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THE ENVIRONMENTAL RELEVANCE OF ENERGY – A LIFE CYCLE PERSPECTIVE

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Purpose: The purpose of this article is to present a potential environmental impact in a life cycle of electricity generated from different sources (coal, natural gas, wind and water).
Design/methodology/approach: The environmental life cycle assessment methodology was used. The functional unit was defined as 1 kWh of electricity delivered to the final consumer. The following stages were analyzed: acquisition and processing of energy carriers (cradle), energy generation, transmission and distribution.
Findings: The results showed that the potential impact for electricity from coal is approx. 2.5 greater than the impact of gas power, about 11 times greater than the result for wind power (onshore) and about 14 times greater than the impact of hydropower (run-of-river). In the case of coal-based power, main sources of this impact to be found in the operations of power plants and mines. In the case of natural gas energy, the cradle (acquisition and transmission of natural gas) proved to be the largest source, followed by power plant generation. The lowest impacts were obtained for wind and water energy. In their case, due to the low impact of cradle and generation, the transmission and distribution of energy in the power grid becomes particularly important.
Originality/value: The value of the paper is a presentation of the results divided into particular life cycle stages of electricity. Although many papers on the electricity's environmental impact have been published, demonstrating this impact on a stage-by-stage basis is rather rare.
Keywords: Climate change, energy, impact, life cycle management, stages.
Category of the paper: Research paper.

1. Introduction

Covering energy demand is an important part of the life cycle of many products (Sartori, Hestnes, 2007; Ulkir, 2023; Lewandowska, 2024). The high importance of energy is due not only to economic (cost) considerations, but also to environmental consequences. One of the most comprehensive methods for assessing the potential environmental impact of products is the Environmental Life Cycle Assessment (LCA) (PN-EN ISO 14040, 2009).

LCA is a tool of environmental management systems (PN-EN ISO 14040, 2009) and a crucial element of ecodesign and a life cycle management (LCM) (Lindhal, Ekermann, 2013). The specificity of this method is that it takes into account a life cycle perspective, which includes also energy. If one were to define a function as the generation and delivery of energy, then in the context of LCA analysis one would have to consider the processes from the extraction/acquisition of the energy carrier (cradle) to the delivery of the generated energy to the final consumer (end of life). Thus, we are talking about the entire energy life cycle from cradle to grave. The beginning of the life cycle (cradle) is associated with the extraction/acquisition of raw materials, e.g. coal ore, natural gas, water, wind kinetic energy, or solar radiation energy. The operation of mines is not only the exploitation of the deposit, but also the consumption of energy for process needs, the combustion of fuels in vehicles, the emission of various compounds into the air, water and soil. Finally, it is also the use of equipment and buildings. The situation is similar at the energy generation stage. In fossil fuel-fired power plants, in addition to greenhouse gases (GHG), many other pollutants are emitted, such as particulate matter and acidifying pollutants. Waste is generated, water is consumed for cooling and infrastructure is used. The same applies to the transmission and distribution network. All these activities make up the energy life cycle and include a variety of environmental aspects. The purpose of this article is to answer the following research questions:

- What is the potential environmental impact of electricity generated from different carriers?
- Is climate change a significant environmental issue in the context of the total impact?
- What share of the total impact are greenhouse gases directly emitted in the generation stage?

2. Life cycle perspective in the context of energy

With regard to energy, the life cycle concept is presented in Figure 1. It depicts the situation when some entities generate and transmit energy, and others purchase and use it for their own needs (final consumers).

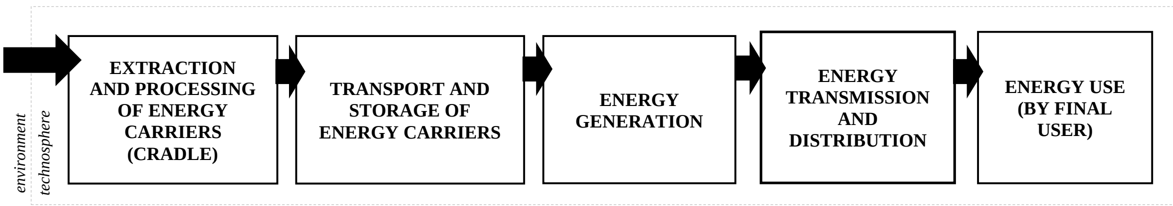

Figure 1. Exemplary stages in the energy life cycle.

