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Chapter 8

Eco-Efficiency Indicators in District Heating Companies

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District Heating Companies (DHC) in Poland and in Central European and Nordic countries play an important role in meeting the demand for heat of city dwellers. The energy crisis that is a consequence of the war in Ukraine caused a sharp increase in the prices of fossil fuels (coal and natural gas), which in turn translated into a significant increase in the prices of heat supplied by municipal heating systems. The increases in heat prices recorded in 2022 in Poland ranged from several dozen to several hundred percent. The highest increase in prices occurred in district heating systems supplied with heat from heating plants or combined heat and power plants (CHPs) fired by natural gas.

However, the observed dynamic increase in heat generation costs caused by the crisis in the fuel market was not fully compensated by the increase in heat prices, which led to the deterioration of the financial situation of DHCs. At the same time, the high increase in heat prices had a negative impact on its competitiveness in relation to alternative technical solutions using renewable energy sources (RES). So far, the main renewable energy source in the district heating sector has been the use of biomass. Nevertheless, a significant increase in fuel prices and, consequently, heat prices led to the profitability of using alternative solutions consisting in 'heat electrification', which are based on heat pumps powered by electricity from RES.

The existing market conditions should accelerate decision-making regarding the energy transformation of district heating systems in a direction consistent with the climate policy of the European Union. The energy transformation of district heating systems should be aimed at a complete departure from fossil fuels which is possible through:

- electrification of heat where electricity for heat pumps should come from RES (PV, wind, hydro and others),
- construction of low-temperature heating microgrids constituting the lower source of heat for water-to-water heat pumps installed in buildings (4^{th} and 5^{th} generation systems),
- use of waste heat,
- use of biomass and municipal waste as a supplementary fuels to heat generation.

Relatively low heat prices until the end of 2021 did not create sufficient motivation for this type of transformation. A radical change in the business environment of DHCs combined with additional funds from the EU can significantly accelerate decisions on energy transformation. In addition to financial resources, carrying it out requires appropriate information support for the decision-making process, which is in line with title and aim of this monograph. The scope and pace of transformation may also be the elements of a strategy to stand out in the district heating market. Informational support for the process of decision-making aimed at energy transformation can be provided by environmental accounting, which also embraces eco-efficiency indicators. The purpose of this chapter is to present the possibilities of using environmental accounting in DHCs, including the development of a methodology for calculating basic eco-efficiency indicators that can be used in this industry. These indicators should be used in integrated and ESG reports as an element of building a competitive advantage on the district heating market. That can be a part of performance measurement and management system in these companies that supports sustainable development.

8.1. The Essence of Environmental Accounting

The concept of environmental accounting appeared along with the need to pay more attention to the protection of the natural environment. Motivation to manage enterprises from the perspective of natural environment protection came primarily from the outside of companies. Most often, state or supra-regional institutions worked out legal regulations, standards and rules of conduct in the field of natural environment protection to which enterprises had to adapt their activities. Failure to comply with the adopted norms and standards in the field of natural environment protection is most often subject to the risk of high financial penalties or, in extreme cases, termination of the business. An important external factor forcing enterprises to comply with the standards in the field of natural environment protection was also the growing ecological awareness of societies. For these reasons maintaining high standards in the field of natural environment protection has become, for many companies, an element of the strategy to stand out on the market. From this point of view, the protection of the natural environment in the decision-making process has a positive impact on financial results.

Both the economic and the natural environment protection aspects in management decisions require adequate informational support. This became the basis for the concept of environmental accounting and environmental management accounting (EMA). The first institution that started promoting environmental management accounting in 1990 was the Environmental Protection Agency in the USA. Subsequently, the United Nations Division for Sustainable Development ([UN DSD] 2001) created a working group for the development of assumptions for environmental management accounting. Selected definitions of environmental accounting are presented in Table 8.1.

