



# Application of the circular economy in the power sector of Małopolska Region – benefits and challenges

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**Abstract:** Circular economy (CE) is a new trend in balanced development, directed at limiting consumption of resources and minimising waste production. In consideration of the European Commission's (EC) postulates of the CE implementation, the article aims at verifying whether coal power plants in Małopolska Province are aware of the CE notion, ready to think and act in compliance with its rules, and to show how their present activities align with this new trend. The results of the study present the energy sector in the context of transformation from linear economy to circular economy and formation of the bases for further development as well as for intensification of activities related to the implementation of the CE.

**Keywords:** circular economy, coal power sector, Małopolska Province

**JEL codes:** O13, O44, Q49, Q56

<https://doi.org/10.25167/ees.2018.45.5>

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## 1. Introduction

Circular economy (CE) is defined as an idea in production and consumption of goods, presuming maintenance of value of materials and energy used in products within a complete value chain and for an optimal time, and thus an effective use of resources at all stages of a product's lifetime (European Commission 2015). It is a new dimension of a diversified progress which is to make it possible through centring of activities on an efficient use of secondary raw materials and minimising the use of resources, to realise growth in the economy which would not add to the impact exerted on the natural environment (Lieder, Rashi. 2016: 36-51). The notion of the CE, promoted by the European Commission (EC) since June 2014, is to lead to creating a sustainable, low carbon and resource-efficient as well as competitive economy (European Commission 2014). It is an approach of special importance to coal power plants, since they are responsible for much of the emission of greenhouse gases (ca. 350 m t of CO<sub>2</sub>eq) and solid wastes in the form of the so-called coal combustion by-products, amounting to ca. 20 m t (Kledyński, Szarek. 2016: 11-28), 7 m t of which (35%) is subject to storage (Szczygielski, Niewiadomski, 2017).

Due to the postulated implementation of the CE, manufacturing enterprises require comprehensive systemic changes, the implementation of which is connected with activities undertaken both by governments and enterprises as well as by consumers (Szyja. 2016:131-141). In the case of the coal power industry, transformation of its present manufacturing system toward the CE may significantly help enterprises of the industry decrease their environmental impact and increase their economic profits (Dong et al. 2017). Studies conducted at Chinese power distribution plants have shown that eco-design of products, taking into consideration proper design of the supply chain, use of power distribution plant waste and of waste heat have enormous potential for the power industry sector in the context of CE. One example of the CE solutions using a coal combustion plant is the industrial park in Kalundborg, Denmark (Kalundborg symbiosis). The power plant located within it draws water from Lake Tissø for cooling processes. At subsequent stages, the water is used by pharmaceutical enterprises. A refinery has been built in Kalundborg, supplying the power plant with fuel and waste, which are converted into thermal energy. The heat produced is subsequently used by the local greenhouses, fisheries and citizens. Power plant combustion waste (gypsum) is used for the manufacture of construction products (plasterboards) and the ashes are used by cement plants and as a road construction material. Enterprises cooperate on the basis of industrial symbiosis, allowing the most efficient utilisation of raw materials and wastes, which enables them to avoid interference in the natural environment caused by the use of natural raw materials. Efficient use of resources translates into lower CO<sub>2</sub> emission and improved air quality, potentially resulting in the investigated sector contributing to the

sustainable development of the region. Successful implementation of the CE is conditional upon development of tools for monitoring its progress, with particular consideration given to the fact that certain elements of the CE concept are already being implemented by enterprises as part of pro-environmental activities conducted within the sustainable development trend (Mapa drogowa. 2016).

The goal of this study was to verify the attitude to the concept of CE in the coal power industry. Therefore, a survey has been carried out among employees of energy companies in Małopolska Province, which made it possible to identify the knowledge, attitudes and activities of the plants, and to specify the possibility of transforming the energy industry in the direction of the CE. The study was conducted as part of the project “The Circular Economy Conception Towards Eco-innovations and Sustainability of Regions”, designed to create a homogenous system of measurement and evaluation of the CE at the level of regions.

## 2. Energy sector in Małopolska Region

In Małopolska Province, the key role in the structure of power and heat energy production is played by hard coal (Lelek, Koneczna, 2012: 115-125), used in power companies, among which one may find:

- the biggest producers of power and heat energy in Małopolska, with the power exceeding 100MW;
- industry producers directing energy carriers to the network not exceeding 100 MW;
- City Heating Companies (MPECs) represented by those not exceeding the power of 100 MW.

In 2016, the sum of the installed electrical capacity in all the plants located in Małopolska Region amounted to 1,961 MW, generating in total 6,374 GWh, which constituted 3.8% share in the general production in the country (Table 1).

**Table 1.** Production of electrical power in 2016

Specification	Małopolska	Poland
Production of electrical power in total [GWh]	6 374	166 634
Installed electrical capacity in total [MW]	1 961	41 249
Consumption of electrical power in total [GWh]	13 007	159 138

Source: own elaboration based on [Central Statistical Office data] (GUS, 2015)

Installed heating capacity in Małopolska Region amounted to 3,949 MW (Table 2), constituting 5.8% of the power in Poland. Almost 70% of the heat energy in the Province was produced through cogeneration.