Calculation of environmental impacts in the energy life cycle is made easier through the use of special databases (Takano et al., 2014; ecoinvent, 2024) and software ((Ormazabal et al.; 2014; Herrmann, Moltesen, 2015). These databases contain information on the inputs (consumption of materials and energy) and outputs (emissions to air, water and soil, and generation of waste and wastewater) necessary for the processes. This makes it possible to model complex systems called product systems. These systems reflect the material and energy flows in products life cycle. Figure 1 indicates the general stages of the energy life cycle, but in reality each of these stages involves the execution of other processes and, consequently, many material and energy flows (Table 1). Some of these flows constitute so-called elementary flows. They concern raw materials taken directly from the environment that have not been subjected to prior human processing, or releases of substances into the environment that will not be further processed. The rest of the flows in the product system are exchanges with the technosphere and include inputs and outputs that have been or will be subject to further processing in the technosphere. Table 1 presents a general concept of data collection for LCA analyses using the energy life cycle as an example. Within each stage, some of the inputs are elementary flows (e.g., taking coal ore from a deposit, taking water from groundwater, occupying or transforming land), as are some of the outputs (e.g., air emissions of metals, hydrocarbons, dust, greenhouse gases, emissions of nutrients to water). The remaining inputs and outputs, on the other hand, are exchanges with the technosphere. Examples of inputs from the technosphere include consumption of polyethylene granulate, glass, steel sheet, electricity, natural gas, district heat. Examples of outputs to the technosphere could be the generation of solid waste intended to further treatment, the generation of wastewater going to a treatment plant, etc. Each input from the technosphere and output to the technosphere is associated with "human processing", which consists of the life cycles of many successive products. These cycles have their inputs and outputs, resulting in systems consisting of up to several thousands of unit processes. Such a system of processes connected by material and energy flows is supposed to perform a specific function, which is referred to as a functional unit (FU). From the point of view of the final energy user, this functional unit may be the provision of a specific amount of electricity or heat.

Table 1.
Exemplary sorts of inputs and outputs in particular stages in the life cycle of energy

Extraction and processing of energy carriers		**Transport and storage of energy carriers**		**Energy generation (power/heat plant)**		**Energy transmission and distribution**		**Energy use (by final user)**	
Examples of input/ output	**Type of input/ output**	**Examples of input/ output**	**Type of input/ output**	**Examples of input/ output**	**Type of input/ output**	**Examples of input/ output**	**Type of input/ output**	**Examples of input/ output**	**Type of input/ output**
Extraction of raw materials Land use	Inputs from environment (elementary flows)	Extraction of raw materials Land use)	Inputs from environment (elementary flows)	Extraction of raw materials Land use (	Inputs from environment (elementary flows)	Extraction of raw materials Land use	Inputs from environment (elementary flows)	Extraction of raw materials Land use	Inputs from environment (elementary flows)
Consumption of materials, fuels, electricity, heat	Inputs from technosphere	Consumption of materials, fuels, electricity, heat	Inputs from technosphere	Consumption of materials, fuels, electricity, heat	Inputs from technosphere	Consumption of materials, fuels, electricity, heat	Inputs from technosphere	Consumption of materials, fuels, electricity, heat	Inputs from technosphere
Emissions GHGs to air	Outputs to environment (elementary flows)	Emissions GHGs to air	Outputs to environment (elementary flows)	Emissions GHGs to air	Outputs to environment (elementary flows)	Emissions GHGs to air	Outputs to environment (elementary flows)	Emissions GHGs to air	Outputs to environment (elementary flows)
Emissions remaining substances to air	Outputs to environment (elementary flows)	Emissions remaining substances to air	Outputs to environment (elementary flows)	Emissions remaining substances to air	Outputs to environment (elementary flows)	Emissions remaining substances to air	Outputs to environment (elementary flows)	Emissions remaining substances to air	Outputs to environment (elementary flows)
Emissions to water	Outputs to environment (elementary flows)	Emissions to water	Outputs to environment (elementary flows)	Emissions to water	Outputs to environment (elementary flows)	Emissions to water	Outputs to environment (elementary flows)	Emissions to water	Outputs to environment (elementary flows)
Emissions to soil	Outputs to environment (elementary flows)	Emissions to soil	Outputs to environment (elementary flows)	Emissions to soil	Outputs to environment (elementary flows)	Emissions to soil	Outputs to environment (elementary flows)	Emissions to soil	Outputs to environment (elementary flows)
Waste to treatment	Outputs to technophere	Waste to treatment	Outputs to technophere	Waste to treatment	Outputs to technophere	Waste to treatment	Outputs to technophere	Waste to treatment	Outputs to technophere
Wastewater to treatment	Outputs to technophere	Wastewater to treatment	Outputs to technophere	Wastewater to treatment	Outputs to technophere	Wastewater to treatment	Outputs to technophere	Wastewater to treatment	Outputs to technophere
Products and co-products	Outputs to technophere	Products and co-products	Outputs to technophere	Products and co-products	Outputs to technophere	Products and co-products	Outputs to technophere	Products and co-products	Outputs to technophere