Several of the most important features of environmental accounting emerge from the above definitions. The tasks of the environmental accounting system are:

- identification and analysis of environmental costs,
- generating financial and non-financial information supporting decision-making aimed at the effective allocation of the natural resources that are at enterprises' disposal,
- support for carrying out analyses related to the flow of materials in the company and its costs, enabling the identification of their impact on the natural environment and financial results,
- extension of traditional financial accounting, cost accounting and management accounting to include aspects related to natural environment protection and sustainable development.

Environmental accounting is therefore intended to provide information supporting optimal decisions from the point of view of natural resource allocation used by the company to produce products and services. The optimal allocation of these resources is, in turn, to translate into reducing the negative impact of enterprises on the natural environment. Therefore, environmental accounting is an accounting subsystem that registers, processes and analyses information on the company's impact on the natural environment. Therefore, environmental accounting is a necessary accounting subsystem in those entities that implement a sustainable development strategy.

An important part of environmental accounting is the cost account providing information related to environmental costs. The general definition of cost accounting indicates that its purpose is to provide various users with multi-sectional economic information concerning the company's activity and its costs. This information is used by both internal and external users in relation to the boundaries of the enterprise structure (Nowak, Piechota, & Wierzbiński, 2004, p. 15). Cost accounting focused on environmental aspects additionally provides a range of information on costs that are directly or indirectly related to the impact of the company's activity on the natural environment.

Table 8.1. Definitions of (management) environmental accounting

Author	Definition
Barrow (1997), as cited in Beer & Friend (2006)	*Environmental management can be defined as the process of allocating natural resources so as to make optimum use of the environment in satisfying basic human needs, if possible, for an indefinite period and with minimal adverse effects to the environment.*
Steele & Powell (2002), as cited in Beer & Friend (2006)	They define *environmental accounting as the identification, allocation and analysis of material streams and their related money flows by using environmental accounting systems to provide insight into environmental impacts and associated financial effects*.
Graff, Reiskin & White Bidwell (1998), as cited in Burritt & Saka (2006)	*Environmental management accounting is the way that businesses account for the material use and environmental costs of their business. Materials accounting is a means of tracking material flows through a facility in order to characterize inputs and outputs for purposes of evaluating both resource efficiency and environmental improvement opportunities.* *Environmental cost accounting is how environmental costs are identified and allocated to the material flows or other physical aspects of a firm's operations*.
Bennett & James (1998), as cited in Burritt & Saka (2006)	EMA is *the generation, analysis and use of financial and non-financial information in order to optimise corporate environmental and economic performance and to achieve sustainable business*.
UN DSD (2001)	*Environmental management accounting* […] *represents a combined approach which provides for the transition of data from financial accounting and cost accounting to increase material efficiency, reduce environmental impact and risk and reduce costs of environmental protection*.
Jasch & Lavicka (2006)	*The concept of sustainable development requires an integrated assessment of the financial, social and environmental aspects. Sustainability management accounting is a tool that assists organisations in becoming more sustainable by highlighting costs, risks and benefits. It extends traditional financial and cost accounting to take account of sustainability impacts at the organisational level. As sustainability is based on a broad stakeholder approach, also the external effects of the organisation and its products must be considered*.
Jasch (2003)	*EMA, in its current approach, has been developed for company internal decision making and therefore focuses on tracing all real environmental and material efficiency loss expenditure for a given year. The focus is on improving a company's information system and decision basis. The focus is not on estimating external effects and 'soft' factors, such as image, credibility, and ethics, as from an accountant's perspective, they will sooner or later be reflected in the annual accounts but should not distort the cost basis of a previous year. For the calculation of investment projects and savings, however, these factors are considered.*

Source: own presentation.

An in-depth classification of environmental costs was developed as part of a project led by a working group established by the United Nations Division for Sustainable Development. This classification is presented in Figure 8.1.