**Table 2.** Production of heat energy together with coal consumption in 2016

Specification	Małopolska	Poland
Total heat production [TJ]	22 295	383 783
Including cogeneration	15 518	234 681
Installed heating energy in total [MW]	3 949	54 260
Hard coal consumption in the production of heat [t]	1 063 707	14 368 049

Source: own elaboration based on: (GUS, 2015) and (Energetyka, 2016)

Dust and gas pollution produced in especially harmful plants in Małopolska Region, among others, in electricity distribution companies, constitute ca. 5% of the total 210.9 m t generated in Poland (Table 3). Emission of CO<sub>2</sub>, linked to the production of heat in Małopolska Region, corresponds to 23% of the total emission of this gas in the Province. At the same time, the quantity of dust generated by the heating sector constitutes 46% of the total emission of dust connected to fossil fuels combustion.

**Table 3.** Emission of air pollutants in 2016

Specification	Małopolska	Poland
<b>Emission of air pollutants from especially harmful plants [t]</b>		
Gases emission in total	10 059 451	210 849 432
Emission of CO <sub>2</sub>	9 977 646	209 420 973
Emission of SO <sub>2</sub>	12 633	260 089
Emission of NO <sub>x</sub>	14 989	239 548
Dust emission in total	2 067	38 598
Emission of dust from combustion of fuels	1 006	22 222

Specification	Małopolska	Poland
<b>Emission of pollutants connected with the production of heat [t]</b>		
Emission of CO <sub>2</sub>	2 323 081	46 282 833
Emission of SO <sub>2</sub>	4 447	113 324
Emission of NO <sub>x</sub>	3 023	62 625
Dust emission	466	20 394

Source: own elaboration based on (Bank Danych lokalnych GUS, 2015) and (Energetyka, 2016)

In the production of energy, power plants, heat and power plants and heating plants utilise ca. 57% of the coal consumed by the whole Province (Table 4).

**Table 4.** Consumption of hard coal in 2015

Specification	Małopolska	Poland
Coal consumption	[Mg]	[Mg]
Total	5 351 000	72 283 000
By power and heat and power plants	2 824 000	37 953 000
By commercial and non-commercial heating plants	233 000	3 309 000

Source: own elaboration based on [Central Statistical Office] (GUS, 2015)

### 3. Questionnaire survey of energy companies in Małopolska Region – the aim, principles, methodology

The study concerning the identification of knowledge, attitudes and activities, as well as the possibility of transforming the energy industry in the direction of the CE, was conducted with the use of questionnaires. They were addressed to 15 coal power plants located in Małopolska Province, which use hard coal as the basic fuel in the process of energy production, such as: Elektrownia Skawina (CEZ Polska sp. z o.o.), *Elektrownia Siersza* (Tauron Wytwarzanie S.A.), *Elektrociepłownia Kraków* (EDF Polska S.A.), *Elektrociepłownia Andrychów sp. z o.o.*, *Energomedia sp. z o.o.* (Grupa Kapitałowa Rafineria Trzebinia S.A.), *Synthos Dwory sp. z o.o.*, *Nadwiślańska Spółka Energetyczna sp. z o.o.* (with heating facilities in Brzeszcze and Libiąż), *TAMEH Polska Sp. z o.o.*, *MPEC sp. z o.o. Bochnia*, *MPEC sp. z o.o. Brzesko*, *MPEC sp. z o.o. Nowy Sącz*, *MPEC sp. z o.o. Nowy Targ*, *Elektrociepłownia Gorlice sp. z o.o.*, *Dalkia Chrzanów sp. z o.o.*, *MPEC S.A. Tarnów*.

The questionnaire comprised 17 questions, including:

- 9 questions making use of a 5-point Likert scale (in which 5 equalled to the statement: “I strongly agree”, and 1 – “I strongly disagree”).
- 6 multiple-choice questions,
- 2 open questions.

Print-outs of the questionnaires were sent to the companies in electronic and traditional paper form. They were addressed to the management boards of the companies and the request was to distribute them among employees for them to fill in, as well as among specialists from such departments as: environmental protection, investments, waste, development, quality assurance, production. The time of collecting the responses was six weeks. The questionnaires were anonymous and the results of the survey were presented collectively.

The article describes only the results concerning the perception of the CE by the managing staff and the specialists, and also attempts at evaluating the implementation of the CE in terms of benefits and challenges (barriers).

#### **4. Results of the study**

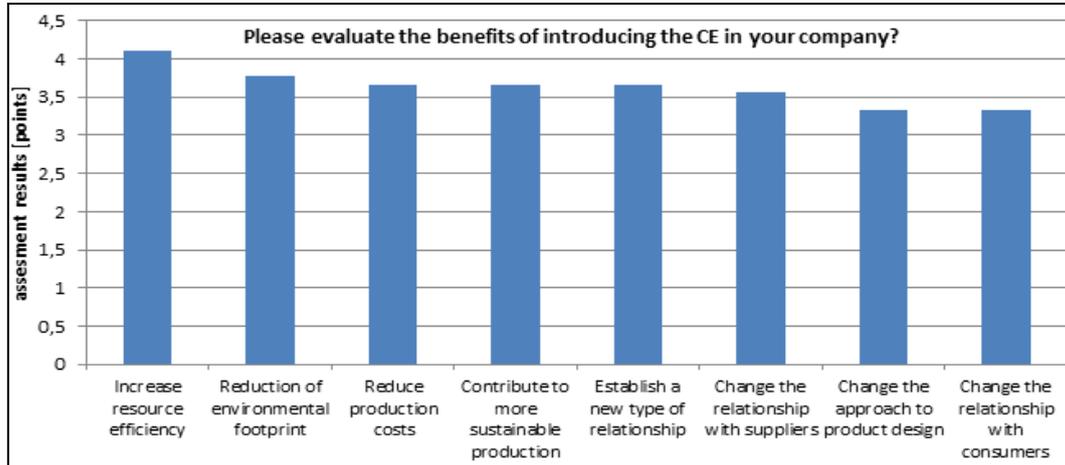
Conducting of the study among the energy companies aimed at:

