non-metallic minerals, other and water, following classification in Appendix 4 – Material classification, which is adapted from Eurostat *Material flow accounts*..[1]. Data from Table 1, "Materials management in 2019" [8] is used to show material balances, across production, imports and exports.

The use of each material is calculated by summing up the sectors in Table 5, "Materials management in 2019" [8]. The results are compared to the total material use reported in this table, and Table 4, "Materials management in 2019" [8]. In cases where the sum of the resource use is found to be lower than reported total use, the difference is included in the "Other consumption" category. Where no information is provided on the use of materials in Table 5, "Materials management in 2019" [8] (e.g. for sawnwood, fibreboards or disodium carbonate), the sum of all materials in the sector is assumed as total material use.

The overall use of materials (excluding water) in Poland, by sector, is shown in Figure 12. Figure 13 presents the overall use of materials including water. More detailed figures for individual sectors presented in:

- Figure 16 for Mining and quarrying,
- Figure 19 for Manufacture of metals and metal products,
- Figure 22 for Bioproducts and non-metallic mineral products,
- Figure 25 for Plastic, rubber and chemical products,
- Figure 28 for Construction,
- Figure 31 for Information and communication and Transportation and storage.

Energy flow diagrams

Direct energy use is analysed using data from the "Energy statistics in 2018 and 2019" [5]. Energy sources are allocated to the following groups: solid fossil fuel, manufactured gasses, oil and petroleum products, natural gas, solid biomass and animal products, biofuels and waste, renewables, non-energy products, heat, electricity and other. Detailed classifications are included in Appendix 5 – Classification of energy source. More detailed analysis is required to show energy materials / carriers for heat and electricity generation.

In 2019, heat production reached 286.3 PJ [5]. The largest share is from public power plants, heat only boilers and public heat plants (96.7%). This analysis estimates the fuel mix across these three sources, with the fuel mix shares, fuel mass coefficients and heat production efficiencies included in Appendix 6 – Heat carriers mix and coefficients. The highest efficiency for heat generation in 2019 is achieved by public power plants - 82.4%, public heat plants - 82.3%, and heating boilers - 81.8%.

Electricity production in Poland reached 164.0 TWh PJ [5] in 2019, and is produced mainly in public power plants, with a 78.7% share of the total production. The conversion efficiency of public power plants has remained constant for several years and is 41.9% in 2019. Autoproducing power plants generate 16.5 TWh of electricity, accounting for 10.1% of total production. Hard coal is the most important fuel for electricity generation in 2019, making up 46.7% of the fuel input, followed by lignite at 25.4%. Production from renewable energy sources accounted for 15.5%, wind energy, biomass and biogas being important renewbale technologies. For this study, the share of carriers of electricity generation is according to Table 2

included in [5]. Energy source mass coefficients are presented in Appendix 7 – Electricity carrier mix and coefficients.

Direct use of energy and material energy / carriers for analysed sectors in Poland present Figure 14 and Figure 15.

More detailed energy and material energy / carriers use for divisions included in analysed sections present:

- Figure 17 and Figure 18 for Mining and quarrying,
- Figure 20 and Figure 21 for Manufacture of metals and metal products,
- Figure 23 and Figure 24 for Bioproducts and non-metallic mineral products,
- Figure 26 and Figure 27 for Plastic, rubber and chemical products,
- Figure 29 and Figure 30 for Construction,
- Figure 32, Figure 33 for Information and communication and Transportation and storage.

All results are also included in excel file that is an integral part of this report.

MATERIAL AND ENERGY DIRECT USE

In this section, we present the resource flow maps for Poland. We start with the overall picture of material and energy use across the analysed industrial sectors. This is followed by detailed analyses of individual sectors, where more detail is provided.

Material and energy use across the industrial sectors

According to Eurostat [1], domestic material use of non-metallic minerals, biomass, metal and other (excluding energy materials / carriers and water) in 2019 is 511.5 Mt. Figure 12 presents the material flows only, by sector, with the sum of all materials found to be 76.2 Mt. Manufacturing is the largest sector, with 64% material flows, followed by Other consumption (30%) and Construction sector (5%). The largest share of materials used in this sector are non-metallic materials and metals, which make up 32% and 31% respectively, followed by products from wood (14%) and Paper and board (8%). The large material flow in the Other consumption sector results from limestone and Portland cement which make up nearly half of the sector. All cement is used in construction (19.8 Mt), but according to national statistics cement use in Construction sector is 1.8 Mt. This mismatch is most likely caused by the statistics only counting cement used by concrete producers directly in the Construction sector, but not in other end-uses. Cement is used in the Manufacturing sector to manufacture elements that are further used in the Construction sector, e.g. prefabricated concrete elements such as concrete blocks, pavement or structural elements. Cement reported in Other consumption is most likely purchased by individual clients and used in Construction sector.

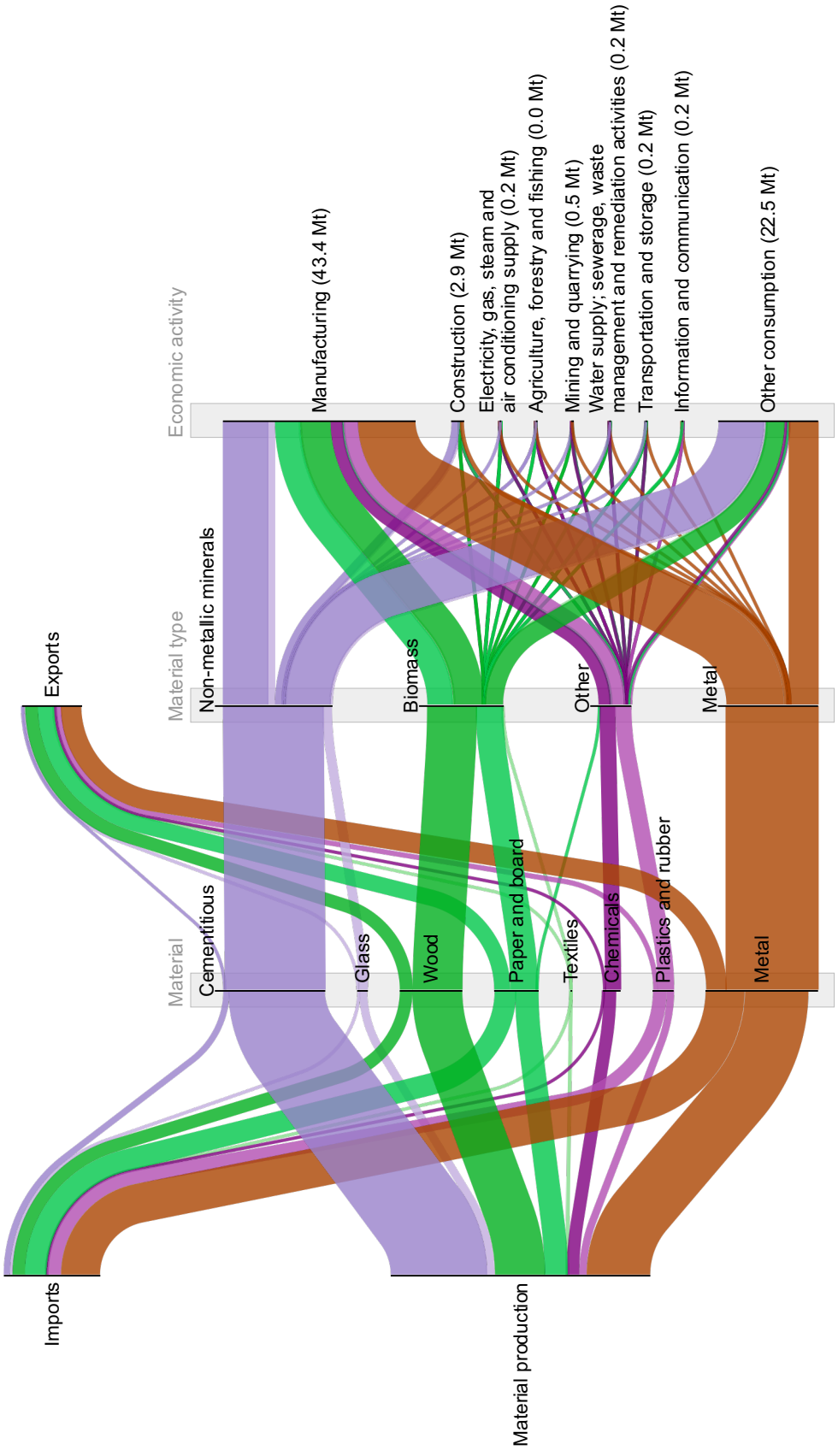


Figure 12 – Material flows (measured in mass) traced from production to use by economic activity (excluding water and energy materials flows). Sum of all materials is 76.2 Mt.

Figure 12 excludes water use as the volume of water is much greater than other materials, as shown in Figure 13. Water use for the needs of the national economy and population in 2019 is reported at 9,253.8[3] m^3 (9,253.8 Mt). Water use across the sectors is 6,278.5 million m^3 (6,278.5 Mt), with 68% of water use for the needs of the national economy and population, 88% of which is used in Electricity, gas, steam and air conditioning supply and 10% in Manufacturing sector.

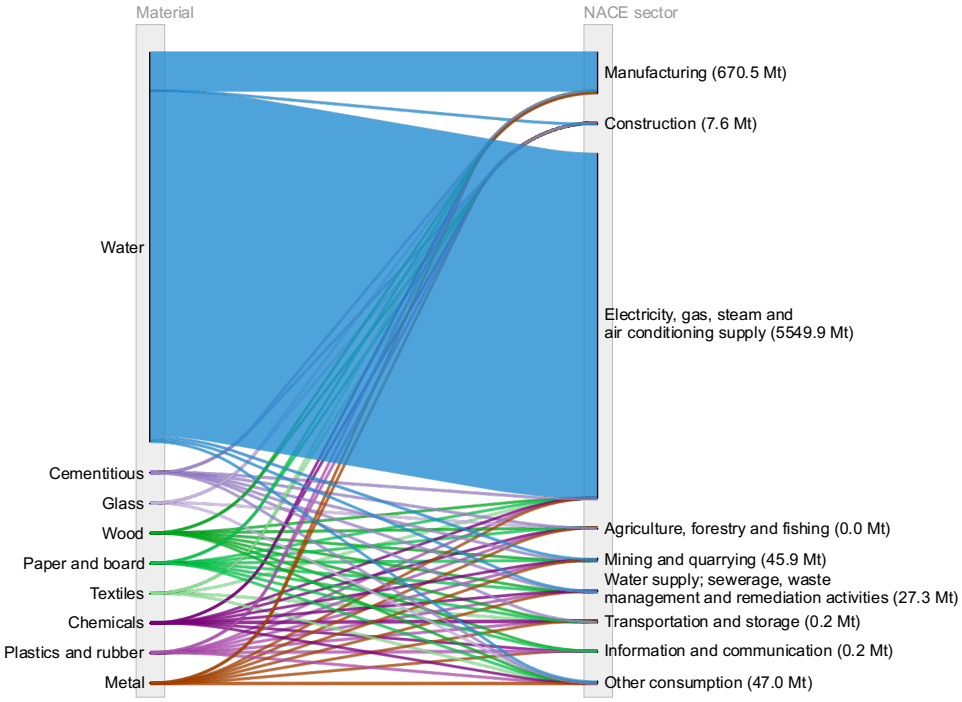


Figure 13 – Materials used (measured in mass) in all analysed sectors (excluding energy materials), by economic activity. Sum of all materials, includig water, is 6,354.7 Mt

Manufacturing is the largest user of direct energy in Poland at 1023.7 PJ (29% of national direct energy use), followed by Transportation and storage sector at 997.8 PJ (28% of national direct energy use) (Figure 14). The vast majority (95%) of direct energy use in Transportation and storage sector is from Oil and petroleum products. In contrast, the energy breakdown for the Manufacturing sector is more diverse, with 27% of energy from natural gas, 20% from electricity and 16% from solid fossil fuel use.

The total energy materials used in the industrial sectors is 101.3 Mt, 59% of which is solid fossil fuels. Some 53.9 Mt of fossil energy is used for electricity and heat production, with 93% and 7% respectively. Losses from electricity production and transformation are 58%, compared 15% for heat production (Figure 15). 5.5 Mt of solid fossil fuels are used directly, with 95% in the Manufacturing sector. Solid fossil fuels are used in the Manufacturing sector for electricity (22.3 Mt) and heat (8.3 Mt). The manufacturing sector consumes 98% of solid biomass and animal products directly, some 3.5 Mt, making up 11% of all fossil energy use in this sector. 7.2 Mt of solid fossil fuels are used in Electricity, gas, steam and air conditioning supply sector to supply electricity and 3.1 Mt to deliver heat. 3.3Mt of solid fossil fuels are used to deliver electricity in Mining and quarrying sector, making up almost all (98%) of the fossil energy use in this sector.