Environmental media / Environmental cost/expenditure categories	Air / Climate	Wastewater	Waste	Soil / Groundwater	Noise / Vibration	Biodiversity / Landscape	Radiation	Other	Total
1. Waste and emission treatment									
2. Prevention and environmental management									
3. Material purchase value of non-product output									
4. Processing costs of non-product output									
∑ Environmental expenditure									
5. Environmental revenues									

Figure 8.1. Classification of environmental costs

Source: (UN DSD, 2001).

The following costs were specified in the environmental cost classification:

1. **Waste and emission treatment** which concern the construction and maintenance of flue gas purification installations, sewage treatment, and waste disposal, as well as incurring fees related to the use of the environmental resources and relevant insurance.

2. **Prevention and environmental management** include the costs of preventing the generation of pollution and waste and therefore relate mainly to the costs of acquisition, maintenance and operation of more environmentally friendly technologies as well as the costs of research into such technologies or employee training. The calculation of this cost category does not take into account savings that may result from the use of more environmentally friendly technologies.

3. **The material purchase value of non-product output** means the cost of material waste that has not been used in the production of final products.

4. **Processing costs of non-product output** relate to the costs of labour, depreciation and maintenance of the machines which were involved in the processing of materials that ultimately turned out to be waste and therefore were not productively utilized as a part of the final products.

The sum of the above cost categories corresponds to all environmental costs incurred by the company. These costs can be reduced by environmental revenues, i.e. by all financial benefits associated with proper environmental management, including, for example, revenues from the sale of by-products or revenues related to waste management.

Environmental costs in the above approach are calculated by two groups of specialists, that is by:

- **management accounting specialists**: they calculate individual categories of environmental costs, which have been indicated above and allocate them to individual cost centres within the production process,
- **technology specialists** who focus on physical measures related to the pollution generated, the water and energy balance of the technological process, the description of the process itself and its boundaries, as well as the allocation of environmental costs to individual utilities.

The classification of environmental costs presented above does not include external costs, i.e., costs incurred by societies in connection with the activities of enterprises (e.g., costs of treating diseases related to air pollution). External costs may be internalized, which means they are transferred to enterprises in the form of various types of taxes or environmental fees (e.g., costs of purchase and redemption of CO_2 emission allowances). If they are internalized, they are included in the first of the environmental costs listed above.

Calculation and classification of environmental costs allow for the generation of a range of information used to calculate eco-efficiency indicators. These indicators, in turn, are the basis for evaluating the effectiveness of enterprises in the field of natural environment protection as well as the progress in implementing the sustainable development strategy.

8.2. Eco-Efficiency Indicators in Sustainable Development

The idea of eco-efficiency dates back to the 70s of the last century, but its popularization took place mainly in the 90s of the last century. At that time, the World Business Council for Sustainable Development defined this concept and then launched an information campaign for a wider implementation of the idea of ecological efficiency management (Figge & Hahn, 2013). Eco-efficiency is defined as an instrument supporting decision-making aimed at sustainable development by focusing attention on both economic and environmental aspects. Therefore, eco-efficiency indicators make it possible to assess the performance of an enterprise as well as local governments or countries achieved in the area of sustainable development (Huppes & Ishikawa, 2009). In other words, eco-efficiency indicators illustrate how effectively scarce natural resources are used by enterprises (Figge & Hahn, 2013).

In general, efficiency is defined as the ratio of the achieved effects (products) of a specific process to the inputs incurred, which can be expressed in terms of quantity or value. The higher the effects achieved within a given process in relation to the resources used, the higher its effectiveness is. If the effects and resources in the above relation are expressed in terms of value, then the relation constructed in this way can be related to economic efficiency. Nevertheless, performance indicators can also be calculated on the basis of quantities expressed in physical units.

Ecological efficiency, in turn, is defined as the ratio of the effects obtained within a given process to its overall impact on the natural environment (Schaltegger & Sturm, 1992 as cited in Burrit & Saka, 2006]. Ecological efficiency can therefore be represented by the formula:

ecological efficiency = output/environmental impact added.