Since GHG emissions from the energy life cycle are a key component of many organizations' carbon footprints, it is worth cross-referencing the information in Table 1 with guidelines for quantifying GHG emissions and removals at the organization level. According to ISO 14064 (PN-EN ISO 14064-1, 2019) and the GHG Protocol standard (GHG Protocol, 2004), GHG emissions can be classified into different ranges/categories, as presented in Table 2. For example, if a company covers a portion of its heat/current needs with energy generated on-site at its own facilities, GHG emissions from those facilities would be classified into range 1/category 1 emissions (the area highlighted in black in Table 1). If the same company would cover part of its needs with energy from the district heating/electricity grid purchased from an external supplier, then from the point of view of this company, the emissions associated with the generation of system energy should be shown in scope 2/category 2. In this case, these would be emissions from an installation located on the premises of the district heating/electricity plant (in Table 1 the area marked in gray). It is worth noting that in both standards, scope 2/category 2 includes emissions, but only from the energy generation process. This means that only GHG emissions should be included in scope 2/category 2, which from the point of view of the energy supplier (power plant, heating plant, etc.) will be direct emissions, while for the final consumer they will be indirect emissions.

Table 2.
Scopes of GHGs emissions in accordance with PN-EN ISO 14064 and GHG Protocol

ISO 14064 (PN-EN ISO 14064-1, 2019)		**GHG Protocol** (GHG Protocol, 2004)	
Category 1	Direct GHG emissions and removals occur from GHG sources or sinks inside organizational boundaries and that are owned or controlled by organization. These sources can be stationary These sources can be stationary, such as heaters, electricity generators, and industrial processes, or mobile, such as vehicles.	Scope 1	Direct GHG emissions occur from sources that are owned or controlled by the company, for example, emissions from combustion in owned or controlled boilers, furnaces, vehicles, etc.; emissions from chemical production in owned or controlled process equipment. Direct CO2 emissions from the combustion of biomass shall not be included in scope 1 but reported separately.
Category 2	The category 2 includes only emissions due to the fuel combustion associated with the production of final energy and utilities like electricity, heat, steam, cooling and compressed air. In excludes all upstream emissions (from cradle to power plant gate) and emissions associated with transport and distribution losses.	Scope 2	Scope 2 accounts for GHG emissions from the generation of purchased electricity consumed by the company. Purchased electricity is defined as electricity that is purchased or otherwise brought into the organizational boundary of the company. Scope 2 emissions physically occur at the facility where electricity is generated.
Category 3	The category 3 includes the GHG emissions occur from sources located outside organizational boundaries. These sources are mobile (mostly due to fuel combusted in transport equipment). If relevant, the category 3 may also include emissions associated with refrigeration gas leaks, construction of transport equipment and upstream emissions from the life cycle od fuel.	Scope 3	Scope 3 emissions are a consequence of the activities of the company, but occur from sources not owned or controlled by the company. Some examples of scope 3 activities are extraction and production of purchased materials; transportation of purchased fuels; and use of sold products and services.
Category 4	Indirect GHG emissions from goods purchased by organization (including upstream emissions associated with electricity production that are not included in Category 2).		

GHG – Green House Gase; ISO – International Organization for Standardization.

3. Life cycle assessment – methodology and assumptions

In order to answer the research questions, an LCA analysis was carried out for *1 kWh of electricity delivered to the end user* (the functional unit, FU). The following life cycle stages were considered: (1) acquisition and processing of energy carriers (cradle), (2) generation of energy, (3) transmission and distribution of energy. The analysis considered and compared electricity from coal (cogeneration), natural gas (cogeneration, combined cycle plant, 400 MW of electric power), wind (onshore turbine, 1-3MW) and water (run-of-river plant). Inventory data was modeled based on representative for Poland datasets from the ecoinvent database (ecoinvent, 2024). The data were used for the electricity from hard coal (heat and power co-generation); the electricity from water (run-of-river); the electricity from natural gas (heat and power co-generation, combined cycle power plant, 400MW electric) and the electricity from wind (1-3MW turbine, onshore). Additionally, based on data from ecoinvent datasets on electricity transmission and distribution, the following assumptions were made:

- for medium-voltage electricity, per functional unit: consumption of 1.13E-07 kg of sulfur hexafluoride (input from the technosphere), air emissions of 1.13E-07 kg of sulfur hexafluoride (output to the environment), and use of a transmission network of 1.86E-08 km (input from the technosphere);
- for low-voltage electricity, per functional unit: consumption of 6.27E-09 kg of sulfur hexafluoride (input from the technosphere), air emissions of 6.27E-09 kg of sulfur hexafluoride (output to the environment), and use of a distribution network of 8.74E-08 km (input from the technosphere).
- total energy losses due to transmission and distribution were assumed at 2.397%. This means that supplying 1 kWh of electricity to the final consumer involves generating 1.02397 kWh of electricity. Thus, the functional unit (FU) in this study is 1 kWh of electricity delivered to the final consumer, and the reference flow is 1.02397 kWh of electricity generated and injected into the grid;
- for energy generated from all the analyzed carriers assumed the same data in terms of transmission and distribution.