[3] Excluding Agriculture and Forestry, Statistics Poland (GUS), https://bit.ly/3Ev02rk

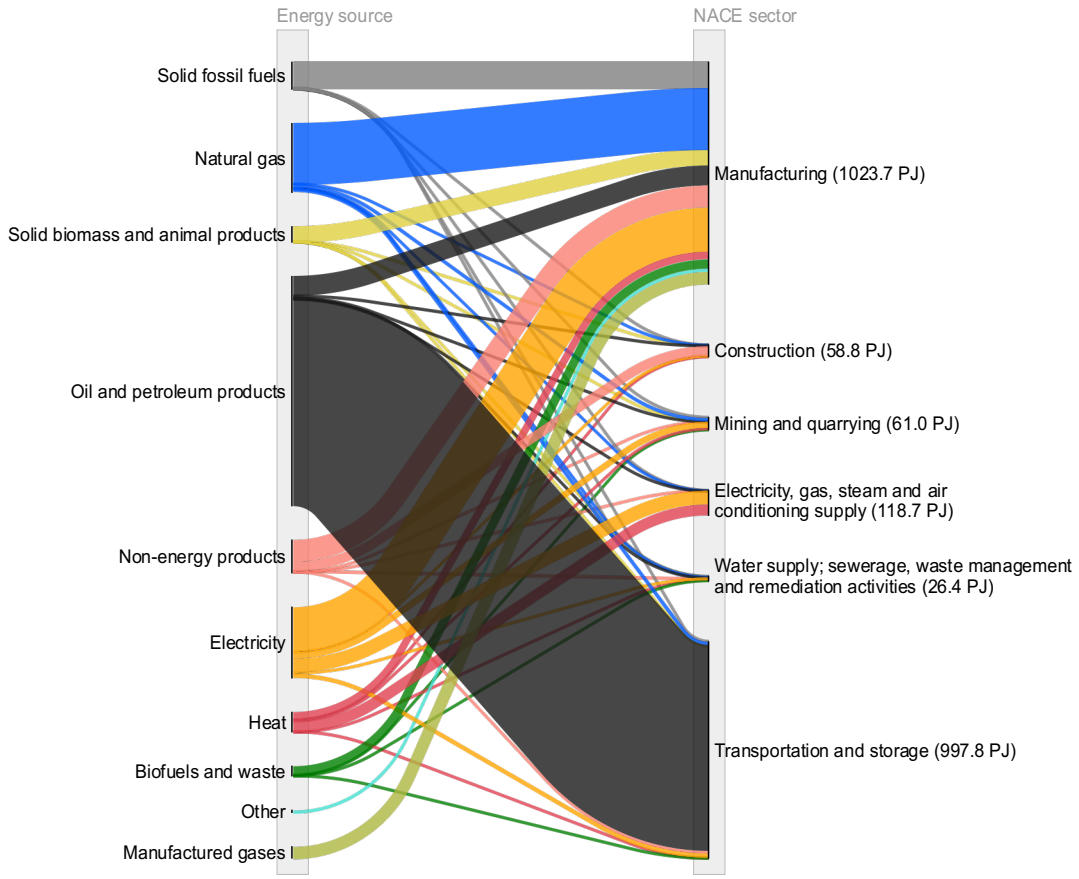


Figure 14 – Direct energy use (energy, including electricity and heat production) - energy flows by economic activity. Sum is 2,286.4 PJ, covering 65% of total direct energy use in Poland.

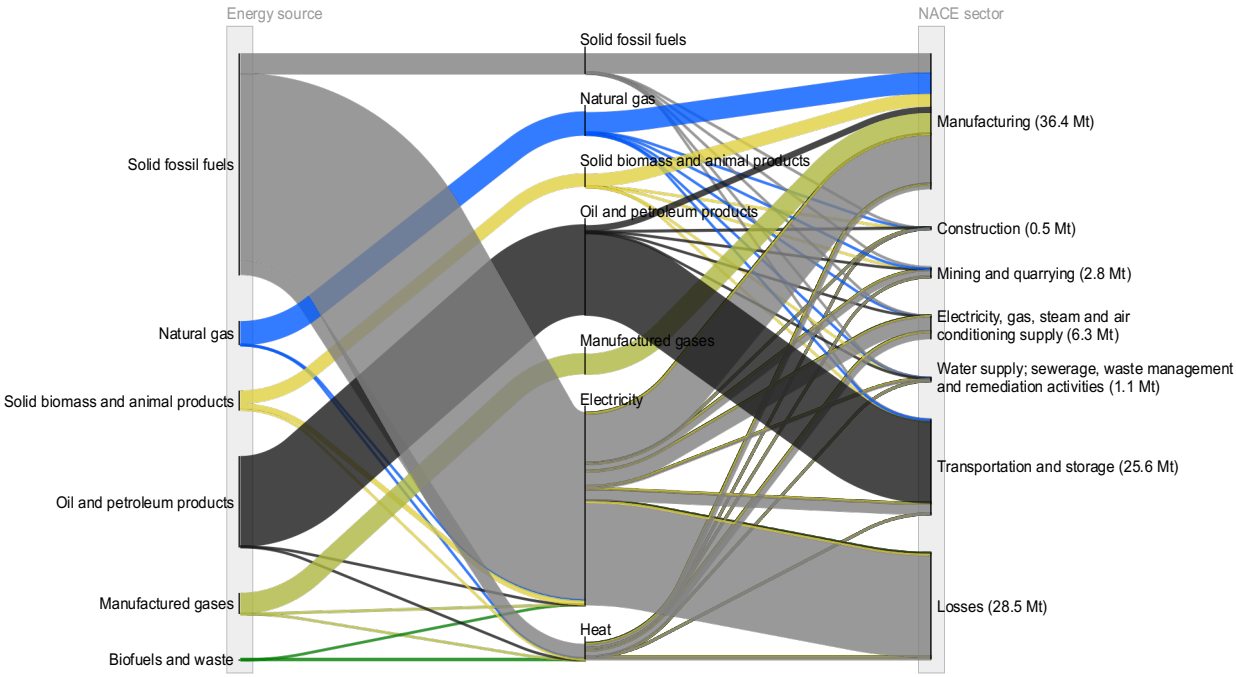


Figure 15 – Energy materials use (measured in mass) by economic activity. Analysis covers 101.3 Mt of energy materials use.

Water is the most used material in Poland, with a total mass of 6,278 Mt across the industrial sectors. This is followed by much smaller flows of: lignite (31 Mt), steam coal (27 Mt), oil and petroleum products (24 Mt), Portland cement (20 Mt) and steel products (18 Mt). Water use across the industrial sectors is between 200 and 350 times higher, by mass, than the other materials used. Water is mainly used for electricity generation.

Most solid fossil fuels are used for electricity and heat production. In 2019, almost a half of CO_2 emissions (49%) result electricity and heat production (see Figure 10). A third of all solid fossil fuel use in the sectors (19 Mt) is used for the production of high energy intensive materials such as cement and steel products. In 2019, emissions from burning coal amount to 63% of territorial CO_2 emissions in Poland (see Figure 9).

Most oil and petroleum products are used for transportation and storage purposes, and 21% of territorial CO_2 emissions in 2019 result transport, compared to 26% for all fossil fuel oil combustion (see Figure 9). The combustion of solid fossil fuels, oil and petroleum products are major contributors to Poland's territorial CO_2 emissions.

Mining and quarrying

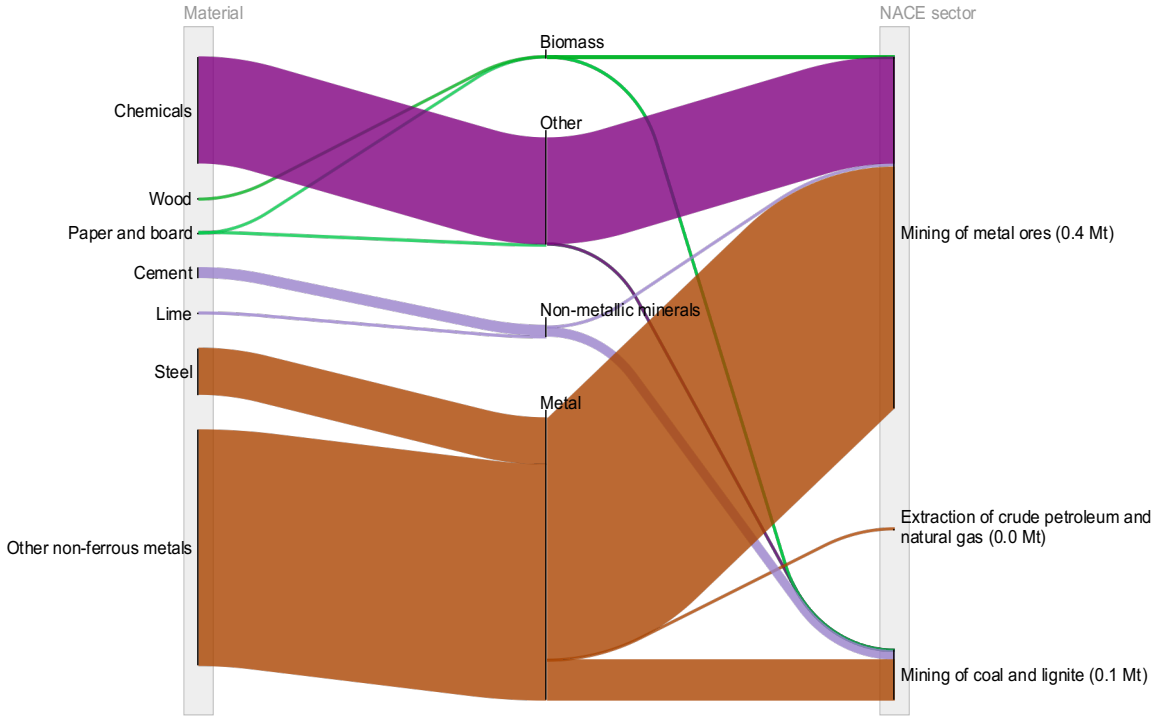


Figure 16 – Direct material use (measured in mass) in the Mining and quarrying section (excluding water and energy materials). Sum of all materials is 0.48M.

Figure 16 presents direct material use in the Mining and Quarrying sector. The Mining of metal ores uses the most materials (0.4 Mt), made up of metal ores (i.e. copper (0.28 Mt) and chemicals (0.13 Mt). The Mining of coal and lignite (0.1 Mt) uses large fractions of steel and cement. National

statistics show that 98% of water use is for the Mining of coal and lignite, 33.1 Mt while only 0.3% of water is used for the national economy and population.

Mining of coal and lignite, mining of metal ores and Extraction of crude petroleum and natural gas are responsible for 80% out of 61 TJ direct energy use in Mining and Quarrying sector. Only these three activities are included in the national statistics, as shown in Figure 17. Mining of coal and lignite uses 39% of the direct energy in the mining sector, followed by extraction of crude petroleum and natural gas with 25%. More than half of the direct energy use in Mining of coal and lignite is from electricity use, followed by natural gas at 32%, with three-quarters of the electricity generated using Solid fossil fuels (2.1 Mt, Figure 18). Across the analysed divisions, 7% of energy is from heat, produced mainly from Solid fossil fuels (0.14 Mt, Figure 18).

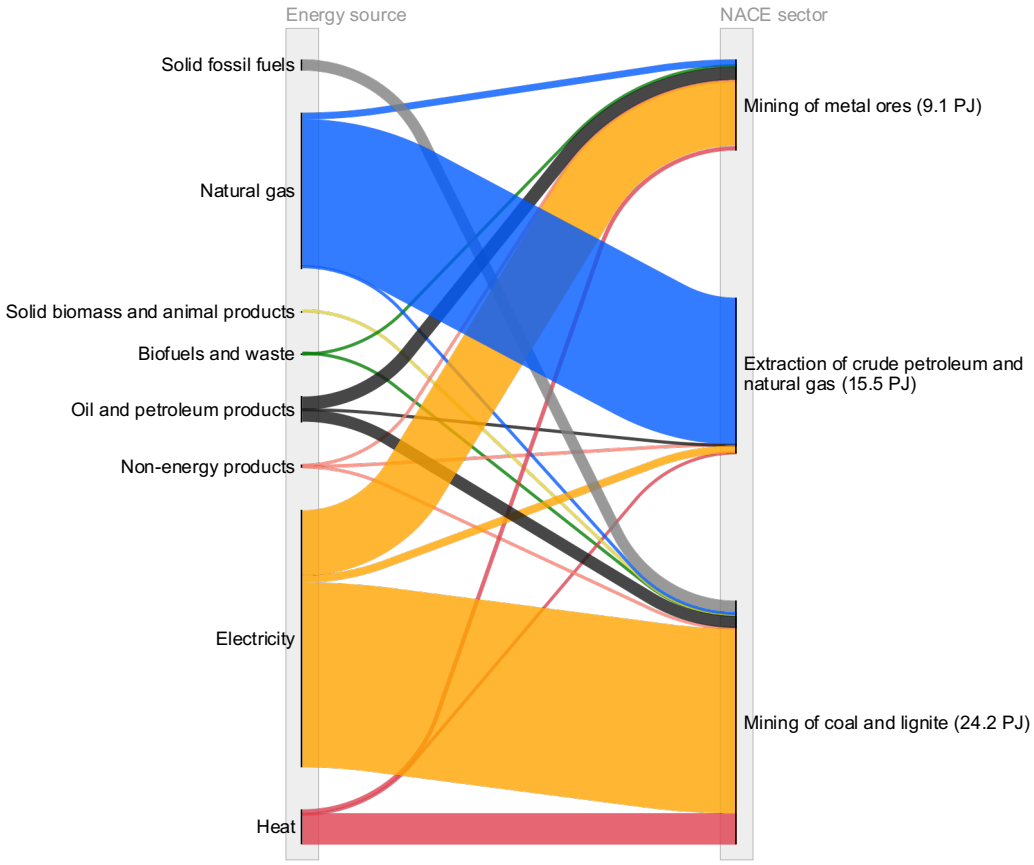


Figure 17 – Direct energy use (measured in energy) in the Mining and quarrying section. Analysis 80% of direct energy use in the sector, equal to 48.8 PJ.