Environmental impact added is defined as the overall impact of a given process or phenomenon on the natural environment. There are two categories of ecological efficiency: ecological product efficiency and ecological functional efficiency. The first of the enumerated types of efficiency is measured on the scale of the entire product life cycle and concerns the ratio of the volume of production to the entire impact of the production process on the natural environment. The second of the mentioned categories of ecological efficiency refers to determining the impact of the implementation of a specific function (e.g., moving from point *A* to point *B*) on the natural environment. The mobility function can be implemented in various ways, i.e., by means of various means of transport, which in a different way affect the use of natural resources, including primary energy carriers. The most ecologically effective will be, for example, the method of transport with the lowest energy consumption or the lowest CO_2 emission per kilometre travelled.

In turn, the combination of the concept of economic and ecological efficiency translates into obtaining the eco-efficiency index, which is measured using the following formula:

eco-efficiency = monetary value added/environmental impact added.

The numerator of the presented formula includes economic or financial values expressed in money, characterizing the effects of a specific process or economic phenomenon. The impact on the natural environment is expressed in physical units and usually refers to the amount of resources used or pollutants emitted.

With the help of eco-efficiency indicators, it is possible to assess the economy of individual countries, economic sectors in individual countries, the activities of individual enterprises or individual processes that are carried out in them from the perspective of the efficiency of the use of natural resources or the impact on the natural environment. The conducted comparative analysis makes it possible to identify companies from a given industry or processes of a given type that are characterized by the highest level of eco-efficiency. The difference in the level of this efficiency between different entities or processes determines the gap that should be closed if the guiding principle of the company's activity is sustainable development. For this reason, the publication of eco-efficiency indicators in integrated or ESG reports may become an important stimulus to reduce the company's negative impact on the natural environment.

8.3. Eco-Efficiency Indicators in District Heating

Meeting the demand on the heat of city dwellers can be conducted in various ways using a number of technologies and business models. In most cities in Poland, the demand for heat is met by district heating systems, the typical value chain of which is shown in Figure 8.2.

Figure 8.2. Value chain of district heating systems

Source: own presentation.

The value chain of district heating systems consists of the extraction of fossil fuels and their transport, then heat generation in heating plants or CHPs, transmission and distribution of heat to end users by means of district heating networks and heat substations in buildings. Heat plants and CHPs use mainly fossil fuels to generate heat, that is coal and natural gas. Biomass is used to a much lesser extent. District heating systems have been operating within the presented value chain for 60–70 years and have a significant impact on the natural environment. This impact is not limited only to the emission of pollutants into the atmosphere during the combustion of fossil fuels, although this element of environmental impact is one of the most important. However, in the entire district heating value chain, there are many more factors that have a negative impact on the natural environment as well as on the scale of resources used, as shown in Figure 8.3.

The impact on the natural environment of the activities carried out in the individual links of the district heating value chain is related to the emission of pollutants into the atmosphere, the use or contamination of underground and surface waters as well as the occupation of land for a given activity or the permanent exclusion of its use for other purposes in connection with contamination or damage. Economic activities in the district heating value chain based on fossil fuels affect not only the state of the air through the emission of carbon dioxide and other pollutants but also the state of water resources and, above all, land use and soil degradation. With regard to the latter, mining damage caused during the extraction of fossil fuels and sinkholes but also areas excluded from other activities should be pointed out. Finally, large areas of land are occupied by heat plants, CHPs and transmission networks, including networks for the transmission of natural gas and heat. No other activity may be conducted in the vicinity of these facilities taking into account the protection zones. These areas are also excluded from natural use.