- estimating the level of familiarity with the issue of the CE through examining the knowledge and recognition of as well as attitudes to it in energy companies,
- identifying activities realised in the context of the CE through a presentation of the current practice, consistent with its elements,
- indicating areas stimulating the realisation of the CE, making it possible to specify the activities in the further development.

The obtained results made it possible to evaluate the attitudes and activities of the energy sector in relation to the idea of the CE. Responses came from the chosen companies, among which types such as a power plant, heating plant and power and heating plant can be discerned. They were sent back by 64% of the interviewees, 56% of whom were representatives of the management and 44% – from the specialists.

In 2016, the totals of 4 330 428 MWh of electric power and 25 100 039 GJ of heat energy were generated in the examined companies, with the consumption of 1 995 437 tons of hard coal. The questions in the first part of the questionnaire concerned the identification of activities related to the CE in the examined companies.

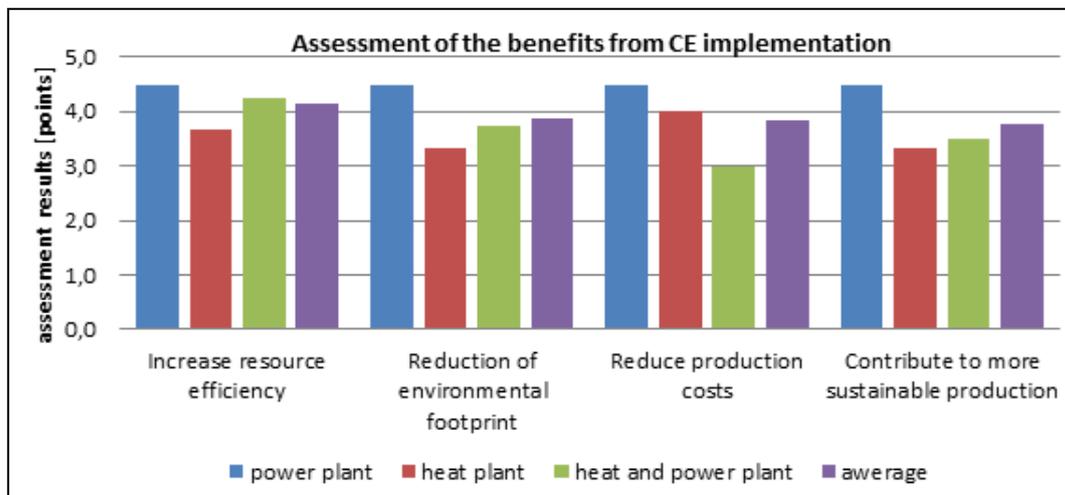
It follows from the study that the notion of the CE means for the employees such benefits as an increase in the efficiency of resource exploitation, which was indicated by 78% of the respondents. In turn, 67% of them pointed out the advantages coming from reducing the generated environmental footprint (Figure 1). Similarly, another aspect which was also assessed highly, by over 55% of the respondents, was a reduction of production costs.



**Figure 1.** Evaluation of benefits from the realisation of the CE

Source: own elaboration

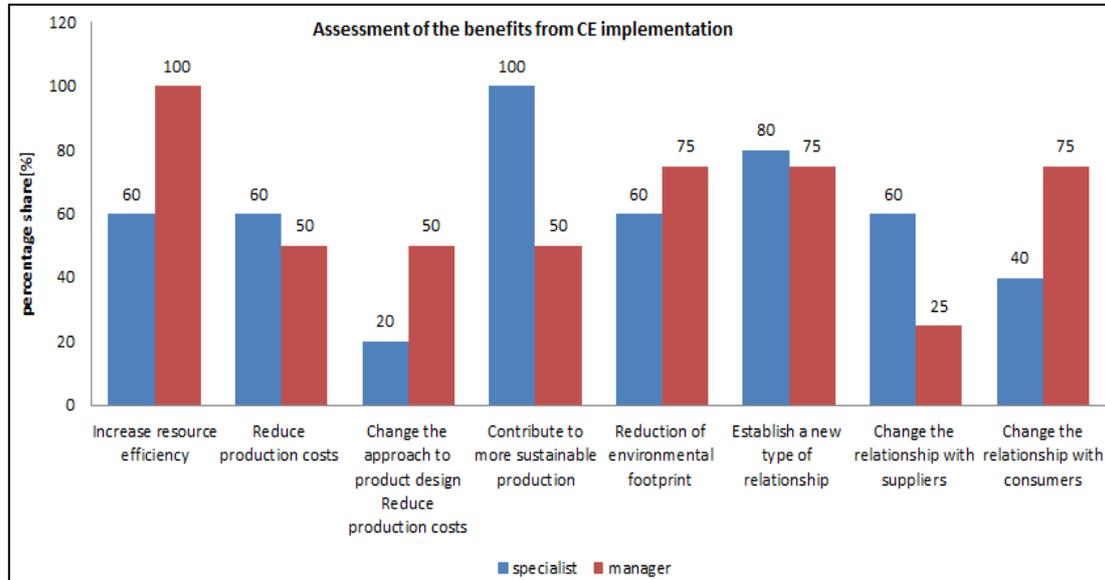
The responses of the interviewees vary depending on the type of the company (Figure 2). An increase in resource efficiency, reduction of environmental footprint and cost production, as well as contribution to more sustainable production were the most important aspects for power plant workers, whereas cost reduction was ranked the lowest by heat and power plant workers.