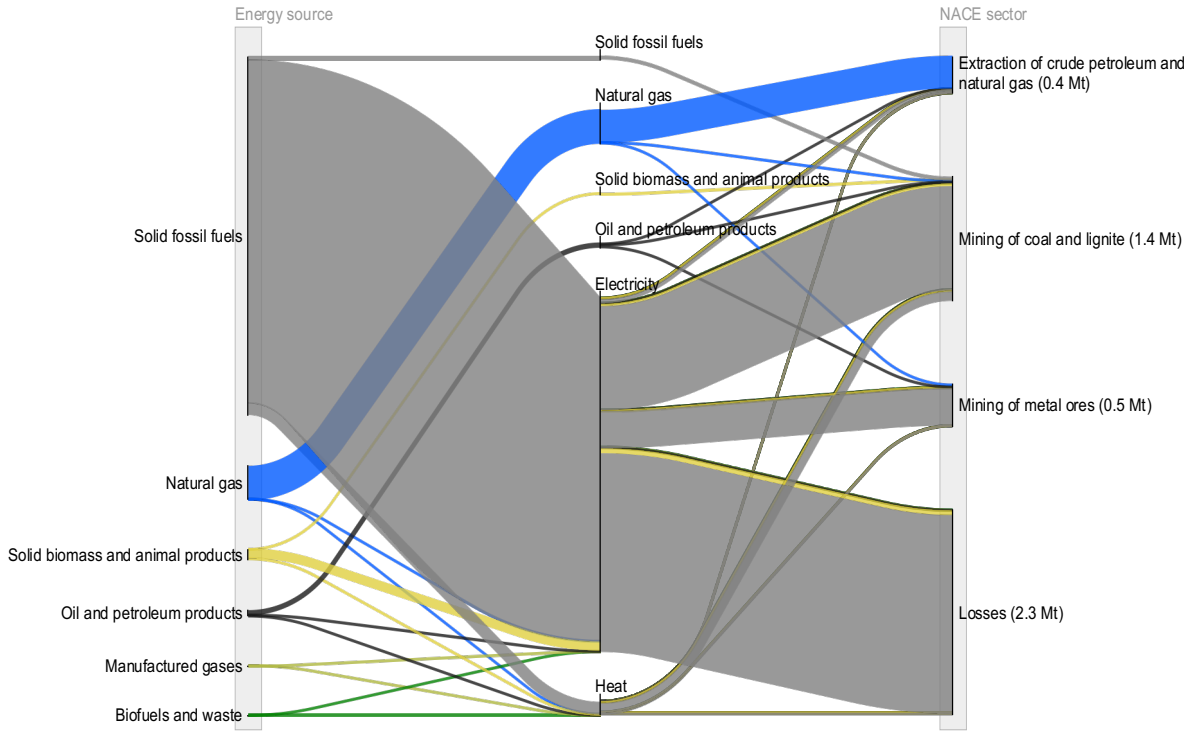


Figure 18 – Energy materials use (measured in mass) in the Mining and quarrying section. Analysis 80% of direct energy use in the sector, equal to 4.66 Mt.

Manufacturing - Manufacture of metals

The Manufacture of metals sector uses 11.2 Mt of metals mainly as steel 11.2 Mt of metals, mainly steel (Figure 19). Metals are used primarily in the sectors called Manufacture of fabricated metal products (except machinery and equipment) (6.0 Mt) and the Manufacture of basic metals (3.4 Mt). Biomass, Non-metallic minerals and Other are together responsible for 8% of all materials used in these sectors. Water is used primarily in the Manufacture of basic metals sector (90%) followed by the Manufacture of fabricated metal products (except machinery and equipment) 4%. The water use across all sectors 32.0 Mt, equal to 0.3% of water use for the needs of the national economy and population.

Energy use in the Manufacture of metals sums to 152.8 PJ and represents 15% of all energy use in Manufacturing sector (Figure 20). 40% of energy used in sector comes from electricity, followed by natural gas (29%), manufactured gasses (11%) and solid fossil fuels (9%). The main energy materials use are solid fossil fuels (8.6 Mt out of 13.7 Mt), used mainly for electricity production (Figure 21).

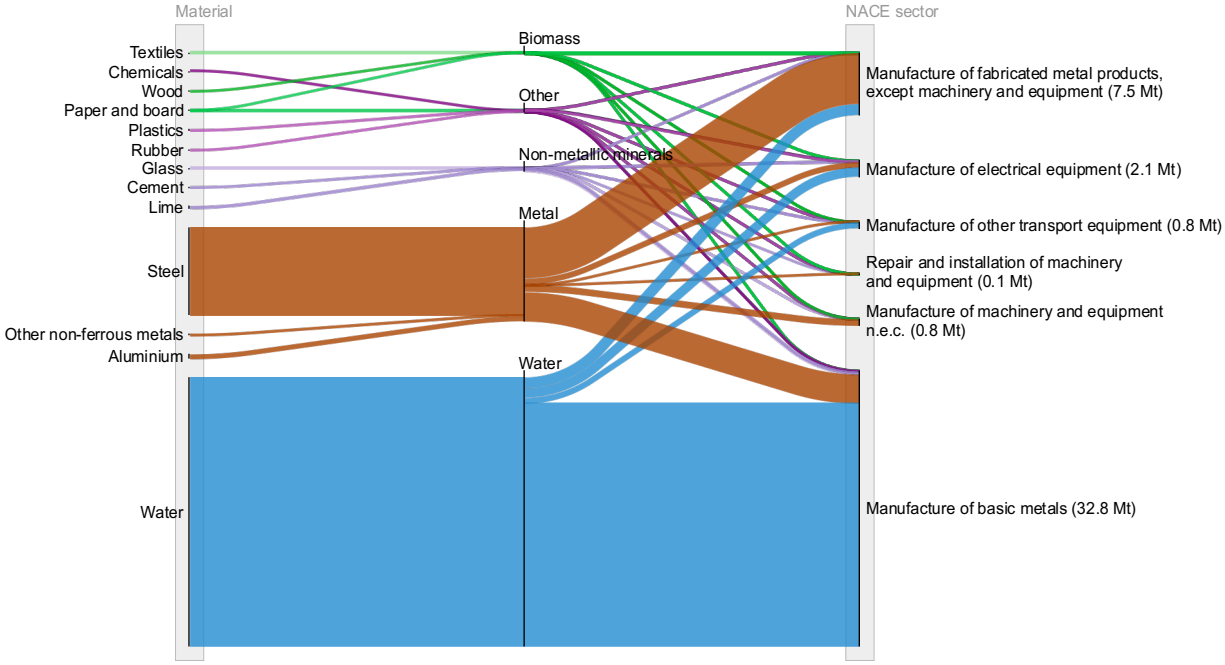


Figure 19 – Direct material use (measured in mass) in the Manufacture of metals. Sum of all materials (excluding water and energy materials) is 12.1 Mt.

The Manufacture of basic materials use the largest share of energy at 96.5 PJ, followed by the Manufacture of fabricated metal products (except machinery and equipment) (16.5 PJ) and the Manufacture of motor vehicles trailers and semi-trailers (15.4 PJ) (Figure 20). One third of energy used in the Manufacture of basic materials is from electricity, 30% from natural gas, 18% from manufacture gas and 13% from solid fossil fuels.

The share of energy delivered by electricity in the Manufacture of fabricated metal products (except machinery and equipment) is 50%, with approximately one third provided by natural gas. The share of electricity increases in the Manufacture of electrical equipment and the Manufacture of motor vehicles, trailers and semi-trailers, up to 60%.

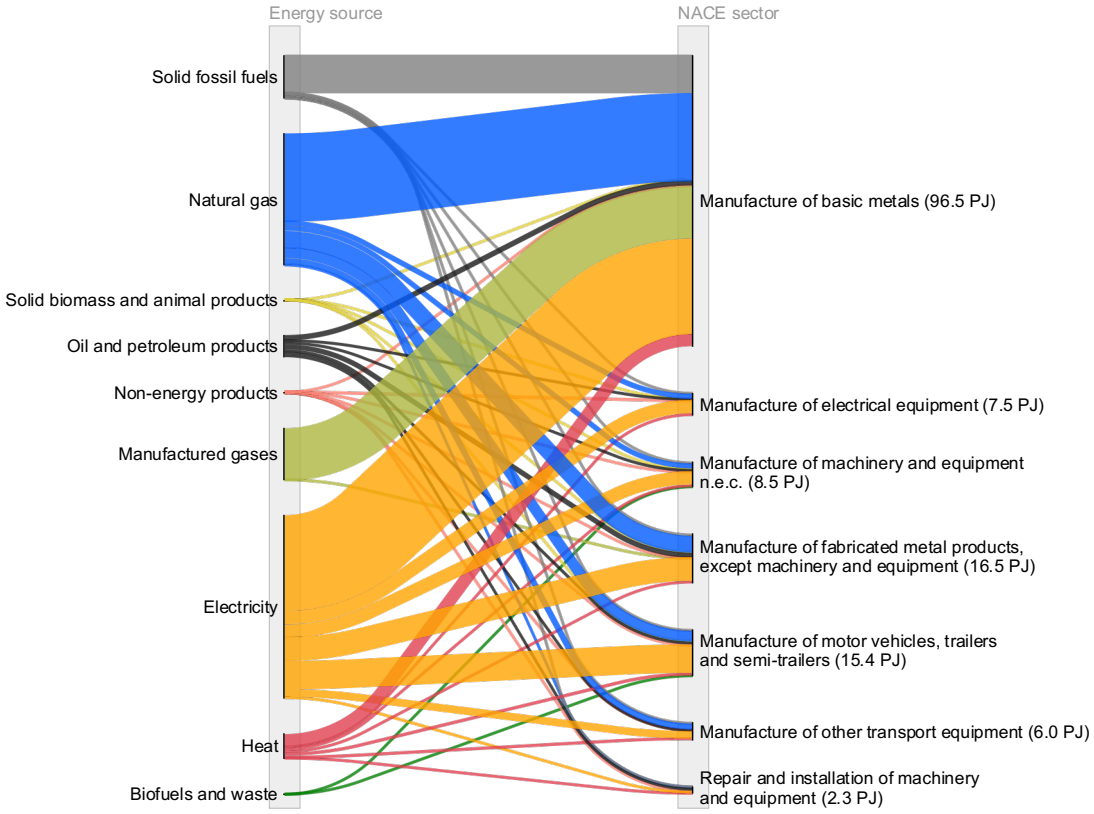


Figure 20 – Direct energy use (measured in energy) in the Manufacture of metals, total 152.8 PJ

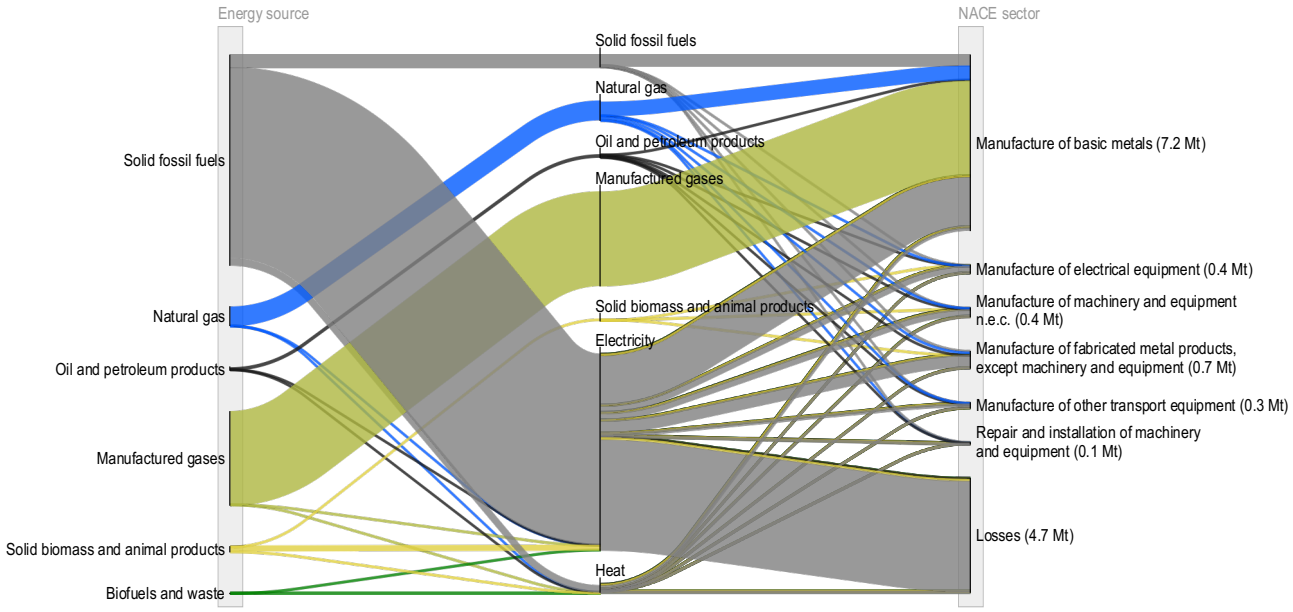


Figure 21 – Energy materials use (measured in mass) in the Manufacture of metals, total 13.7 Mt

Manufacture and production of bioproducts and non-metallic mineral products

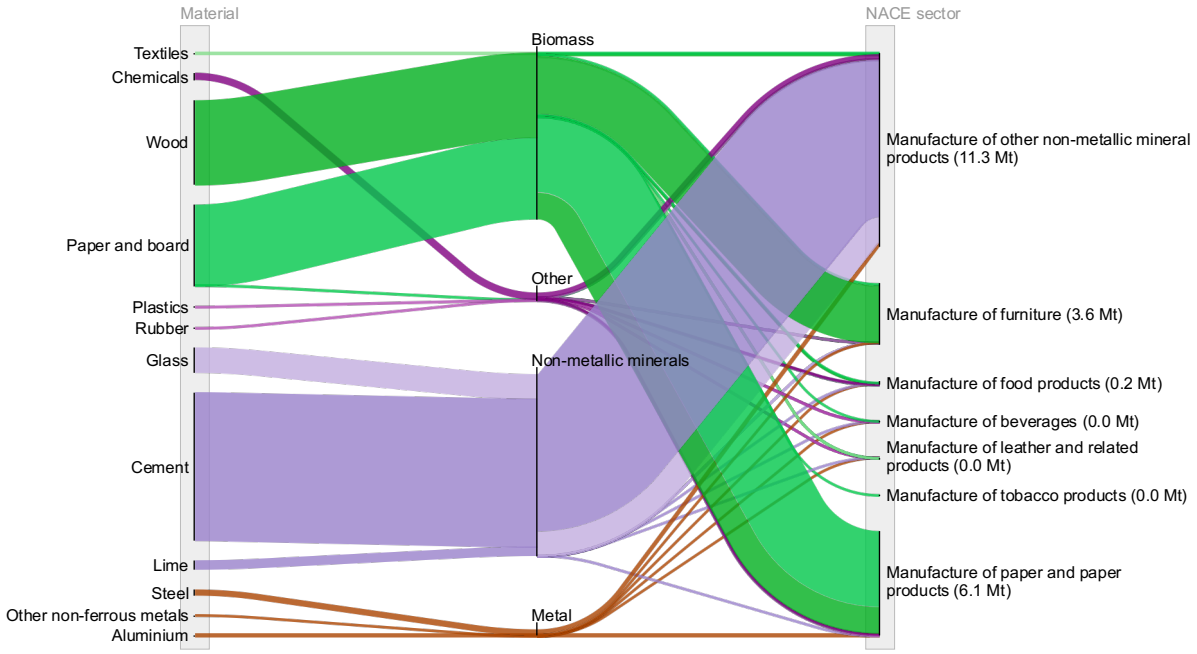


Figure 22 – Direct material use (measured in mass) for Bioproducts and non-metallic mineral products (excluding water and energy materials). The sum of all materials is 21.3 Mt

The largest share of material use in Figure 22 results from the Manufacture of other non-metallic mineral products (11.3 Mt), made up of 76% cement. The Manufacture of paper and paper products (6.1 Mt) is second, made up of 72% paper and paperboard (4.4 Mt). Total water use for this sector is 0.2 Mt, of which 43% is used in the Manufacture of paper and paper products, followed by 39% for the Manufacture of food products. Material use for the Manufacture of food products is 0.2 Mt, or 0.9% of material use from all sectors analysed in Figure 22.