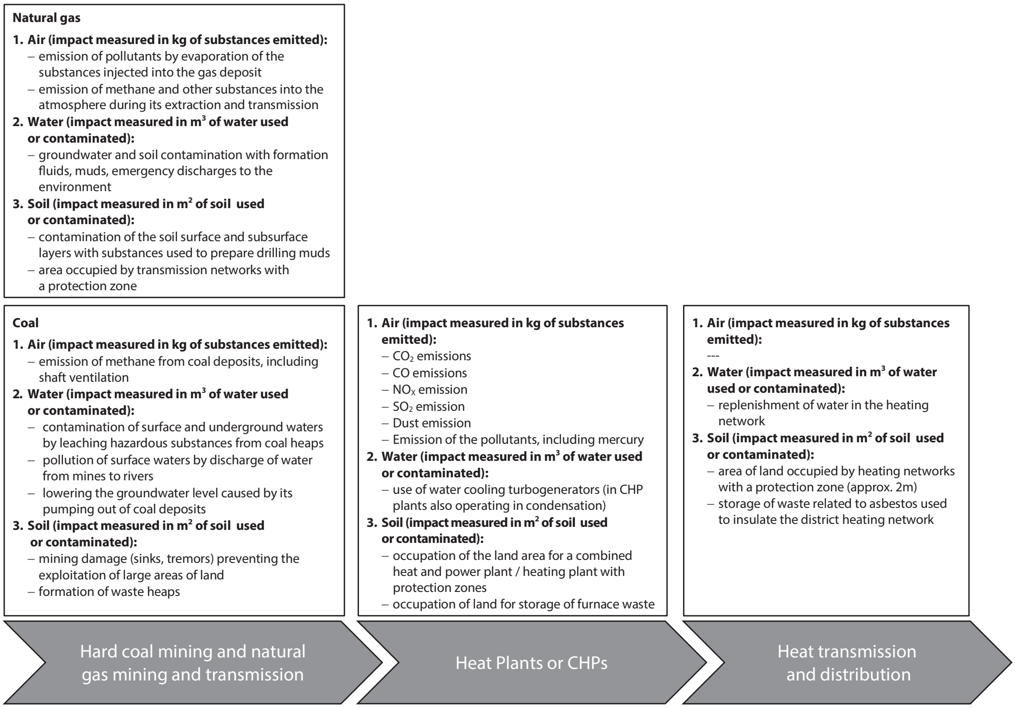

Figure 8.3. Direct impact on the natural environment of activities carried out in individual links of district heating value chain

Source: own presentation.

An important issue is the adoption of one unit of measurement of the impact of activities in a given link of the value chain on the natural environment which then enables the calculation of synthetic eco-efficiency indicators. Most often, the amount of pollutant emissions into the atmosphere is measured in kg, the use of groundwater or surface water in m^3 and the use of land for a given activity or its exclusion from use for other purposes in m^2 or ha. All the above data is most often collected and processed by departments responsible for environmental protection in enterprises and, in most cases, is reported to government agencies.

Figure 8.3 shows the direct impact of the activities carried out in individual links of the sectoral value chain of district heating on the condition of the natural environment. If the eco-efficiency indicators were calculated separately for individual links of the value chain on the basis of their direct impact on the natural environment, a misleading picture could be created as to the real impact of this method of heating buildings on the use of environmental resources. For example, direct emissions of pollutants into the atmosphere caused by heat transmission from heat plants or CHPs to final consumers are small or non-existent. Also, the use of water in the heat transmission is not significant. Therefore, the eco-efficiency indicators calculated for this link of the sectoral value chain on the basis of factors directly influencing the state of the natural environment could seem beneficial. Hence, sometimes many representatives of the district heating sector claim that this type of heating of buildings is one of the most ecological, even if fossil fuels are used to generate heat, primarily natural gas. Nevertheless, the eco-efficiency indicators calculated in this way create only an illusory impression that this type of heating does not significantly impact the natural environment.

Therefore, the eco-efficiency of district heating systems should be measured not only within individual links of the value chain but in an incremental way taking into account the environmental impact of activities carried out in earlier links as well. The correct way of calculating the eco-efficiency indicators for the district heating systems is shown in Figure 8.4.