**Figure 2.** Evaluation of benefits from the realisation of the CE by companies of various types

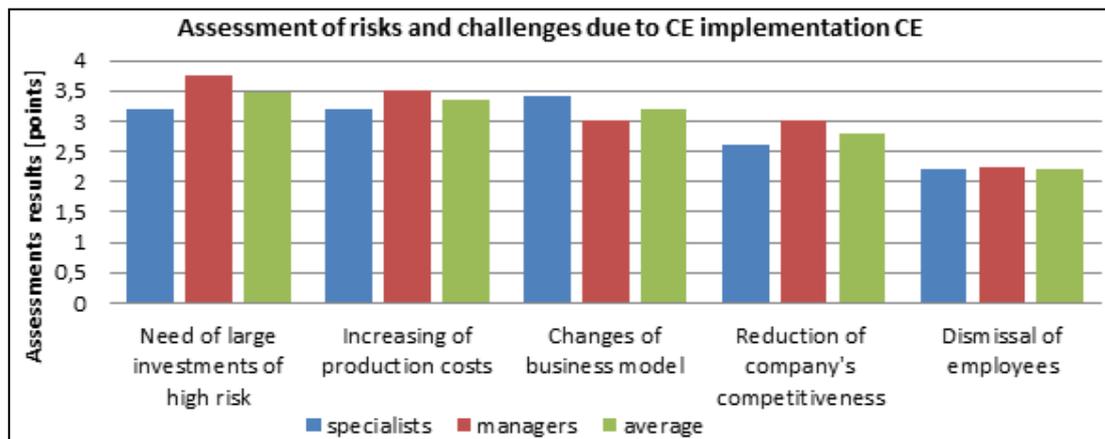
Source: own elaboration.

In the case of assessments made only by the managerial staff, the greatest benefits were thought to be coming from an increase in the efficiency of resource exploitation, while the specialists recognised the “contribution to sustainability of production” as the key benefit of implementing of the CE (Figure 3).



**Figure 3.** The percentage of opinions assessing the benefits of the CE

Source: own elaboration



**Figure 4.** Risks and challenges coming from the implementation of the CE identified by the managing staff

Source: own elaboration

The respondents arranged in the hierarchical order the risks and challenges (Figure 4) which, in their view, may be posed by the implementation of the concept of the CE in the understanding relevant to this hierarchy (beginning with the items marked the highest):

- need for considerable investments with the high level of risk – 56%,

- increase in production costs by 56%,
- need for the overall change of the business model followed so far by the company – 44%,
- reduction of competitiveness of the production of the company – 11%,
- necessity of dismissing employees of the company – 0%.

Among the respondents, 75% of the managing staff and 40% of the specialists associate the CE with the necessity of incurring considerable financial expenses connected with implementation of the investment (Figure 5). However, 25% of the managers and 20% of the specialists do not have such doubts, and 40% of the specialists are undecided.

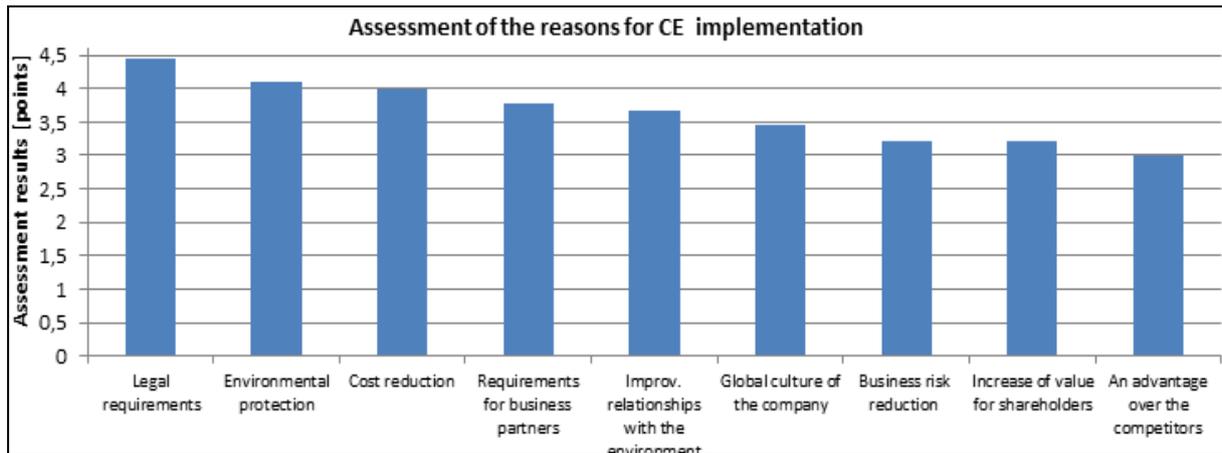


**Figure 5.** Percentage of assessments of agreement with the doubts connected to the necessity of realisation of large investments

Source: own elaboration

The second part of the study focused on identifying the current activities of the energy sector which are consistent with the CE trend. All the types of plants questioned indicated unequivocally that in the context of realisation of the CE, solid waste produced in the process of carbon combustion has the greatest potential for treatment. With the aim of reducing material and energy intensity, the respondents listed actions taken in connection with investments in modernisation of devices and systems. The respondents stressed that their realisation may result in improvement of energy efficiency, verified by the conducted energy audits.