The largest energy uses are the Manufacture of other non-metallic mineral products, including cement and lime (42%), the Manufacture of food products (28%) and the Manufacture of paper and paper products (26%) (Figure 24). The manufacture other metal and plastic products, together uses 332.7 PJ, or 33% of all direct energy use in the Manufacturing sector. The share of natural gas in the energy mix is 28%, followed by electricity (22%), solid fossil fuels (17%), solid biomass and animal products (14%) and biofuels and waste (13%). The largest share of energy materials use is attributed to Sold fossil fuels (10.0 Mt out of 12.6 Mt), used mainly for electricity production (7.9 Mt, Figure 24).

Energy use in the Manufacture of other non-metallic mineral products, is provided natural gas (33%), biofuels and waste (25%), solid fossil fuel (17%) and electricity (15%). The share of natural gas, solid fossil fuels and electricity in the Manufacture of food products is 35%, 27% and 27% respectively. The largest share of energy in the Manufacture of Paper and paper products is solid biomass and animal products, with a share of 47%.

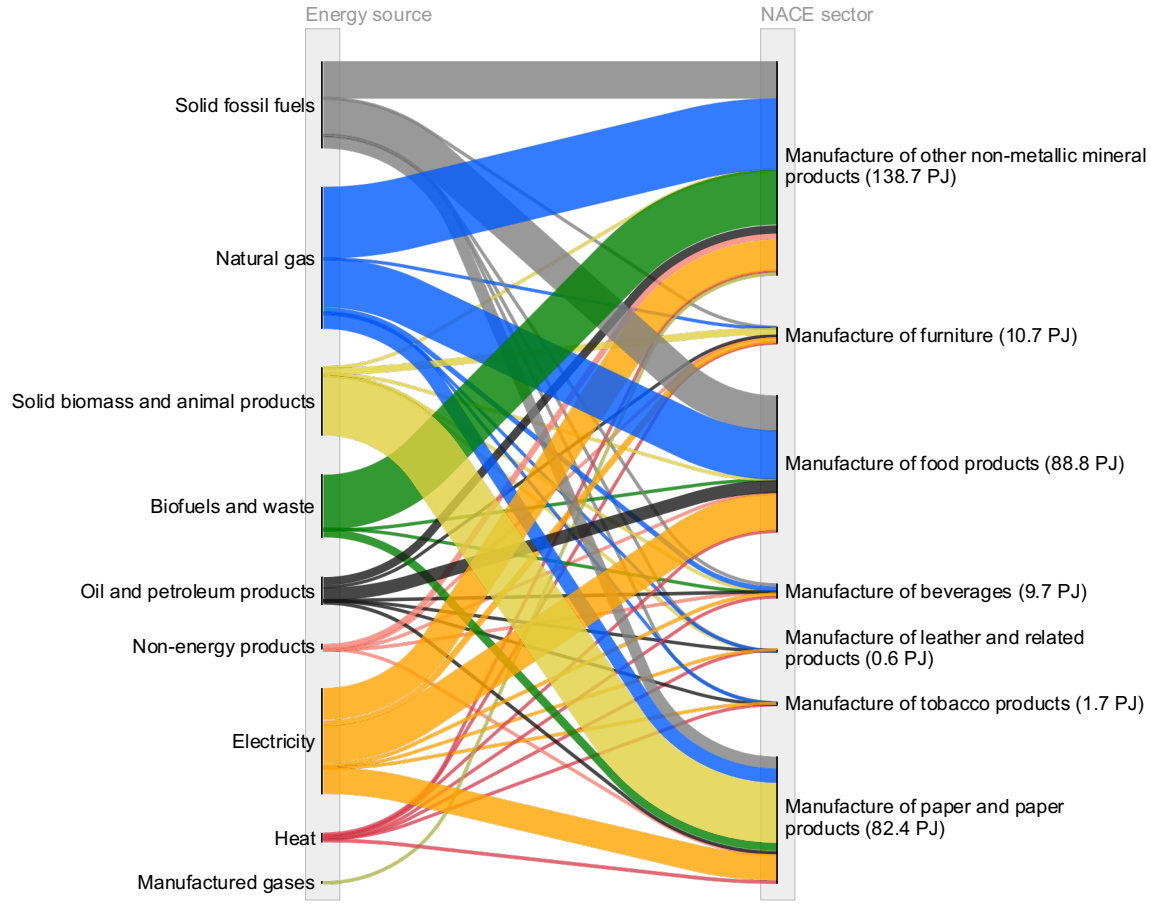


Figure 23 – Direct energy use (measured in energy) for Bioproducts and non-metallic mineral products, total 322.7 PJ

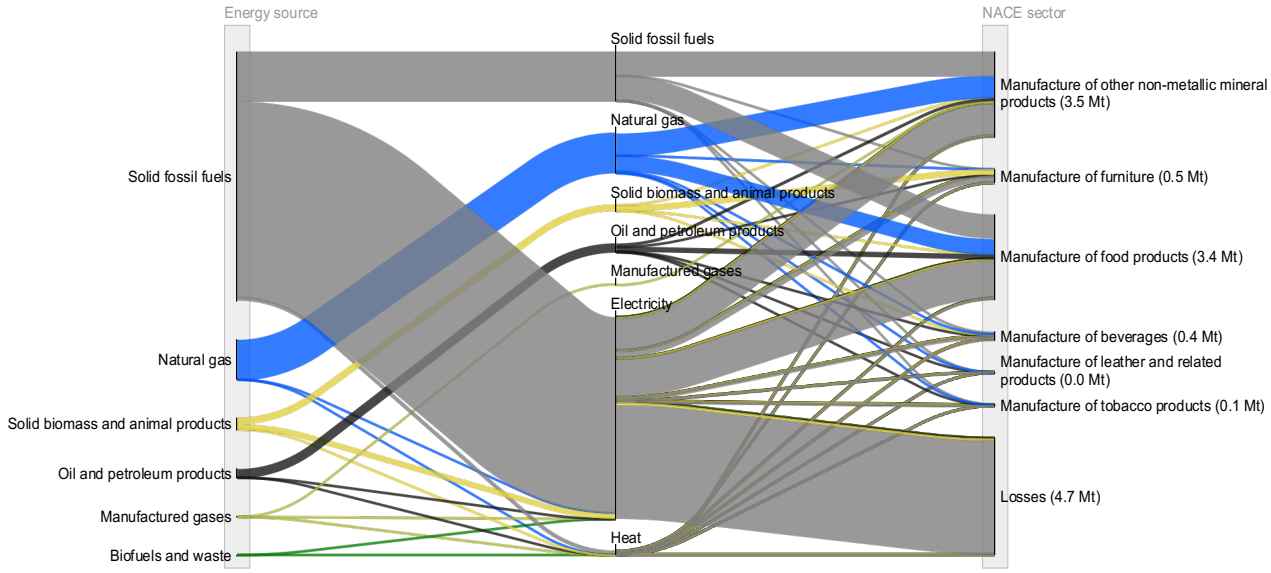


Figure 24 – Energy materials use (measured in mass) in the Bioproducts and non-metallic mineral products, total 12.61 Mt

Manufacture of plastic, rubber and chemical products

Material use in the Manufacture of plastic, rubber and chemical products is 6.1 Mt, with similar shares of 48% each, allocated to the Manufacture of chemicals and chemical products and the Manufacture of rubber and plastic products (Figure 25). Some 77% of material use in the Manufacture of chemicals and chemical products relates to disodium carbonate, sodium hydroxide, sulphur and sulphuric acid with oleum. Plastics and rubber (chemical fibres and synthetic rubber, plastics) are the main materials used in the Manufacture of rubber and plastic products, with an 86% share, whereas chemicals make up 76% of material use for the Manufacture of chemicals and chemical products, and 8% for cement. Total water use in this sector is 351.6 Mt, or 4% of water use for the national economy and population. The greatest use of water is found for the Manufacture of chemicals and chemical products division (83%), followed by Manufacture of coke and refined petroleum products division (13%).

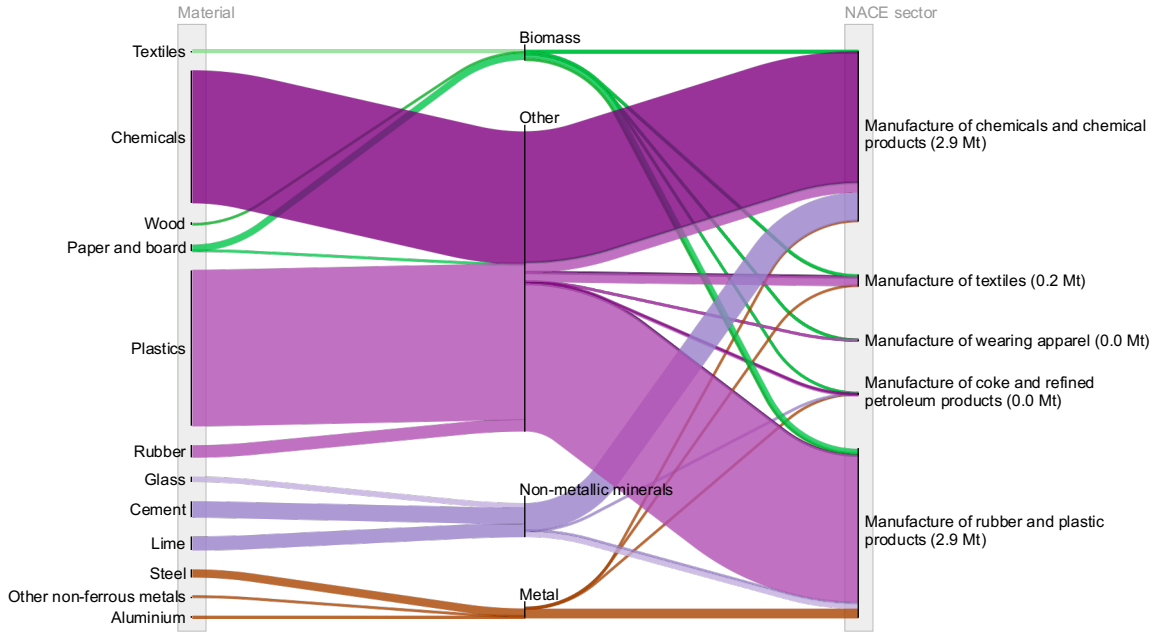


Figure 25 – Direct material use (measured in mass), Manufacture of chemicals, (excluding water and energy materials). The sum of all materials is 6.1 Mt

Energy use in this sector in 2019 is 479.8 PJ, with a largest share used for the Manufacture of coke and refined petroleum (53%) followed by 41% for the Manufacture of chemicals and chemical products (Figure 26).

Non-energy products, manufactured gases and natural gas make up the largest shares in the energy mix for the Manufacture of coke and refined petroleum division, at 33%, 28% and 17% respectively. In the Manufacture of chemicals and chemical products, the largest shares of energy material use are natural gas (47%) and solid fuels (25%). The Manufacture of chemicals and chemical products results in the largest use solid fossil fuels, making up 5.2Mt out of 11.2 Mt, with 2.1 Mt used directly and 3.1 Mt used indirectly for electricity production (Figure 27).