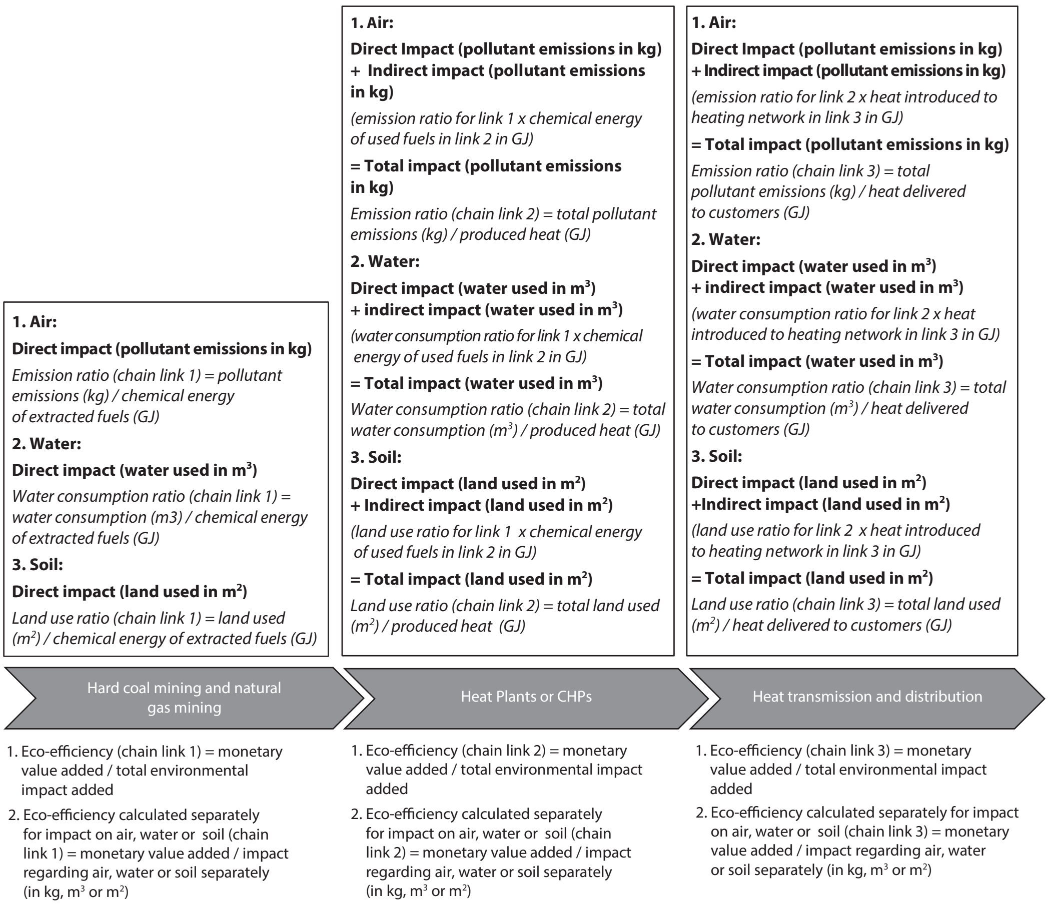

Figure 8.4. Calculation method of eco-efficiency indicators for district heating systems

Source: own presentation.

To calculate eco-efficiency indicators for district heating, it is necessary to obtain the following:

- non-financial information about the impact of activities in a given link of the sectoral value chain on the natural environment where this impact should be measured in three basic categories, i.e., in relation to air, water and soil (sometimes this impact is also defined in relation to biodiversity);
- financial data enabling the calculation of the added value generated in each link separately.

The total environmental impact of activities carried out in a given link of the sectoral value chain is the sum of the following:

- direct impact (direct emissions of pollutants into the atmosphere in a given link, direct use of water or soil);
- indirect impact being the product of the indicator showing the impact on the natural environment of the activity in the earlier link and the use of products of the activity of the earlier link.

By summing up the direct and indirect impact, the eco-efficiency indicators calculated for a given link take into account the impact on the natural environment of the activities carried out in the previous links. In this way, the impact is calculated incrementally.