The LCA analysis was performed using SimaPro software and a method of the Environmental Footprint 3.1 (adapted) V1.00/EF 3.1 normalization and weighting set. The study considered the following environmental issues (called impact categories): *Climate change; Resource use, fossils; Eutrophication, freshwater; Acidification; Resource use, minerals and metals; Photochemical ozone formation; Eutrophication, terrestrial; Human toxicity, non-cancer; Particulate matter; Eutrophication, marine; Water use; Ecotoxicity, freshwater; Human toxicity, cancer; Land use; Ionizing radiation; Ozone layer depletion*.

4. Results and discussion

The potential environmental impact will be presented in the form of weighted results expressed in micropoints (µPt). In addition, characterized results for one impact category - *Climate change*, which is expressed in kg CO2eq, will also be presented. Both results should be interpreted in the same way - the higher the score, the greater the negative impact.

The total potential environmental impact associated with the implementation of the functional unit is 96.4 µPt for energy generated from coal, 39.6 µPt for energy generated from gas, 8.7 µPt for wind energy and 6.8 µPt for hydropower (Table 3, Figure 2). This means that the potential life-cycle environmental impact of electricity generated at the included facilities from the fossil fuels is many times higher than that of energy generated from water and wind. In the case of energy from coal, the impact is mainly in terms of: *Climate change*, *Resource use - fossils*, *Eutrophication of freshwater*, *Acidification*, *Resource use - minerals and metals*. For energy from gas, the following significant impact categories were identified: *Climate change*, *Resource use - fossils*, *Resource use - minerals and metals*. For wind and water energy, the dominant environmental issue is *Resource use - minerals and metals*, followed by *Climate Change*, *Eutrophication freshwater* and *Human toxicity (non-carcinogenic effects)*.

Table 3.
Potential environmental impact in the life cycle of electricity generated from different carriers - weighted results [μPt/FU] (the most relevant impact categories marked grey)

Impact category	**Unit**	**Electricity, hard coal, cogeneration**		**Electricity, natural gas, cogeneration**		**Electricity, wind, onshore**		**Electricity, hydro, run-of-river**	
Climate change	μPt	33.9	35%	17.0	43%	0.7	8%	0.4	6%
Resource use, fossils	μPt	17.7	18%	11.8	30%	0.4	4%	0.1	2%
Eutrophication, freshwater	μPt	11.9	12%	0.6	1%	0.5	6%	0.4	6%
Acidification	μPt	10.9	11%	0.9	2%	0.4	5%	0.3	5%
Resource use, minerals and metals	μPt	4.5	5%	4.5	11%	4.8	55%	4.2	63%
Photochemical ozone formation	μPt	4.3	5%	1.7	4%	0.2	2%	0.1	1%
Eutrophication, terrestrial	μPt	2.8	3%	0.5	1%	0.1	1%	0.1	1%
Human toxicity, non-cancer	μPt	2.7	3%	0.6	2%	0.6	7%	0.5	8%
Particulate matter	μPt	2.4	3%	0.6	2%	0.4	5%	0.3	4%
Eutrophication, marine	μPt	2.0	2%	0.3	1%	0.1	1%	0.0	0%
Water use	μPt	1.4	1%	0.6	2%	0.1	1%	0.0	1%
Ecotoxicity, freshwater	μPt	1.1	1%	0.3	1%	0.2	2%	0.2	2%
Human toxicity, cancer	μPt	0.4	0.4%	0.2	0.5%	0.2	2%	0.09	1%
Land use	μPt	0.2	0.2%	0.03	0.1%	0.04	1%	0.01	0.2%
Ionising radiation	μPt	0.1	0.1%	0.03	0.1%	0.01	0.2%	0.01	0.1%
Ozone depletion	μPt	0.00	0.00%	0.06	0.1%	0.00	0.0%	0.00	0.0%
Total	**μPt**	**96.4**	**100%**	**39.7**	**100%**	**8.7**	**100%**	**6.8**	**100%**

μPt – micropoint.