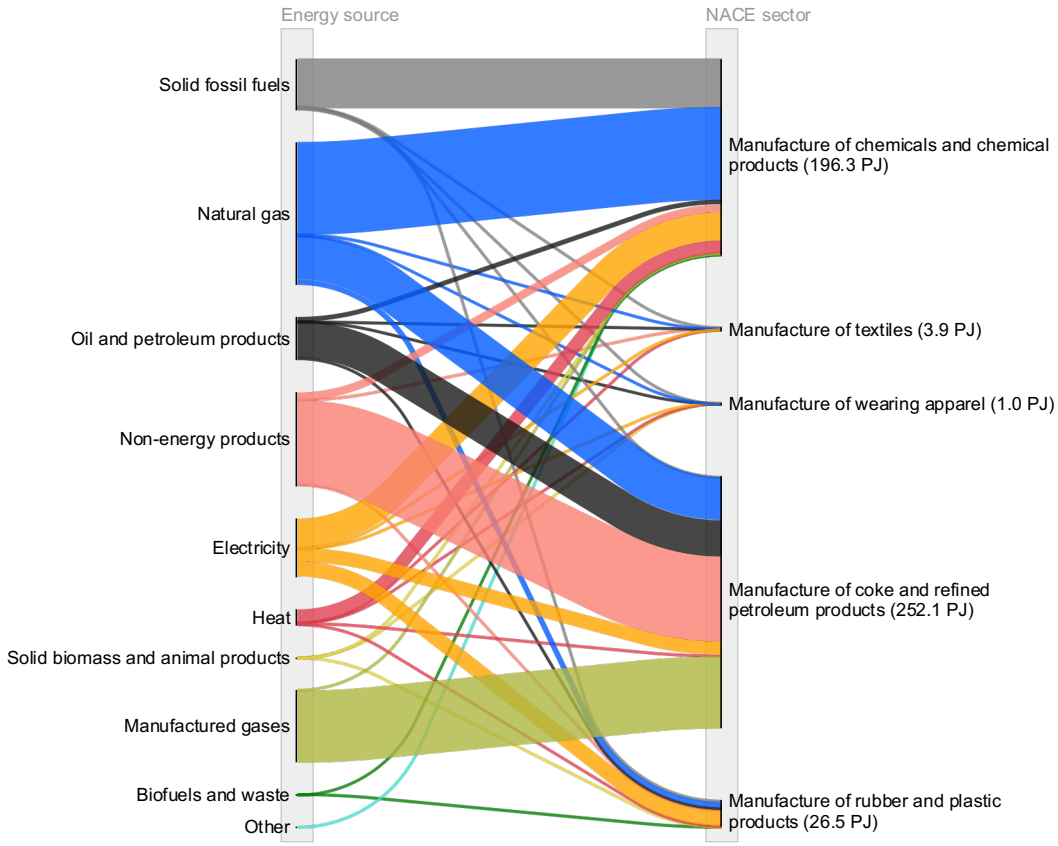


Figure 26 – Direct energy use (measured in energy) in the Manufacture of plastic, rubber and chemical products, total 479.8 PJ

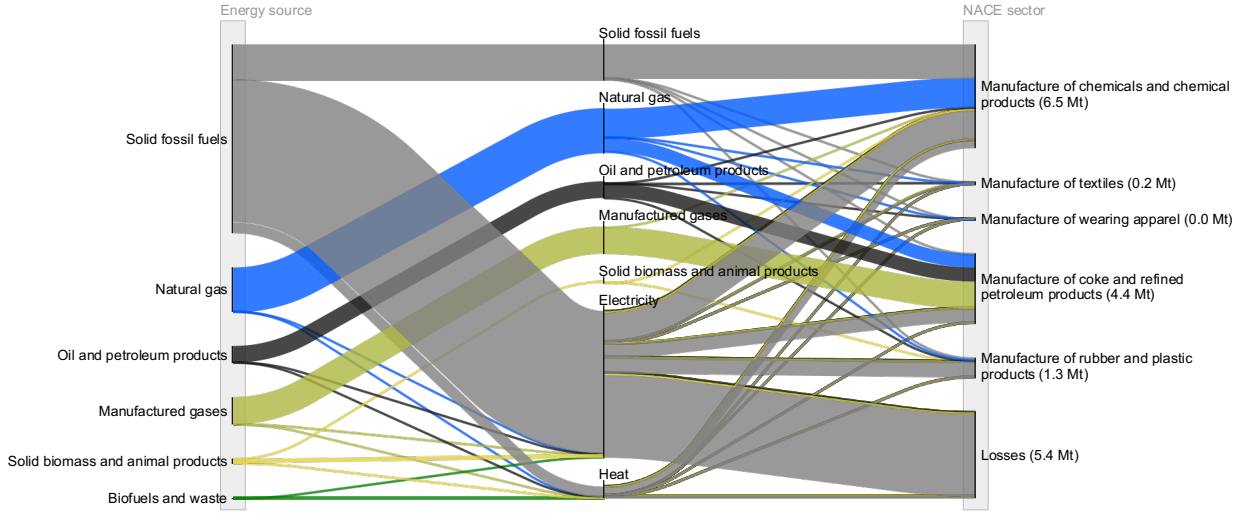


Figure 27 – Energy materials use (measured in mass) in the Manufacture of plastic, rubber and chemical products, total 17.81 Mt

Construction

Material use in the Construction sector is found to be 2.9 Mt (Figure 28), not including water use which totals 4.7 Mt. Cement and steel are the most used materials in Construction, with shares of 61% and 28% respectively. This value for cement use is likely to be used directly by concrete producers in the Construction sector and represents only about 9% of all cement used in Polish construction.

Energy use in the Construction sector is 58.8 PJ, with 77% relating to non-energy products, 13% from oil and petroleum products and 6% from electricity. Non-energy products include the use of fuels as raw materials as feedstocks for products, for example plastics (Figure 29). The generation of electricity used in the Construction sector uses 0.5 Mt of solid fossil fuels used (Figure 30).

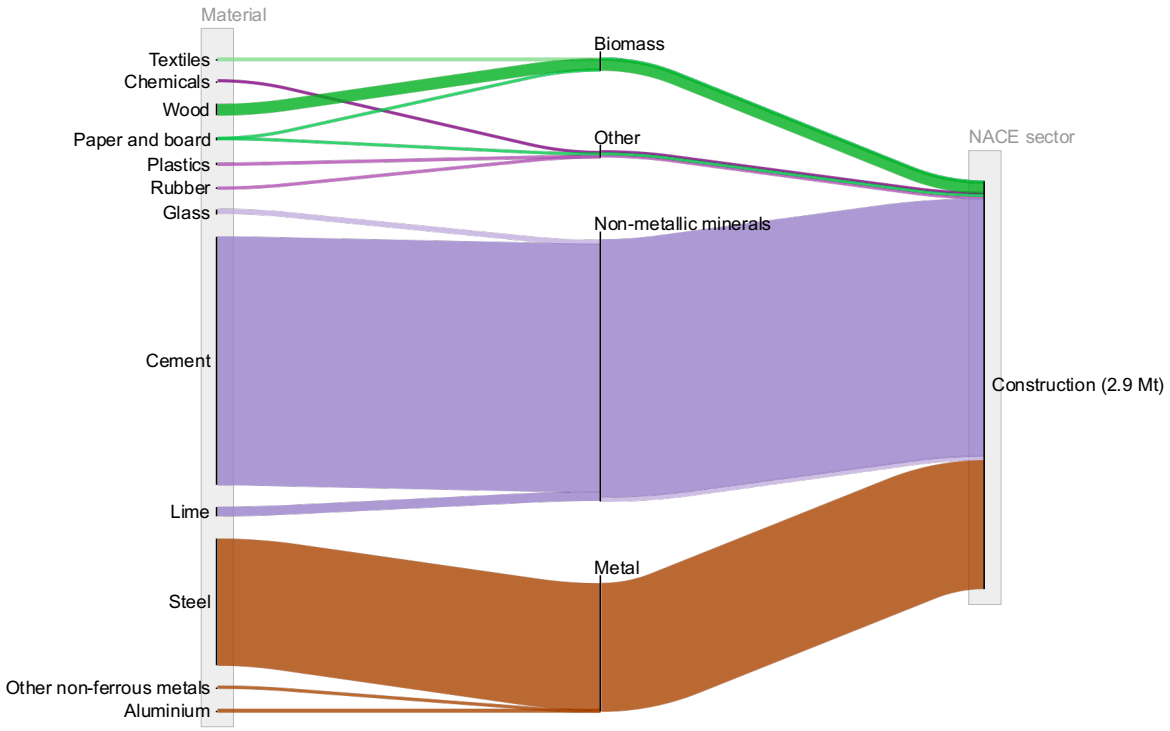


Figure 28 – Direct material use (measured in mass) in the Construction sector (excluding water and energy materials). The sum of all materials is 2.9 Mt

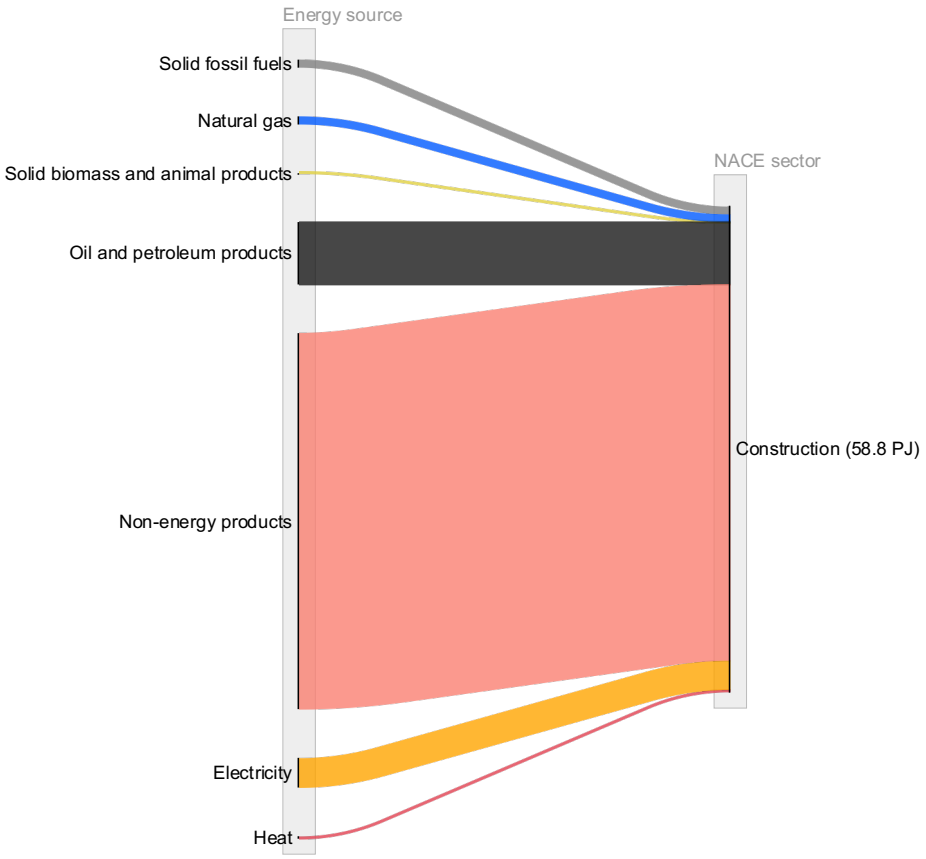


Figure 29 – Direct energy use (measure in energy) in Construction, total 58.8 PJ

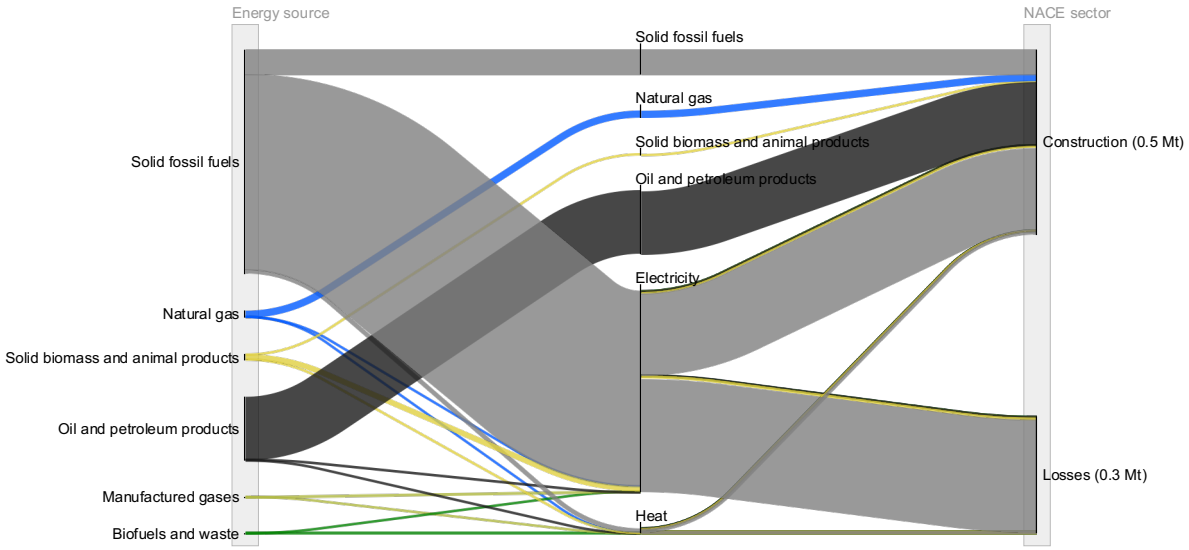


Figure 30 – Energy materials use (measured in mass) in the Construction, total 0.8 Mt

Information and communication and Transportation and storage

Material use in the Printing and reproduction of recorded media equates to 0.72 Mt and in the Publishing activities, to 0.23 Mt (Figure 31). In both sectors, the use of paper and board dominates. Almost two-thirds of materials used in Transportation and storage division is cement, used in transport infrastructure. No information is found on water use for these sectors.

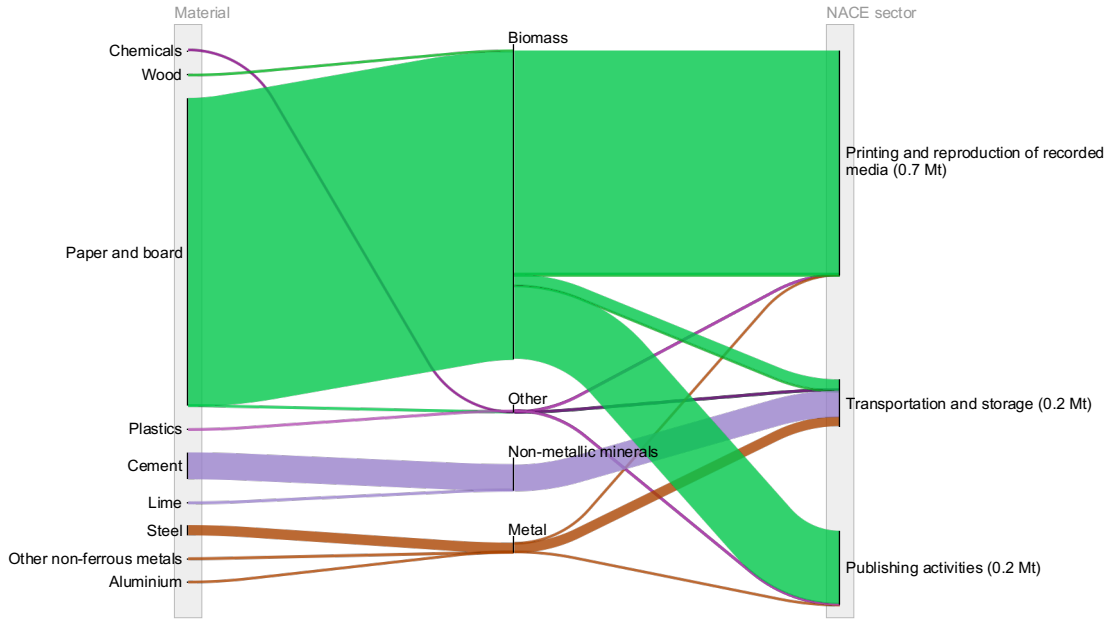


Figure 31 – Direct material use (measured in mass) in the Information and communication sector (excluding water and energy materials). The sum of all materials is 1.1 Mt.