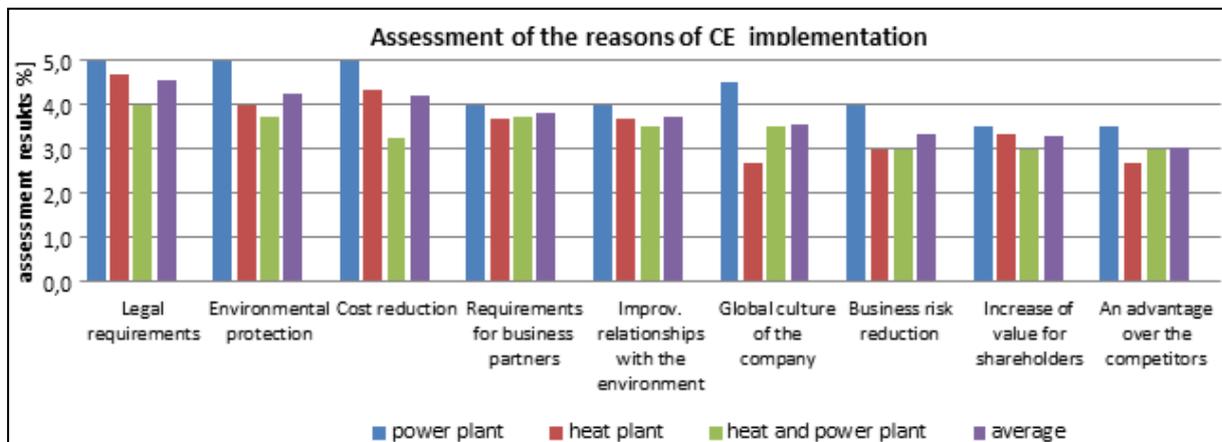
For the plants being the subjects of this study, the main reason for the CE implementation are legal requirements (Figure 6), as was pointed out by 89% of the respondents (including 80% of the specialists and 100% of the managing staff).



**Figure 6.** Assessment of the current reasons of realisation of the CE

Source: own elaboration

An analysis of responses considering the types of the plants also confirmed that the legal aspect is the key factor in the motivation for implementing the CE in the sector (Figure 7). For power and power and heating plants, the second place is taken by aspects linked to the awareness of the importance of environmental protection, while heating plants indicated the next important reason which is the chance of reduction of costs.



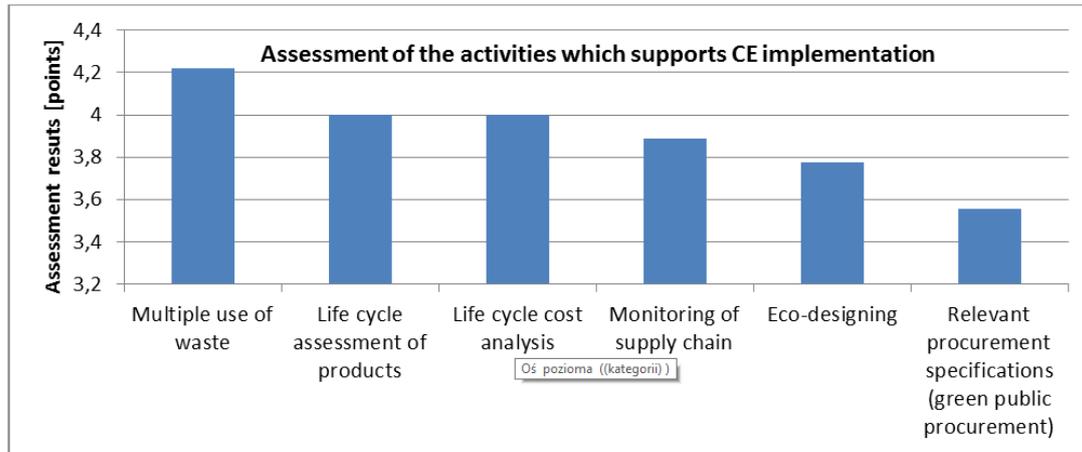
**Figure 7.** Assessment of the reasons for the implementation of the CE, taking into account the type of an enterprise

Source: own elaboration

All the plants pointed to the element of an advantage over the competition as the least motivating factor for the implementation of the CE. Its significance was evaluated in this way by 22% of the respondents (20% of the specialists and 25% of the managing staff).