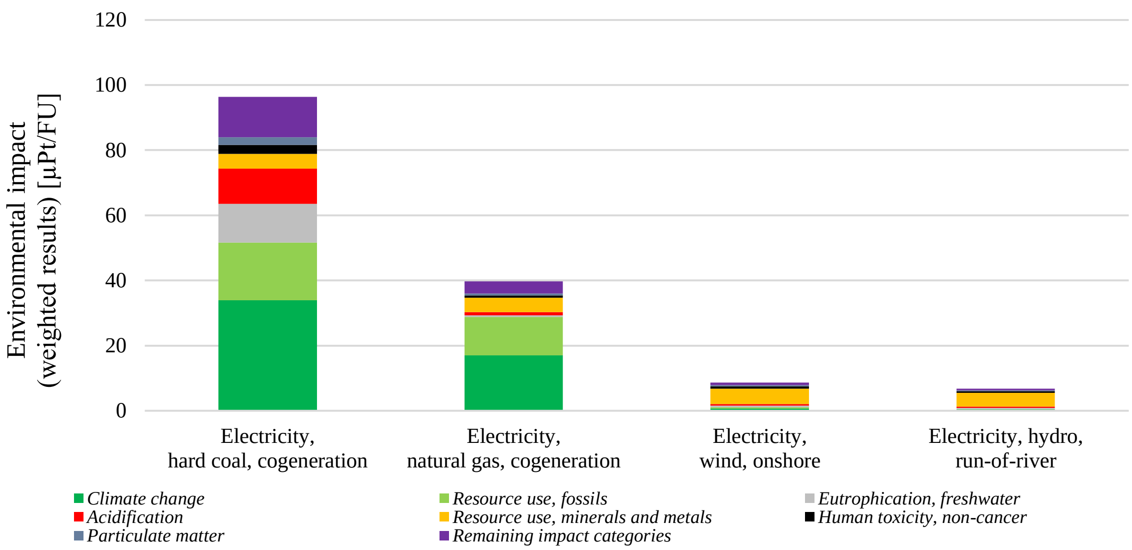

Figure 2. Potential environmental impact in the life cycle of electricity generated from different carriers - weighted results for different impact categories [μPt/FU].

Table 3 and Figure 2 present the environmental impacts by environmental issue (impact categories). Subsequently, the same impact will be attributed to the different stages of the energy life cycle. As shown in Table 4 and Figures 3-6, the distribution of environmental impacts between stages varies depending on the source of energy and how it is generated. In the case of coal-based energy (Figure 3), generation at the power plant plays the dominant role (generation = 47.8 μPt/FU = 50% of the total impact), with direct emissions from the generation stage responsible for most of the impact (generation-related emissions = 44.3 μPt/FU = 46% of the total impact). The second most important source of impact is the cradle (coal mine operations). This stage is responsible for 44% of the impact (42.2 μPt/FU). For coal-based energy, transmission and distribution play a secondary role (6.4 μPt/FU). As shown in Figure 3, coal mine operations are primarily impacts in terms of *Resource use, fossils*, *Eutrophication freshwater* and *Climate change*. In contrast, two categories dominate in Figure 3 for the energy generation stage: *Climate change* and *Acidification*. These impacts are primarily the result of direct emissions - fossil carbon dioxide, nitrogen oxides and sulfur dioxide.

Table 4.
Potential environmental impact in particular life cycle stages – as weighted results [μPt/FU] and as characterized results for Climate Change [kg CO2 eq/FU] (the most relevant life cycle stages marked grey)

Life cycle stage	Unit	Electricity, hard coal, cogeneration		Electricity, Natural gas, cogeneration		Electricity, wind, onshore		Electricity, hydro, run-of-river	
Weighted results for all impact categories (single score)									
Extraction and processing of energy carriers (cradle)	μPt	42.2	44%	20.0	50%	0.0	0%	670.1	-
Electricity generation	μPt	47.8	50%	13.3	33%	2.3	27%	-669.8	-
Where: direct emissions to air and water from the generation stage[1]	*μPt*	*44.3*	*46%*	*11.7*	*30%*	*0,0*	*0%*	*-670.1*	-
Electricity transmission and distribution	μPt	6.4	7%	6.4	16%	6.4	73%	6.4	-
Total	**μPt**	**96.4**	**100%**	**39.7**	**100%**	**8.7**	**100%**	**6.8**	**100%**
Characterized results for Climate Change									
Extraction and processing of energy carriers (cradle)	kg CO_2 eq	0.177	15%	0.175	29%	0.0	0%	0.0	0%
Electricity generation	kg CO_2 eq	1.029	85%	0.425	70%	0.017	65%	0.004	32%
Where: direct emissions to air from the generation stage[2]	*kg CO_2 eq*	*1.021*	*84%*	*0.424*	*70%*	*0.0*	*0%*	*0,0*	*0%*
Electricity transmission and distribution	kg CO_2 eq	0.009	1%	0.009	2%	0.009	35%	0.009	68%
Total	**kg CO_2 eq**	**1.2**	**100%**	**0.6**	**100%**	**0.03**	**100%**	**0.01**	**100%**

μPt – micropoint; CO_2 eq – equivalents of carbon dioxide.