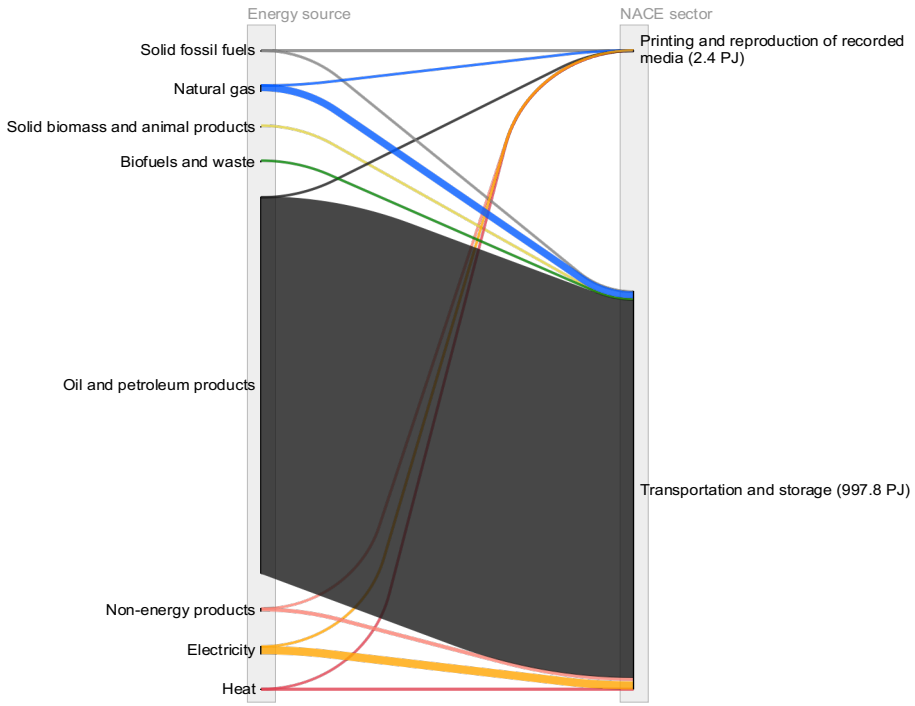


Figure 32 – Direct energy use (measured in energy) in the Information and communication sector and Transportation and storage sector, total 1,000.2 PJ

Direct energy use in Transportation and storage division is 0.98 Mt, of which 97% is derived from oil and petroleum products (Figure 32). The generation of electricity used in Printing and reproduction of recorded media requires the use of 0.2 Mt of solid fossil fuels (Figure 33).

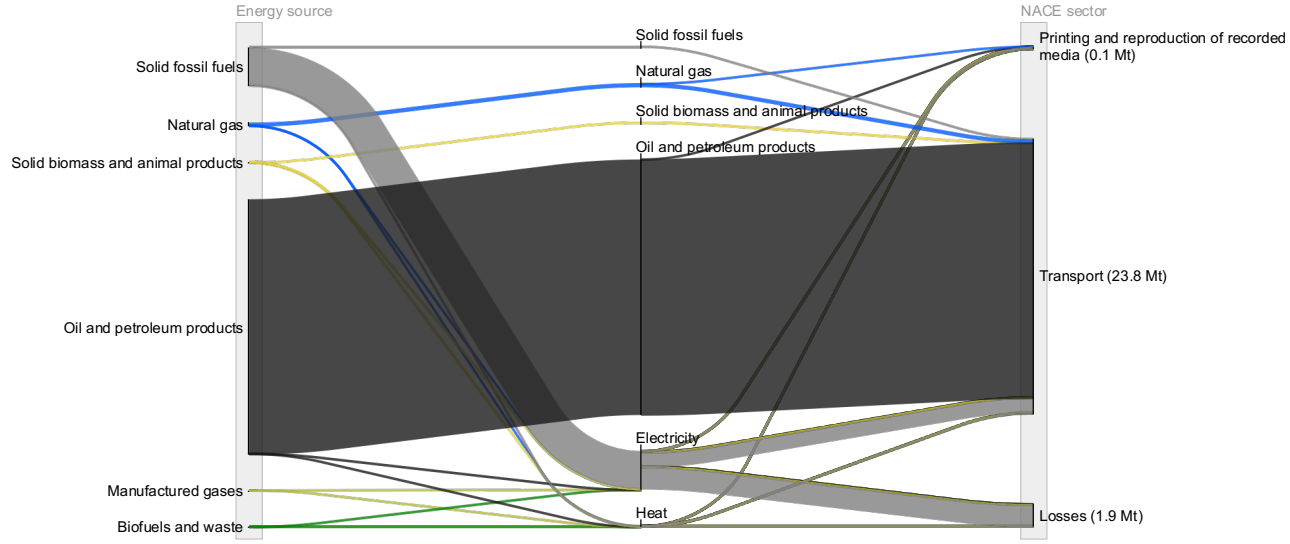


Figure 33 – Energy materials use (measured in mass) in the Information and communication and Transportation and storage sectors, total 25.8Mt

DISCUSSION

This report presents resource flow diagrams for energy and material use in Polish industry for 2019. An overview picture of resource use is created for the following sectors: Agriculture, forestry and fishing, Manufacturing, Construction, Mining and quarrying, Electricity, gas, steam and air conditioning supply, Water supply; sewage, waste management and remediation activities, Transportation and storage, Information and communication (when the data is available); Other consumption. More detailed analysis includes: Mining and quarrying; Manufacture of metals, bio-products, non-metallic minerals, plastics, rubber and chemicals; Construction; Information and communication; Transportation and storage. The study covers 26% of domestic material use in Poland (76.2 Mt out of 668.7 Mt) and 65% of total direct energy use in Poland (2,286.4 PJ out of 3,356.7 PJ) in 2019. Across the analysed industrial sectors, the most consumed materials are:

- Water: 6,278 Mt, with most used electricity generation,
- Lignite: 31 Mt, with most used for electricity generation,
- Steam coal: 27 Mt, with 70% used for electricity generation,
- Oil and petroleum products: 24 Mt, with 92% used for transportation,
- Portland cement: 20 Mt, with 98% used in construction,
- Steel products: 18 Mt, with 72% used to manufacture other products.

Water use, is by far the largest material use by mass. However, fossil fuels still dominate territorial CO_2 emissions, with the combustion of lignite and steam coal contributing 63% of emissions and oil use contributing 26%. Almost half of all CO_2 emissions (49%) results from the generation of electricity and heat, with solid fossil fuels being the dominant fuel.

The most important findings from this report are (Table 1):

- The dominant user of energy in Poland is the Manufacturing sector with a direct use of 1023.7 PJ or 29% of national direct energy use. This is followed by the Transportation and storage section with direct energy use of 997.8 PJ or 28% of national direct energy use,
- Hard coal and lignite remain important fuels, making up 74% of electricity generation and 72% of energy use.
- Energy losses are 58% from electricity generation and 15% from heat production.
- The Manufacturing uses the greatest share of materials (48.6 Mt), followed by Other consumption (22.7 Mt) and Construction (3.6 Mt).
- The largest shares of materials are used for the production of Non-metallic materials and Metals, with shares 32% (24.7 Mt) and 31% (23.7 Mt) respectively, followed by products from wood (14%, 10.7 Mt) and Paper and board (8%, 6.1 Mt).
- Water use across the analysed industrial sectors summed to 6,278.5 Mt, equivalent to 68% of water use for the national economy and population. The majority of water (88%) is used Electricity, gas, steam and air conditioning supply, with only 10% used in the Manufacturing sector.

Table 1 Summary of material and energy use for analysed sectors

	Metals	Non-metallic minerals	Biomass	Other	Water	Energy	Energy materials direct use	Energy materials - indirect use
	kt					PJ	kt	
Agriculture, forestry and fishing	2	4	1	1	-	N/A	N/A	N/A
Mining and quarrying	353	53	1	136	45,400	61	638	4,922
Manufacturing	15,234	11,702	12,641	9,036	627,100	1,024	21,658	33,527
Electricity, gas, steam and air conditioning supply	18	154	1	7	5,549,700	119	121	12,374
Water supply; sewerage, waste management and remediation activities	8	126	1	27	27,100	26	317	1,794
Construction	1,520	1,890	85	56	4,700	59	267	579
Transportation and storage	52	85	36	1	-	998	22,363	3,231
Information and communication	1	-	234	5	-	N/A	N/A	N/A
Other consumption	6,491	10,647	4,249	1,306	24,500	N/A	N/A	N/A
SUM	23,680	24,662	17,247	10,576	6,278,500	2,286	45,364	56,427

Table 1 summarises the material and energy use across the Polish industrial sectors. Water use sits apart from the other resource uses, being several orders of magnitude higher than any other flow (6,279 Mt) and used mostly in the sector Electricity, gas, steam and air conditioning supply. For the remaining materials, the total masses used are comparable, ranging from 10.6 to 24.7 Mt, and comparable to the mass of energy materials, direct (45.3 Mt) and indirect (56.4 Mt) used in the sectors. Furthermore, the sectors of Manufacturing, Construction, and Other Consumption are clearly important to the Polish economy, dominating the use of materials. Whereas the sectors of Transport, Construction and Electricity, gas, steam and air conditioning supply are significant users of energy.

Further research is needed to fill in data gaps, particularly for energy where data is missing, and to ensure energy and materials are not being double counted where sectors overlap or a connected to each other in the wider industrial system. However, the analysis point towards the important resource flows, by scale, which are likely to hold the greatest potential for change, to reduce material and energy use, improve resource efficiency, and mitigate climate change emissions.

Challenges going forward

We identify three key challenges going forward for the Polish industrial sector:

1. The shares of fossil fuel required to deliver energy remain very high, with hard coal and lignite at 46% and crude oil at 26%. The combustion of these fossil fuels contributes 63% for coal and 26% for oil, of territorial CO_2 emissions in Poland. Reducing this reliance on fossil fuels in the energy mix will enable reductions in territorial CO_2 emissions.
2. For electricity generation, hard coal and lignite account for 74% of the energy inputs and result in high energy losses (58%). Nearly half of all territorial CO_2 emissions result from the production electricity and heat, mostly from the combustion of solid fossil fuels. The transition to low-carbon electricity, will significantly reduce territorial CO_2 emissions.
3. Material use per capita in Poland is approximately 20% higher than in Germany, 25% higher than in all EU-28 countries and more than 50% higher than in the UK.
    - Poland is the third largest producer of cement in Europe, after Germany and Italy.
    - Poland is fifth largest producer of steel, after Germany, Italy, France and Spain
    - Poland is sixth largest producer of plastic, after Germany, Italy, France, Spain and UK

Improving resource efficiency in production, by reducing wastes and lowering the energy and material intensity of industrial processes, will lead to overall reduction s in energy and material use for Poland.

Actions to pursue

This report analysed the flows of material and energy separately. The authors propose that a logical next step is to extend the analysis to consider energy and material flows in the same units, using exergy (a measure of the maximum work that can be extracted from a thermodynamic system). Using exergy would allow a direct comparison between the useful outputs of industry and all the required inputs (which represent the resources required to produce goods). This would enable the evaluation of the resource efficiency of industry in Poland. The focus on energy and materials, and the interactions between them, might contribute to identify opportunities for reducing resource use that would not be identified otherwise. Good resource management enables: waste avoidance, wise use of scarce resources, cost reduction, responsiveness to future regulation, and perhaps most importantly, reduction in industrial energy-related CO_2 emissions [10].

This report does not include waste production and waste management. Using method included in this report, detailed analysis of waste frow (production, import, export, processing) in Poland could be included in further work, as this could lead to proposing interventions to close the Circular Economy gap in Poland.

Another possible extension to this work is to assess the greenhouse gas (GHG) emissions in the relevant industrial activities to identify the biggest areas of improvement. The GHG intensity of material production can vary significantly so extending the current analysis to consider GHG emissions (from Whole Life Carbon perspective) would provide a deeper understanding of the environmental impact of industry in Poland.

Material / Energy / Emissions

- Due to climate emergency, efforts should be made to reduce the use of fossil fuels as quickly as possible, especially the combustion of solid fossil fuels such as coal and lignite.
- Switching to renewable energy sources should be accelerated.
- Electrification of industrial production should be accelerated, especially for Manufacture basic metals, Manufacture of chemicals and chemical products, manufacture of coke and refined petroleum products and manufacture of non-metallic minerals.
- Transport electrification should be accelerated.
- Heat recovery, especially from energy and heat intensive industries should be explored.
- Efforts should be made to reduce the impact of the production of non-metallic minerals such as Portland cement.

Scope and structure of available data

The main sources of data for this analysis are “Materials management in 2019” [8], “Statistical Yearbook of Industry 2020” [9] and the “Energy statistics in 2018 and 2019” [5].

The following suggestions aim to improve the analysis by altering the scope and structure of the material use data:

- The interactions between the reported NACE activities are not captured in the statistics. For example, some material produced by “Manufacture of basic metals” might also be used in “Manufacture of fabricated metal products, except machinery and equipment” but the data does not report this in detail. Calcification is required for some of the sector labelling and activities. For example, the meaning of “use” is not clearly defined, and could mean either the input of material to a process, or the output from that process.
- Some sectors could be described as producers of material, but the data implies that they are consumers, for example: (a) the “Manufacture of paper and paper products” consumes wood and reclaimed paper to produce “Paper and board”; (b) the “Manufacture of basic metals” consumes metal ores and scrap to produce “Steel” and other metals ; (c) “Construction” is the main consumer of cement but only a small fraction of the total cement use is allocated to “Construction” in the data; (d)The data could be structured in a way that tracks in the inputs and outputs of industrial activities instead of just measuring “use”.
- There are materials which commonly (in most countries) have significant mass flows that are missing from the statistics, for example: metal ores; sand, rocks and aggregates.
- There are small mass imbalances across some processes, where imports plus inputs to a process do not match exports plus outputs. Mapping the flows of materials between processes helps identify these imbalances, allowing correction.