The analysis of activities supporting the CE implementation has shown that multiple re-utilisation of waste is the highest-rated aspect, indicated by 20% of the respondents as very

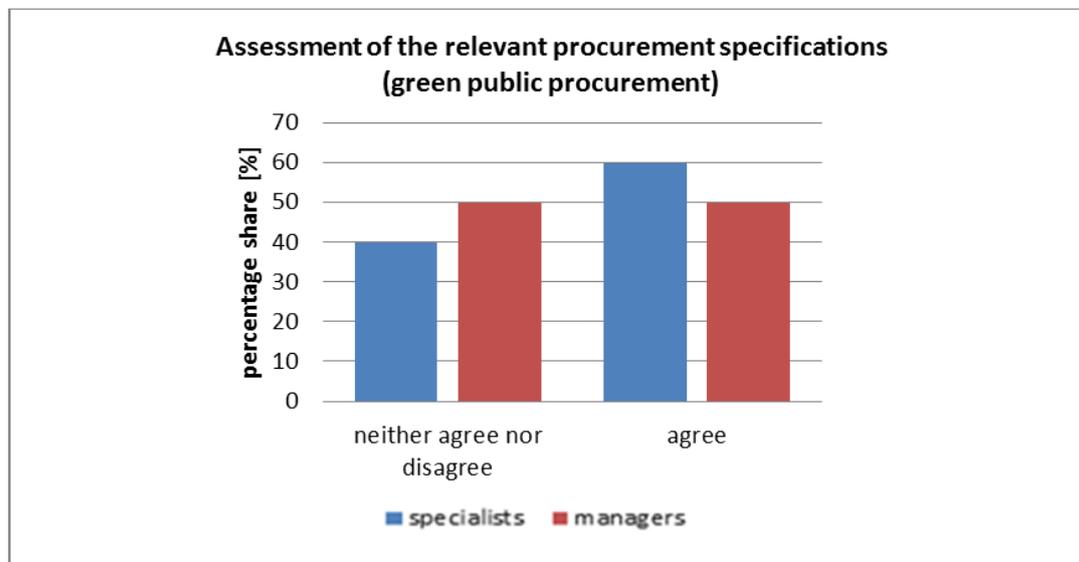
important (Figure 8). Next, ranked equally important as the activities supporting the CE development, were the product life cycle assessment and the life cycle cost analysis.



**Figure 8.** Assessment of activities supporting the CE implementation

Source: own elaboration

The activity least-seen as supporting the CE development was the proper specification of purchases implemented by green public procurement, which was indicated as important by 55% of the respondents. 44% of those polled were unsure how to assess that aspect, rating it as ‘neither agree nor disagree’ (Figure 9).



**Figure 9.** Percentage of ratings assigned to proper specification of purchases

Source: own elaboration

In the question regarding barriers which are the major hindrance in the cooperation between plants, when the realisation of the CE is concerned, the plants ranked highest both

the impediment connected with the fact that the raw materials reclaimed from waste are not sought for by buyers (89% of responses) and the problem stemming from the lack of acceptance of products based on recycled waste (78% of responses) (Figure 10).

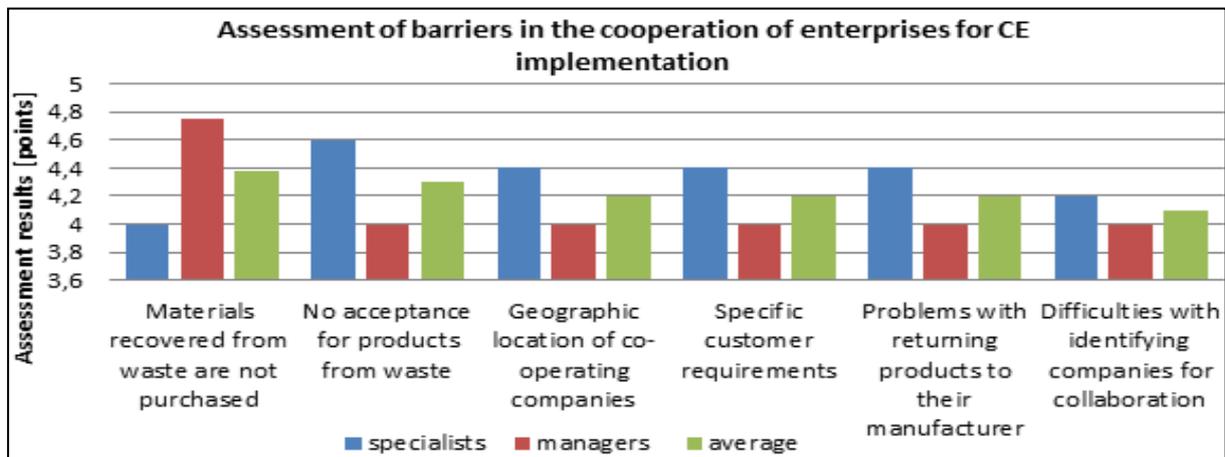


Figure 10. Assessment of barriers in the implementation of the CE

Source: own elaboration

Among the main reasons for pro-environment activities undertaken by the heating and power plants within the range of the CE, 78% of the respondents included both the requisites of the law and high fees for the storage of waste and the emission of pollutants to the atmosphere and water. Next in line of the reasons for undertaking ecological actions were economic advantages and corporate social responsibility. Among the respondents, only the managing staff linked the reason of the pro-environment activities with the strategy of the company consistent with the trend of sustainable development (Figure 11).