[1] "Direct" from the power plant's perspective.
[2] "Direct" from the power plant's perspective.

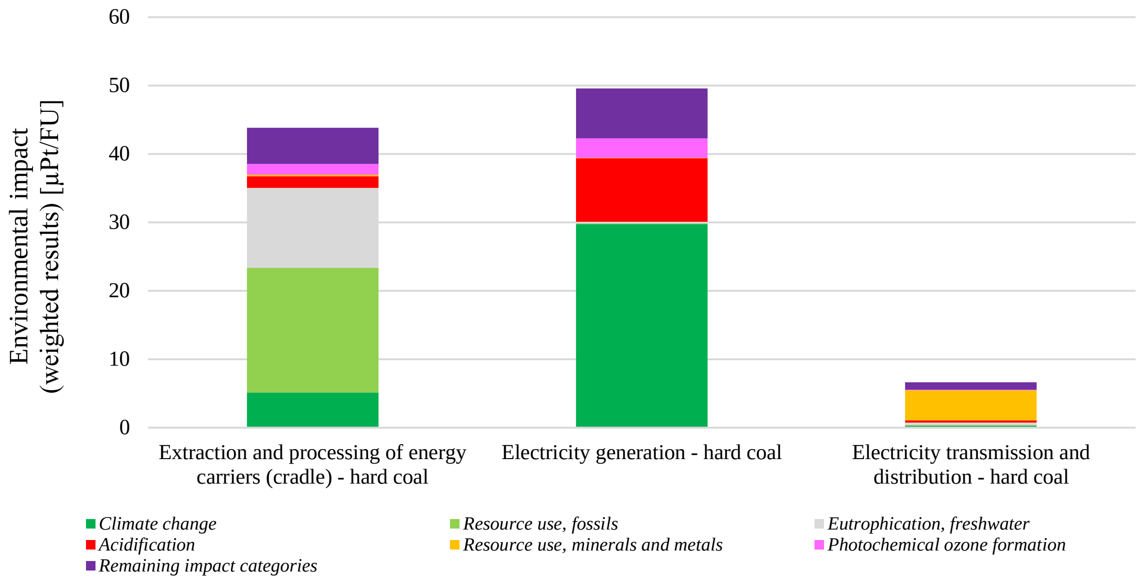

Figure 3. Potential environmental impact in particular stages of the life cycle of electricity generated from hard coal – weighted results [µPt/FU].

In the case of gas-generated energy (Figure 4), natural gas extraction and distribution (cradle) proved to be the most important source of potential impact. This stage is responsible for 50% of the impact in the life cycle (20.0 µPt/FU). As Figure 4 shows, the impact of cradle is primarily related to *Resource use, fossils* and *Climate change*. In second place is the generation of energy in a gas-fired power plant (13.3 µPt/FU). At this stage, direct emissions (11.7 µPt/FU) play a very important role, leading mainly to *Climate change* impacts as a result of fossil carbon dioxide emissions.

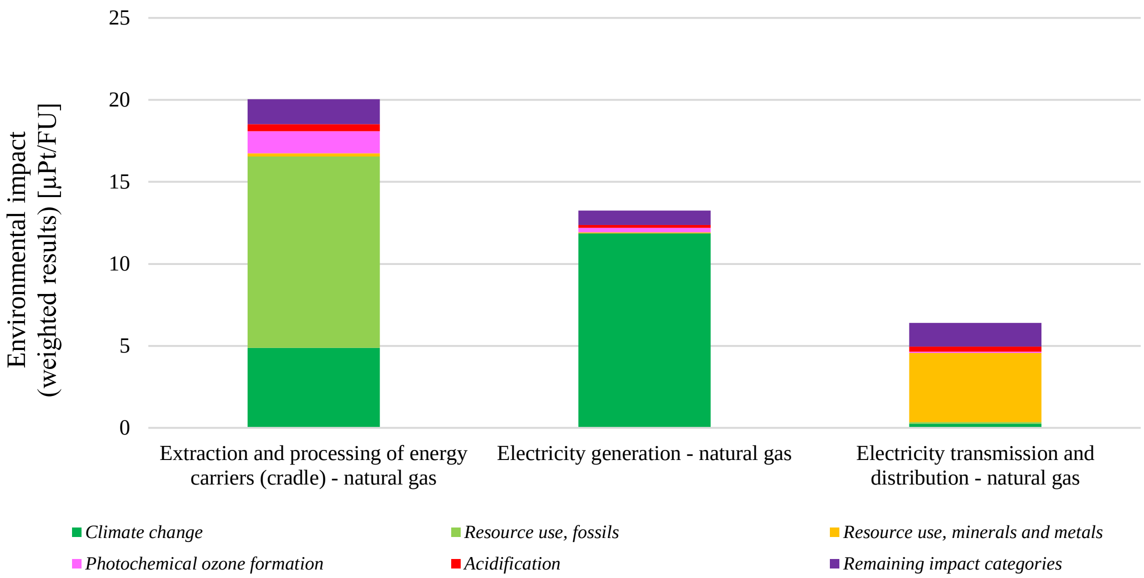

Figure 4. Potential environmental impact in particular stages of the life cycle of electricity generated from natural gas – weighted results [µPt/FU].