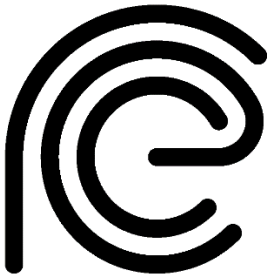
Data reporting

The following suggestions for methodological improvements could facilitate similar analyses in the future:

- The data are reported in formats that are not machine readable. This increases the time required to transform the data into a format that can be used.
- The material types should be reported in accordance with a classification system, such as The Combined Nomenclature (CN). Using a classification system for materials would help to guarantee that the chosen categories and mutually exclusive and collectively exhaustive and would facilitate the comparison with similar analyses of other countries.
- The data could be reported with more consistency:
    - In the material use tables, for some materials, the reported totals do not equal to the sum of all the sub-categories. This should be avoided;
    - The results should be reported in a way that strictly conforms to the NACE classification system;
    - The data is reported with an extra category called “Other consumption”. This should be avoided, and the values allocated to “Other consumption” should be allocated to existing NACE codes.
    - In some cases, the titles of NACE categories are altered, for example “Agriculture, forestry and fishing” is changed to “Agriculture, forestry, hunting and fishing - crop and animal”. This should be avoided.

REFERENCES

1. *Material flow accounts. ENV_AC_MFA*. 2021: Eurostat.
2. *Water abstracted by sector of use. TEN00006* 2021: Eurostat.
3. *Generation of waste by waste category, hazardousness and NACE Rev. 2 activity, ENV_WASGEN*. 2021: Eurostat.
4. Eurostat. *Simplified energy balances [nrg_bal_s]*. 2020 [cited 2020 April 19]; Available from: https://bit.ly/3fMNLS9.
5. *Energy statistics in 2018 and 2019 - Statistical analyses (Gospodarka paliwowo-energetyczna w latach 2018 i 2019 - Analizy statystyczne)*. 2020, GUS.
6. *Greenhouse gas emissions by source sector (source: EEA) - ENV_AIR_GGE* 2021: Eurostat.
7. Schmidt, M., *The Sankey Diagram in Energy and Material Flow Management.* Journal of Industrial Ecology, 2008. **12**(1): p. 82-94.
8. *Materials management in 2019 - Statistical analyses (Gospodarka materiałowa w 2019 r. - Analizy statystyczne)*. 2020, GUS.
9. *Statistical Yearbook of Industry – Poland (Rocznik Statystyczny Przemysłu)*. 2020: GUS.
10. Cullen, J.M., et al., *Wizualizacja efektywnego wykorzystania zasobów dla energochłonnych gałęzi przemysłu w Polsce [Visualising resource efficiency energy-intensive industry in Poland]*. 2018, University of Cambridge: Cambridge.



Resource Efficiency Collective is a research initiative at Cambridge University. Together, we seek answers to a challenging question: how can we deliver future energy and material services, while at the same time reducing resource use and environmental impact?

At the heart of the Resource Efficiency Collective lies a stock-standard research group, with the normal mix of PhD students, research associates and staff. But by calling ourselves a Collective we hope to be more inclusive, to blur the boundaries a little, and to invite our many friends and colleagues to participate. Please feel free to join in!

For more information, please visit www.refficiency.org

APPENDIX 1 – NACE SECTIONS AND DIVISIONS

SEKCJI I DZIAŁÓW PKD W 2019 R.	*NACE SECTIONS AND DIVISIONS IN 2019*
WYSZCZEGÓLNIENIE	SPECIFICATION
Rolnictwo, leśnictwo, łowiectwo i rybactwo - uprawy rolne, chów i hodowla zwierząt, łowiectwo	***Agriculture, forestry, hunting and fishing - crop and animal production, hunting***
Górnictwo i wydobywanie	***Mining and quarrying***
wydobywanie węgla kamiennego i brunatnego (lignitu)	*mining of coal and lignite*
górnictwo ropy naftowej i gazu ziemnego	*extraction of crude petroleum and natural gas*
górnictwo rud metali	*mining of metal ores*
pozostałe górnictwo i wydobywanie	*other mining and quarrying*
działalność usługowa wspomagajaca górnictwo i wydobywanie	*mining support service activities*
Przetwórstwo przemysłowe	***Manufacturing***
produkcja artykułów spożywczych	*manufacture of food products*
produkcja napojów	*manufacture of beverages*
produkcja wyrobów tytoniowych	*manufacture of tobacco products*
produkcja wyrobów tekstylnych	*manufacture of textiles*
produkcja odzieży	*manufacture of wearing apparel*
produkcja skór i wyrobów skórzanych	*manufacture of leather and related products*
produkcja wyrobów z drewna, korka, słomy i wikliny	*manufacture of products of wood, cork, straw and wicker*
produkcja papieru i wyrobów z papieru	*manufacture of paper and paper products*
poligrafia i reprodukcja zapisanych nośników informacji	*printing and reproduction of recorded media*
produkcja koksu i produktów rafinacji ropy naftowej	*manufacture of coke and refined petroleum products*
produkcja chemikaliów i wyrobów chemicznych	*manufacture of chemicals and chemical products*
produkcja wyrobów farmaceutycznych	*manufacture of pharmaceutical products*
produkcja wyrobów gumowych i z tworzyw sztucznych	*manufacture of rubber and plastic products*
produkcja wyrobów z pozostałych mineralnych surowców niemetalicznych	*manufacture of other non-metallic mineral products*
produkcja metali	*manufacture of basic metals*
produkcja wyrobów z metali	*manufacture of metal products*
produkcja komputerów, wyrobów elektronicznych i optycznych	*manufacture of computers, electronic and optical products*
produkcja urządzeń elektrycznych	*manufacture of electrical equipment*
produkcja maszyn i urządzeń	*manufacture of machinery and equipment n.e.c.*
produkcja pojazdów samochodowych, przyczep i naczep	*manufacture of motor vehicles, trailers and semi-trailers*
produkcja pozostałego sprzętu transportowego	*manufacture of other transport equipment*
produkcja mebli	*manufacture of furniture*
pozostała produkcja wyrobów	*manufacturing n.e.c.*
naprawa, konserwacja i instalowanie maszyn i urządzeń	*repair and installation of machinery and equipments*
Wytwarzanie i zaopatrywanie w energię elektryczną, gaz, parę wodną i gorącą wodę	***Electricity, gas, steam and air conditioning supply***
Dostawa wody; gospodarowanie ściekami i odpadami; rekultywacja	***Water supply; sewerage, waste management and remediation activities***
w tym pobór, uzdatnianie i dostarczanie wody	*of which water collection, treatment and supply*
gospodarka odpadami; odzysk surowców	*waste collection, treatment and disposal activities materials recovery*
Budownictwo	***Construction***
Transport i gospodarka magazynowa	***Transportation and storage***
Informacja i komunikacja - działalność wydawnicza i telekomunikacja	***Information and communication - publishing activities and telecommunications***
w tym działalność wydawnicza	*of which publishing activities*
Pozostałe zużycie	***Other consumption***

APPENDIX 2 – MATERIALS IN DCU

MATERIAŁY W ZUŻYCIU KRAJOWYM
DOMESTIC USE IN USE

	WYSZCZEGÓLNIENIE	*SPECIFICATION*
1	Wełna	*Wool*
2	Siarka	*Sulphur*
3	Płyty pilśniowe z drewna lub materiałów drewnopochodnych	*Fibreboards of wood or ligneous materials*
4	Płyty wiórowe i podobne płyty z drewna lub materiałów drewnopochodnych	*Particle boards and similar boards of woodor ligneous materials*
5	Masa celulozowa drzewna	*Wood pulp*
6	Papier i tektura	*Paper and paperboard*
7	Wodorotlenek sodu	*Sodium hydroxide*
8	Kwas siarkowy z oleum	*Sulphuric acid with oleum*
9	Polimery etylenu	*Polymers of ethylene*
10	Polipropylen i kopolimery etylenowo -propylenowe	*Polypropylene and ethylene-propylene copolymers*
11	Polichlorek winylu i kopolimery winylowe	*Polyvinyl chloride and vinyl copolymers*
12	Polimery styrenu	*Polymers of styrene*
13	Kauczuk syntetyczny	*Synthetic rubber*
14	Włókna chemiczne	*Chemical fibres*
15	Szkło typu "float"	*Sheets of float glass*
16	Cement portlandzki, glinowy, żużlowy i podobne rodzaje cementu hydraulicznego	*Portland cement, aluminous cement, slag cement and similar hydraulic cements*
17	Wapno	*Lime*
18	Papa	*Building paper*
19	Wyroby walcowane na gorąco (bez pół-wyrobów)	*Hot rolled products (excluding semi-finished products)*
20	Blachy stalowe walcowane na zimno	*Cold rolled steel sheets*
21	Blachy i taśmy pokrywane cynkiem	*Zinc coated sheets and strips*
22	Rury stalowe	*Steel tubes*
23	Aluminium nieobrobione plastycznie, niestopowe	*Unwrought, non-alloy aluminium*
24	Ołów rafinowany nieobrobiony plastycznie	*Refined lead, not plastically deformed*
25	Cynk technicznie czysty, niestopowy	*Unwrought non-alloy zinc, technically pure*
26	Cyna niestopowa	*Unalloyed tin*
27	Miedź rafinowana nieobrobiona plastycznie, niestopowa	*Unwrought, unalloyed refined copper*
28	Woda	*Water*

APPENDIX 3 – MATERIALS – CONVERSION FACTORS

WYBRANE MATERIAŁY WEDŁUG SEKCJI PKD W 2019 R.	*CONSUMPTION OF SELECTED MATERIALS BY NACE SECTIONS IN 2019*	Conversion factors	
Wełna w t	*Wool in t*	N/A	
Siarka w t	*Sulphur in t*	N/A	
Skóry bydlęce lub zwierząt jednokopytnych, odwłoszone, wyprawione po garbowaniu w m^2	*Leather, of bovine or enquine animals, without hair, prepared after tanning in m^2*	6.4	kg/m2
Skóry świńskie odwłoszone, pergaminowane lub wyprawione po garbowaniu w m^2	*Pig leather, without hair, parchment-dressed or prepared after tanning in m^2*	6	kg/m2
Tarcica ogółem w dam^3	*Total sawnwood in dam^3*	549	kg/m3
w tym tarcica iglasta w dam^3	*of which coniferous sawnwood in dam^3*	549	kg/m3
Płyty pilśniowe z drewna lub materiałów drewnopochodnych w tys. m^2	*Fibreboards of wood or ligneous materials in thous. m^2*	8.3	kg/m2
w tym płyty pilśniowe twarde w tys. m^2	*of which hard fibreboards in thous. m^2*	8.3	kg/m2
Płyty wiórowe i podobne płyty z drewna lub materiałów drewnopochodnych w m^3	*Particle boards and similar boards of wood or ligneous materials in m3*	657.9	kg/m3
Masa celulozowa drzewna w t	*Wood pulp in t*	N/A	
Papier i tektura w t	*Paper and paperboard in t*	N/A	
Węglan sodu w t	*Disodium carbonate in t*	N/A	
Wodorotlenek sodu w t	*Sodium hydroxide in t*	N/A	
Kwas siarkowy z oleum w t	*Sulphuric acid with oleum in t*	N/A	
Tworzywa sztuczne ogółem w t	*Total plastics in t*	N/A	
polimery etylenu w t	*polymers of ethylene in t*	N/A	
polipropylen i kopolimery etylenowo-propylenowe w t	*polypropylene and ethylene-propylene copolymers in t*	N/A	
polichlorek winylu i kopolimery winylowe w t	*polyvinyl chloride and vinyl copolymers in t*	N/A	
polimery styrenu w t	*polymers of styrene in t*	N/A	
Kauczuk syntetyczny w t	*Synthetic rubber in t*	N/A	
w tym lateks w t	*of which latex in t*	N/A	
Włókna chemiczne w t	*Chemical fibres in t*	N/A	
w tym włókna syntetyczne w t	*of which synthetic filament yarn in t*	N/A	
w tym włókna poliestrowe cięte w t	*of which cut polyester fibre in t*	N/A	
Szkło typu ''float'' w tys. m^2	*Sheets of float glass in thous. m^2*	12.5	kg/m2
Cement portlandzki, glinowy, żużlowy i podobne rodzaje cementu hydraulicznego w tys. t	*Portland cement, aluminous cement, slag cement and similar hydraulic cements in thous. t*	N/A	
Wapno w t	*Lime in t*	N/A	
Papa w tys. m^2	*Building paper in thous. m^2*	4.0	kg/m2
Wyroby walcowane na gorąco (bez półwyrobów) w t	*Hot rolled products (excluding semi-finished products) in t*	N/A	
w tym: blachy w t	*of which: sheets in t*	N/A	
taśmy (bednarka) w t	*strips in t*	N/A	
walcówka w t	*wire rod in t*	N/A	
pręty (bez walcówki) w t	*bars (excluding wire rod) in t*	N/A	
szyny w t	*rails in t*	N/A	
Blachy stalowe walcowane na zimno w t	*Cold rolled steel sheets in t*	N/A	
Blachy i taśmy ocynowane w t	*Tin-plated sheets and strips in t*	N/A	
Blachy i taśmy pokrywane cynkiem w t	*Zinc coated sheets and strips in t*	N/A	
Taśma walcowana na zimno w t	*Cold rolled strip in t*	N/A	
Pręty i profile ciągnione lub obrobione na zimno w t	*Cold-drawn and cold-treated bars and sections in t*	N/A	
Drut ze stali (ciągniony) w t	*Steel wire (drawn) in t*	N/A	
Rury stalowe w t	*Steel tubes in t*	N/A	
Rury stalowe w km	*Steel tubes in km*	N/A	
Srebro w t	*Silver in t*	N/A	
Aluminium nieobrobione plastycznie, niestopowe w t	*Unwrought, non-alloy aluminium in t*	N/A	
Płyty, blachy i taśmy z aluminium i stopów aluminium o grubości większej niż 0,2 mm w t	*Boards, sheets and strips of aluminium and aluminium alloy over 0,2 mm thick in t*	N/A	
Wyroby wyciskane i ciągnione z aluminium i stopów aluminium w t	*Extruded and drawn products of aluminium and aluminium alloy in t*	N/A	
Ołów rafinowany nieobrobiony plastycznie w t	*Refined lead, not plastically deformed in t*	N/A	
Cynk technicznie czysty, niestopowy w t	*Unwrought non-alloy zinc, technically pure in t*	N/A	
Cyna niestopowa w t	*Unalloyed tin in t*	N/A	
Miedź rafinowana nieobrobiona plastycznie, niestopowa w t	*Unwrought unalloyed refined copper in t*	N/A	
Przewody gołe w t	*Conductors not electrically insulated in t*	N/A	
Drut nawojowy izolowany w t	*Winding wire electrically insulated in t*	N/A	
Woda	*Water*	N/A	