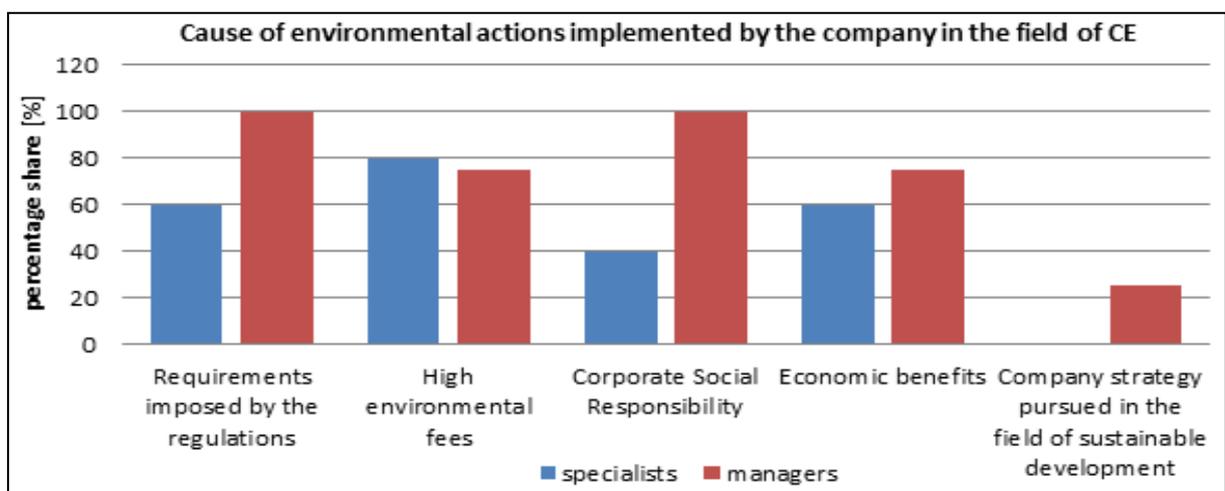
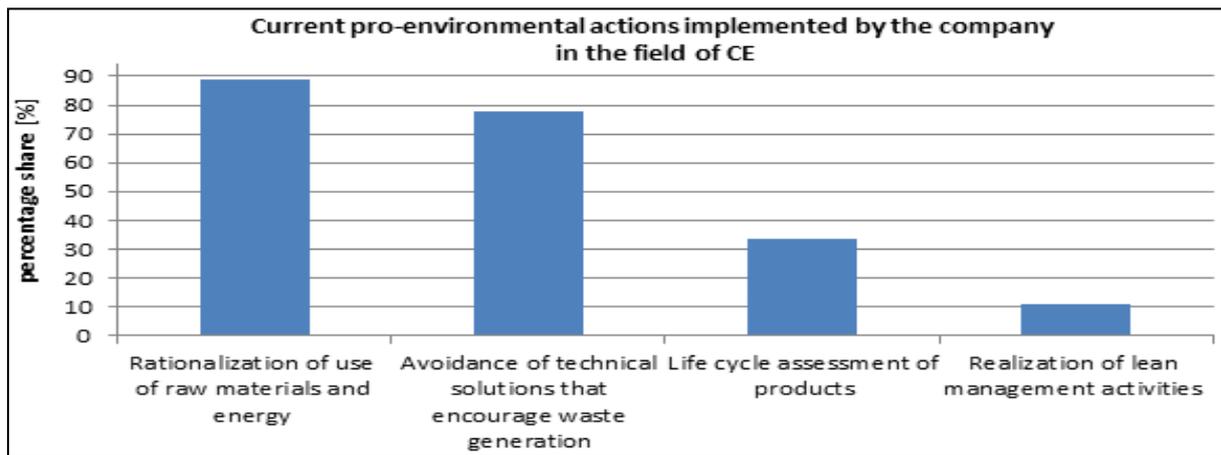


Figure 11. The percentage of votes for pro-environment activities undertaken in the context of the CE

Source: own elaboration

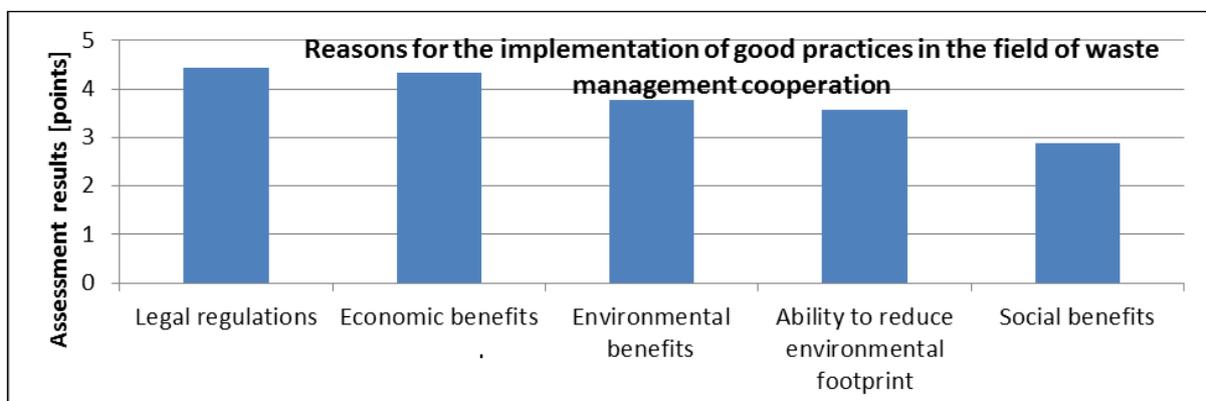
As the pro-environment activities presently realised within the CE, the questioned interviewees indicated, from the perspective of the production processes (Figure 12), rationalisations of the use of materials and energy in processes (89% of the respondents), avoidance of technological solutions favouring production of waste (78% of the respondents), conducting evaluation of the life cycle of products (33% of the respondents), and taking actions connected to lean management and facilitating the elimination of losses (11% of the respondents).