In the case of wind energy (Figure 5), the mere acquisition of the carrier (extraction of wind kinetic energy from the environment) does not involve a negative impact. The generation of energy in a wind power plant requires the generation and operation of infrastructure, hence the accrued impact, which is 2.3 µPt/FU. However, this is not the main source of impact in the life cycle of hydropower. This is because transmission and distribution were considered the most significant stage. Generation and use of grid infrastructure are associated with an impact of 6.4 µPt/FU, and this is the same for all scenarios compared. This impact is primarily due to the use of copper and the associated exploitation of copper deposits (mineral and metal resource consumption). The mining of copper ores involves the intake from the environment of not only copper itself, but also a number of associated elements including, for example, tellurium, gold, silver. This is the main reason for the accrued impact in terms of energy transmission and distribution. Of some importance is also the emission into the air of sulfur hexafluoride, which is a very potent greenhouse gas.

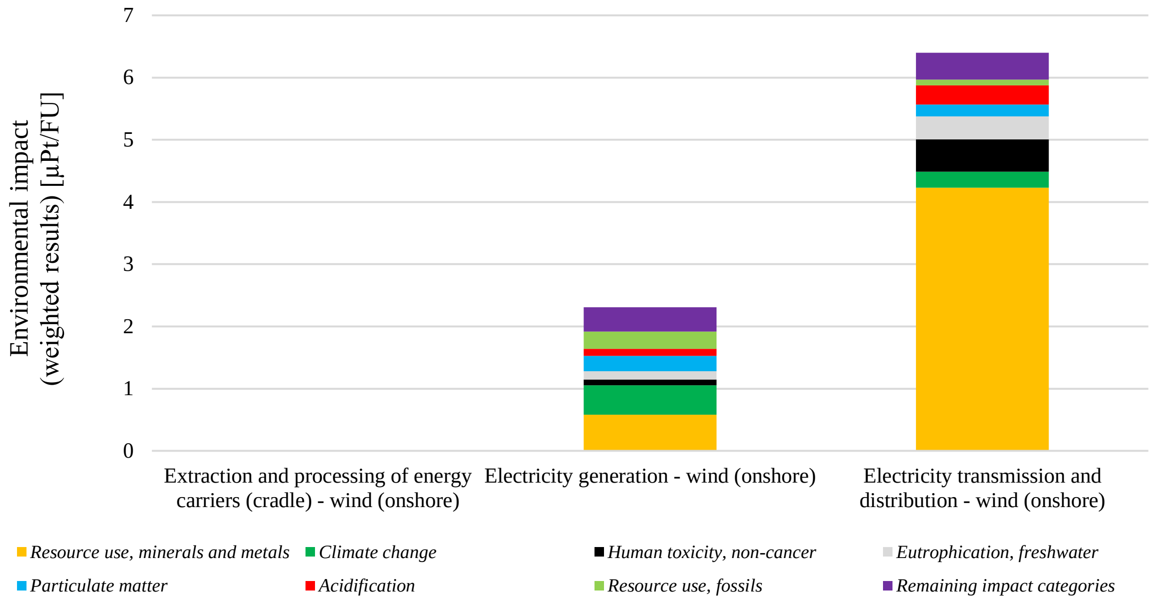

Figure 5. Potential environmental impact in particular stages of the life cycle of electricity generated from wind (onshore) – weighted results [µPt/FU].

The hydropower life cycle (Figure 6) generates a potential impact of 6.8 µPt, and this is the lowest of all the compared alternatives. In this case, the cradle is a very significant source of impact (670.1 µPt/FU), but it includes basically one category - *Water use*. The elementary flow, which is the extraction of water from the environment, is the reason for charging such an impact. At the generation stage, this water is given back to the environment, as illustrated by the negative result of the indicator (-670.1 µPt/FU). The impact of the hydropower plant infrastructure itself is of negligible significance. Once the impact for cradle and generation is balanced, the transmission and distribution of energy becomes important. As with wind power, the impact here too is 6.4 µPt/FU.