APPENDIX 4 – MATERIAL CLASSIFICATION

WYBRANE MATERIAŁY WEDŁUG SEKCJI PKD W 2019 R.	*CONSUMPTION OF SELECTED MATERIALS BY NACE SECTIONS IN 2019*	*Classification*
Wełna w t	*Wool in t*	Biomass
Siarka w t	*Sulphur in t*	Other
Skóry bydlęce lub zwierząt jednokopytnych, odwłoszone, wyprawione po garbowaniu w m^2	*Leather, of bovine or enquine animals, without hair, prepared after tanning in m^2*	Biomass
Skóry świńskie odwłoszone, pergaminowane lub wyprawione po garbowaniu w m^2	*Pig leather, without hair, parchment-dressed or prepared after tanning in m^2*	Biomass
Tarcica ogółem w dam^3	*Total sawnwood in dam^3*	Biomass
w tym tarcica iglasta w dam^3	*of which coniferous sawnwood in dam^3*	Biomass
Płyty pilśniowe z drewna lub materiałów drewnopochodnych w tys. m^2	*Fibreboards of wood or ligneous materials in thous. m^2*	Biomass
w tym płyty pilśniowe twarde w tys. m^2	*of which hard fibreboards in thous. m^2*	Biomass
Płyty wiórowe i podobne płyty z drewna lub materiałów drewnopochodnych w m^3	*Particle boards and similar boards of wood or ligneous materials in m3*	Biomass
Masa celulozowa drzewna w t	*Wood pulp in t*	Biomass
Papier i tektura w t	*Paper and paperboard in t*	Biomass
Węglan sodu w t	*Disodium carbonate in t*	Other
Wodorotlenek sodu w t	*Sodium hydroxide in t*	Other
Kwas siarkowy z oleum w t	*Sulphuric acid with oleum in t*	Other
Tworzywa sztuczne ogółem w t	*Total plastics in t*	Other
polimery etylenu w t	*polymers of ethylene in t*	Other
polipropylen i kopolimery etylenowo-propylenowe w t	*polypropylene and ethylene-propylene copolymers in t*	Other
polichlorek winylu i kopolimery winylowe w t	*polyvinyl chloride and vinyl copolymers in t*	Other
polimery styrenu w t	*polymers of styrene in t*	Other
Kauczuk syntetyczny w t	*Synthetic rubber in t*	Other
w tym lateks w t	*of which latex in t*	Other
Włókna chemiczne w t	*Chemical fibres in t*	Other
w tym włókna syntetyczne w t	*of which synthetic filament yarn in t*	Other
w tym włókna poliestrowe cięte w t	*of which cut polyester fibre in t*	Other
Szkło typu ''float'' w tys. m^2	*Sheets of float glass in thous. m^2*	Non-metallic minerals
Cement portlandzki, glinowy, żużlowy i podobne rodzaje cementu hydraulicznego w tys. t	*Portland cement, aluminous cement, slag cement and similar hydraulic cements in thous. t*	Non-metallic minerals
Wapno w t	*Lime in t*	Non-metallic minerals
Papa w tys. m^2	*Building paper in thous. m^2*	Other
Wyroby walcowane na gorąco (bez półwyrobów) w t	*Hot rolled products (excluding semi-finished products) in t*	Metal
w tym: blachy w t	*of which: sheets in t*	Metal
taśmy (bednarka) w t	*strips in t*	Metal
walcówka w t	*wire rod in t*	Metal
pręty (bez walcówki) w t	*bars (excluding wire rod) in t*	Metal
szyny w t	*rails in t*	Metal
Blachy stalowe walcowane na zimno w t	*Cold rolled steel sheets in t*	Metal
Blachy i taśmy ocynowane w t	*Tin-plated sheets and strips in t*	Metal
Blachy i taśmy pokrywane cynkiem w t	*Zinc coated sheets and strips in t*	Metal
Taśma walcowana na zimno w t	*Cold rolled strip in t*	Metal
Pręty i profile ciągnione lub obrobione na zimno w t	*Cold-drawn and cold-treated bars and sections in t*	Metal
Drut ze stali (ciągniony) w t	*Steel wire (drawn) in t*	Metal
Rury stalowe w t	*Steel tubes in t*	Metal
Rury stalowe w km	*Steel tubes in km*	Metal
Srebro w t	*Silver in t*	Metal
Aluminium nieobrobione plastycznie, niestopowe w t	*Unwrought, non-alloy aluminium in t*	Metal
Płyty, blachy i taśmy z aluminium i stopów aluminium o grubości większej niż 0,2 mm w t	*Boards, sheets and strips of aluminium and aluminium alloy over 0,2 mm thick in t*	Metal
Wyroby wyciskane i ciągnione z aluminium i stopów aluminium w t	*Extruded and drawn products of aluminium and aluminium alloy in t*	Metal
Ołów rafinowany nieobrobiony plastycznie w t	*Refined lead, not plastically deformed in t*	Metal
Cynk technicznie czysty, niestopowy w t	*Unwrought non-alloy zinc, technically pure in t*	Metal
Cyna niestopowa w t	*Unalloyed tin in t*	Metal
Miedź rafinowana nieobrobiona plastycznie, niestopowa w t	*Unwrought unalloyed refined copper in t*	Metal
Przewody gołe w t	*Conductors not electrically insulated in t*	Metal
Drut nawojowy izolowany w t	*Winding wire electrically insulated in t*	Metal
Woda	*Water*	Water

APPENDIX 5 – CLASSIFICATION OF ENERGY SOURCE

Energy source (original)	Energy source (grouped)
Anthracite	Solid fossil fuels
Coking coal	Solid fossil fuels
Other bituminous coal	Solid fossil fuels
Sub-bituminous coal	Solid fossil fuels
Lignite	Solid fossil fuels
Patent fuel	Solid fossil fuels
Coke oven coke	Solid fossil fuels
Gas coke	Solid fossil fuels
Coal tar	Solid fossil fuels
Brown coal briquettes	Solid fossil fuels
Hard coal briquettes	Solid fossil fuels
Lignite briquettes (BKB)	Solid fossil fuels
Coke and semi-coke	Solid fossil fuels
Steam coal	Solid fossil fuels
Oil shale and oil sands	Solid fossil fuels
Gas works gas	Manufactured gases
Coke oven gas	Manufactured gases
Blast furnace gas	Manufactured gases
Other recovered gases	Manufactured gases
Crude oil	Oil and petroleum products
Natural gas liquids	Oil and petroleum products
Refinery feedstocks	Oil and petroleum products
Additives and oxygenates (excluding biofuel portion)	Oil and petroleum products
Other hydrocarbons	Oil and petroleum products
Refinery gas	Oil and petroleum products
Ethane	Oil and petroleum products
Liquefied petroleum gases	Oil and petroleum products
Motor gasoline (excluding biofuel portion)	Oil and petroleum products
Aviation gasoline	Oil and petroleum products
Gasoline-type jet fuel	Oil and petroleum products
Kerosene-type jet fuel (excluding biofuel portion)	Oil and petroleum products
Other kerosene	Oil and petroleum products
Naphtha	Oil and petroleum products
Gas oil and diesel oil (excluding biofuel portion)	Oil and petroleum products
Fuel oil	Oil and petroleum products
White spirit and special boiling point industrial spirits	Oil and petroleum products
Lubricants	Oil and petroleum products
Bitumen	Oil and petroleum products
Petroleum coke	Oil and petroleum products
Paraffin waxes	Oil and petroleum products
Other oil products	Oil and petroleum products
Feedstocks	Oil and petroleum products
Natural gas	Natural gas
High-methane natural gas	Natural gas
Nitrified natural gas	Natural gas
Solid biomass and animal products	Solid biomass and animal products
Peat	Solid biomass and animal products
Peat products	Solid biomass and animal products
Fuel wood	Solid biomass and animal products
Peat and wood	Solid biomass and animal products
Solid waste fuels	Biofuels and waste
Primary solid biofuels	Biofuels and waste
Charcoal	Biofuels and waste

Biogases	Biofuels and waste
Renewable municipal waste	Biofuels and waste
Pure biogasoline	Biofuels and waste
Blended biogasoline	Biofuels and waste
Pure biodiesels	Biofuels and waste
Blended biodiesels	Biofuels and waste
Pure bio jet kerosene	Biofuels and waste
Blended bio jet kerosene	Biofuels and waste
Other liquid biofuels	Biofuels and waste
Liquid fuels from biomass	Biofuels and waste
Industrial waste (non-renewable)	Biofuels and waste
Non-renewable municipal waste	Biofuels and waste
Municipal wastes	Biofuels and waste
Liquefied petroleum gas (LPG)	Oil and petroleum products
Motor gasoline	Oil and petroleum products
Jet fuel	Oil and petroleum products
Automotive diesel oil	Oil and petroleum products
Other diesel oil	Oil and petroleum products
Light fuel oil	Oil and petroleum products
Heavy fuel oil	Oil and petroleum products
Hydro	Renewables
Tide, wave, ocean	Renewables
Wind	Renewables
Solar photovoltaic	Renewables
Solar thermal	Renewables
Geothermal	Renewables
Ambient heat (heat pumps)	Renewables
Hydro and wind energy	Renewables
Geothermal energy	Renewables
Nuclear heat	Renewables
Non-energy products	Non-energy products
Other energy sources	Other
Heat	Heat
Electricity	Electricity
Heat losses	Heat losses
Electricity losses	Electricity losses

APPENDIX 6 – HEAT CARRIERS MIX AND COEFFICIENTS

PALIWO (2019)	*INPUT (2019)*	Share	Coefficient	Unit	Notes
Węgiel kamienny energetyczny	*Steam coal*	74.1%	21.87	TJ/kt	
Węgiel brunatny	*Lignite*	1.3%	8.18	TJ/t	
Węgiel kamienny koksowy	*Coking coal*	0.0%	-	-	
Gaz ziemny wysokometanowy	*High-methane natural gas*	6.7%	34.79 0.716	TJ/Mm^3 kg/m^3	
Gaz ziemny zaazotowany	*Nitrified natural gas*	1.3%	23.45 0.716	TJ/Mm^3 kg/m^3	
Koks i półkoks	*Coke and semi-coke*	0.0%	-	-	
Gaz ciekły	*Liquefied petroleum gas (LPG)*	0.0%	-	-	
Gaz koksowniczy	*Coke oven gas*	2.0%	17.01 0.45 0.0378	TJ/Mm^3 kg/m^3 TJ/t	
Olej opałowy lekki	*Light fuel oil*	0.2%	43.11	TJ/t	
Olej opałowy ciężki (z gudronem)	*Heavy fuel oil (with gudron)*	0.1%	-	-	
Siarka	*Sulphur*	0.0%	-	-	
Drewno opałowe	*Fuel wood*	4.4%	9.50 748	TJ/Mm^3 kg/m^3	
Paliwa odpadowe stałe	*Solid waste fuels*	1.8%	8.18	TJ/t	assumed as lignite
Odpady przemysłowe stałe i ciekłe	*Solid and liquid industrial wastes*	0.0%	-	TJ/t	
Biogaz	*Biogas*	0.4%	14.50 0.45	TJ/t kg/m^3	coefficient from IPPT PAN
Odpady komunalne	*Municipal wastes*	0.0%	-	-	
Brykiety z węgla brunatnego	*Lignite briquettes (BKB)*	0.0%	-	-	
Gaz wielkopiecowy	*Blast furnace gas*	2.4%	3.30 1.169	TJ/Mm^3 kg/m^3	
Paliwa odpadowe stałe roślinne i zwierzęce	*Solid waste fuels*	1.8%	8.18	TJ/t	assumed as lignite
Paliwa odpadowe gazowe	*Gaseous waste fuels*	0.2%	14.50	TJ/t	assumed as biogas
	SUM	96.7%			

APPENDIX 7 – ELECTRICITY CARRIER MIX AND COEFFICIENTS

PALIWO (2019)	INPUT (2019)	Share	Coefficient	Unit
Węgiel kamienny energetyczny	Steam coal	45.0%	21.87	TJ/kt
Węgiel brunatny	Lignite	29.0%	8.18	TJ/t
Gaz ziemny wysokometanowy	High-methane natural gas	9.0%	34.79 0.716	TJ/Mm^3 kg/m^3
Pompy ciepła	Heat pump	0.0%	-	-
Biomasa i biogaz	Biomass and biogas	4.0%	-	-
Woda	Water	1.0%	-	-
Wiatr	Wind	9.0%	-	-
Fotowoltanika	Photovoltanic	0.0%	-	-
Inne	Other fuels	3.0%	-	-
	SUM	100.0%		

To include the energy sources used to produce heat and electricity in the material diagrams of energy sources, the following steps are followed:

1. Calculate the share of energy output by fuel and type of electricity or heat generation
2. Calculate the share of energy losses by fuel and type of electricity or heat generation
3. Multiply the shares of energy in steps 1 and 2 by the direct energy consumption of each sector to obtain the shares of energy by sector
4. Multiply the shares of energy by sector by the conversion factors in kt/TJ to obtain mass units
5. Draw the Sankey showing the energy sources on the left hand side (including those that lead to electricity and heat), the energy sources already as electricity and heat, where appropriate, and finally, the direct energy consumption for each sector on the right hand side.

APPENDIX 8 – RESULTS

All results are prepared in excel files. Access to data on request.