Financial data should make it possible to calculate the added value generated in each link of the sectoral value chain separately. The added value should be understood as the sales revenue of the enterprise (enterprises) operating in a given link less the costs of material consumption and external services. Alternatively, value added can be calculated as the sum of income generated, interest paid, taxes and wage costs.

Eco-efficiency indicators can be calculated:

- separately for each type of pollution, water or soil use,
- in a synthetic way covering the total impact of the activity conducted in a given link on the natural environment.

In the latter case, it is necessary to express the total impact of activity in a given link of the value chain on the use of natural resources, which may be monetary units. For this reason, the total environmental impact of an activity can be calculated according to the following formula:

$$\text{Total environmental impact added} = \sum_{i=1}^{3} \text{impact}_i \times \text{rate}_i,$$

where:

impact_i – emission of pollutants into the atmosphere (in kg), use of water resources (in m^3) or land use (in m^2),

rate_i – rate for emission of pollutants into the atmosphere (in PLN/kg), use of water resources (in PLN/m^3) or use of land (in PLN/m^2).

The rates used in the above formula should correspond to the external costs associated with a given type of impact of the activity on the natural environment.

These rates are related to fees and taxes for pollutant emissions, water or land use and are most often calculated by government agencies. As stated earlier, external costs should be understood as costs that are not incurred directly by enterprises but are related to their activities and are covered by societies in the form of expenses for health care, liquidation of mining damage, restoration of biodiversity, etc. These costs can only be internalized by imposing appropriate taxes and environmental charges on companies.

Finally, the eco-efficiency ratio expressed as a monetary value ratio added to the total environmental impact added is an unnominated unit. The higher its value, the higher the level of eco-efficiency of the activity conducted in a given link of the sectoral value chain. The values of these indicators should be used to assess the eco-efficiency of district heating systems in relation to alternative methods of heating buildings, including individual heat sources with heat pumps.

8.4. Conclusions

District heating systems play a significant role in meeting the demand for heat of the inhabitants of Polish cities. The heat supplied to them is generated in CHPs or heat plants that are most often fired by hard coal, natural gas or, to a lesser extent, biomass, and then it is sent to heat substations in buildings *via* the heating network. In the minds of city dwellers, district heating systems are considered ecological, even if the heat is produced from hard coal because its production does not involve the so-called low emissions and heat sources are most often equipped with flue gas cleaning installations. This type of image of district heating systems is also created by entities from the industry.

Unfortunately, the actual impact of district heating systems on the natural environment is not positive, especially if we take into account the negative consequences of activities carried out in the earlier links of the sectoral value chain related to fuel extraction. One of the tools for assessing these negative consequences for the natural environment in connection with the efficiency of the resources used is eco-efficiency indicators. These indicators make it possible to relate the overall impact of activities carried out in the district heating sector on the natural environment to the scale of natural resources used, including air, water and soil. These indicators for a given link of the value chain should be calculated, taking into account the impact of activities carried out in earlier links on the use of natural resources. Only the incremental method of calculating these indicators guarantees to obtain a reliable picture of the impact of activities related to the generation and supply of heat on the natural environment and the scale of the resources used.

District heating systems in Poland face the necessity of transformation towards renewable energy sources. This transformation can take different directions, but it should also be assessed from the perspective of eco-efficiency indicators. In addition, comparative analyses of eco-efficiency indicators for activities related to heat generation before and after the transformation should be carried out, which would enable its deeper economic justification but also from the ecological perspective. Such analyses would also allow for greater social acceptance of the transformation of the district heating systems towards renewable energy sources. Nevertheless, conducting such analyses requires the publication by individual entities from the sectoral value chain of a number of information on the natural resources used, the impact of the conducted activity on the natural environment and the added value generated. At the moment, not all data and information necessary to calculate eco-efficiency indicators are publicly available, which should change in the future.

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