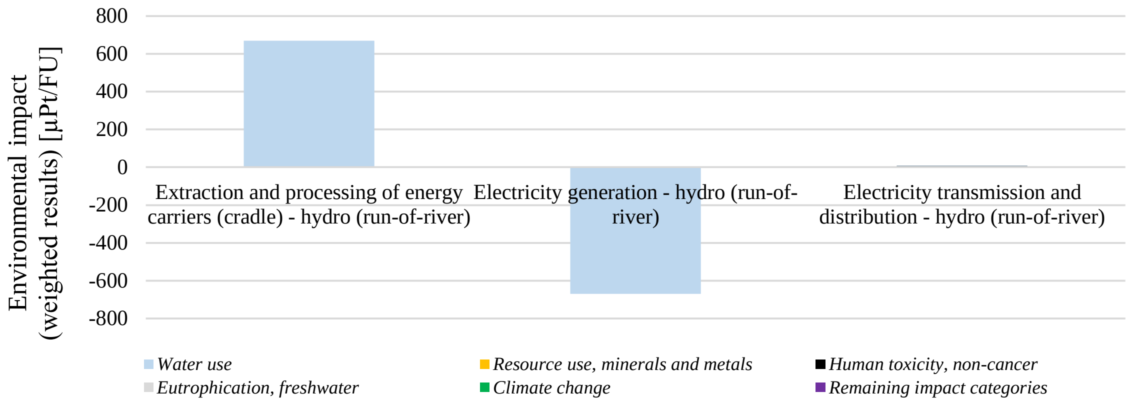

Figure 6. Potential environmental impact in particular stages of the life cycle of electricity generated from water (run-of-river) – weighted results [μPt/FU].

The results presented in the first part of Table 4 and Figures 3-6 refer to the cumulative impact, which takes into account more than a dozen environmental issues. The second part of Table 4 shows environmental impact related to one impact category only - *Climate change*. These are characterized results. They refer mainly to one type of environmental aspect - air emissions of greenhouse gases. When considering only this type of emissions, the importance of the energy generation stage increases significantly for fossil-fuel-based electricity. In turn, direct emissions at the power plant site, primarily fossil carbon dioxide emissions, play a key role in this stage. From the *Climate change* perspective, the generation stage also plays the most important role in the case of wind power. However, here the cause is not direct emissions, but emissions from the life cycle of the power plant infrastructure, consumables and transportation. For hydro-generated power, the main source of life-cycle greenhouse gas emissions is to be found in transmission and distribution, including primarily air emissions of sulfur hexafluoride.

5. Conclusions

Energy intensity is one of the key aspects in products' life cycle. This is because the energy life cycle can be a significant source of environmental impact. As the results of the conducted LCA study showed, the potential environmental impact during the life cycle of electricity generated from different carriers may be significantly different. In the presented study, the potential impact was determined per kWh of electricity delivered to the final consumer (taking into account losses in the transmission and distribution network). The results showed that the potential impact for electricity from coal is approx. 2.5 greater than the impact of gas power, about 11 times greater than the result for wind power and about 14 times greater than the impact of hydropower. These results refer to the assumptions made in the analysis (e.g., in terms of electricity generation technology and inventory data). Also worth noting is the different distribution of environmental impacts between the different stages of the life cycle. If one looks at the values of the cumulative weighted indicator, in the case of fossil fuel-based energy, the generation and cradle (acquisition of carriers) stages play a dominant role. In the case of hydropower and wind energy, due to the low impact of the first stages, transmission and distribution become much more important.

Since carbon footprint calculations have been gaining particular importance for many organizations, it is worth making some comment in the context of GHG emissions in the electricity life cycles analyzed. As the presented results showed, the carbon footprint in the entire life cycle of fossil fuel-based electricity is much higher than the result for the renewable one. From the perspective of electricity's final user, the direct GHG emissions from the electricity generation stage are classified to the scope 2 (the category 2). Because of potential relevance of these emissions in the life cycle of different products and organizations, they are listed separately in Table 4. The value obtained for the scope 2 is 1.021 kg CO2 eq/FU for power from coal and 0.424 kg CO2 eq/FU for power from gas. In both cases, the GHG emissions from the scope 2 are major drivers with the highest contribution in the entire life cycle. In terms of the scope 2, the renewable electricity is burden free. Also the impact resulted from emissions from the scope 3/category 4 is much lower for renewable power. The results may be valuable especially for organizations operating with high energy demand. Their decisions regarding the electricity supplier and the electricity origin may play a crucial role. If renewable electricity procured, the Guarantees of Origin (GOs) could be used to ensure the final consumer that a given quantity of electricity was produced from renewable sources.

List of abbreviations

FU – Functional Unit.
GHG – Green House Gase.
GOs – Guarantees of Origin.
ISO – International Organization for Standardization.
LCA – Life Cycle Assessment.
LCM – Life Cycle Management.

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