**Figure 12.** Evaluation of the presently taken actions consistent with the CE trend within the sphere of technological processes

Source: own elaboration

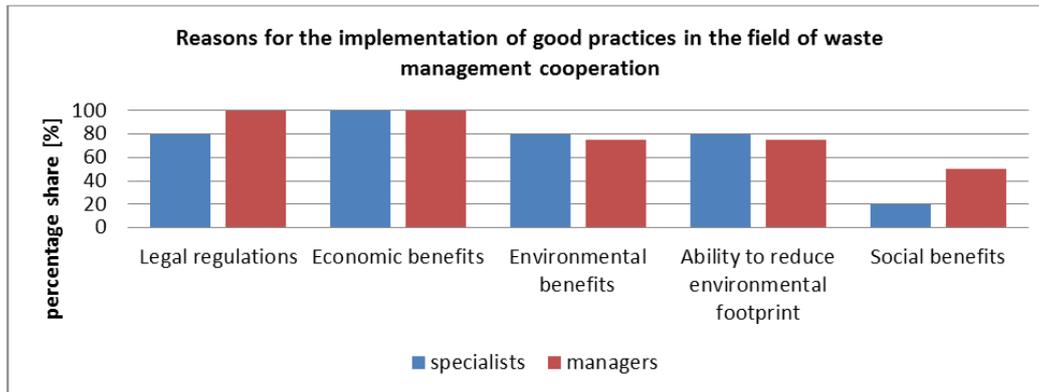
The respondents rated the legal obligations as the most important reason for implementing good practices associated with establishment of cooperation in waste management (Figure 13).



**Figure 13.** Assessment of the reasons for CE implementation

Source: own elaboration

Economic benefits were also rated high (Figure 14), being equally important for specialists (100% responses) and for executives (100% responses). Ranked next were the environmental benefits (80% of the specialists' responses and 75% of the executives' responses) and the ability to decrease the ecological footprint (rated by the respondents as above).

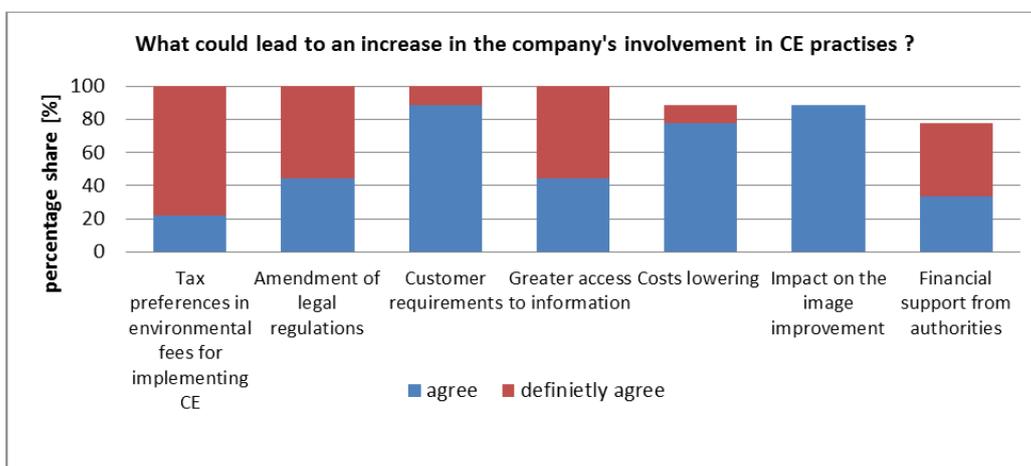


**Figure 14.** Percentage of votes cast for the current reasons for implementing good waste management practices

Source: own elaboration

Both groups of respondents (managers and specialists) rated social advantages attributed to activities motivated by the public pressure exerted due to the enterprise's harmful impact on the environment the lowest.

All the respondents indicated that incentives which could increase their involvement in the CE implementation are primarily (Figure 15) activities which directly translate into the economic aspect, such as: financial support for implementation of CE activities from the authorities, acquisition of tax preferences on the environmental charges for CE implementation, and decreased costs.



**Figure 15.** Percentage of votes cast for incentives supporting CE

Source: own elaboration

Aside from the direct reference to the financial aspect, respondents indicated the following: customers' requirements (100% responses), amendments to the legislative regulations (78% responses), better access to information on what kind of benefits circular economy may provide (100% responses) and impact on the company image improvement (89% responses).

The survey also asked questions regarding the assessment of the activities conducted by authorities with regard to propagation of the transformation from a linear economy to a circular one. With regard to those problems, all enterprises agreed that the responsibility for the implementation of sustainable development practices and of the CE lies with both local government authorities and with the central government. The enterprises are aware of their responsibility for the CE implementation. However, they see the aforesaid authorities as the leaders of those activities.

## **5. Discussion**

In the coal power industry of Małopolska Region, the concept of CE is accurately identified by companies with changes aimed at resource efficiency, as well as with decreased environmental impact of the activities conducted. Power industry enterprises also see in the CE the potential associated with decreased production costs resulting from the improved efficiency of the materials used.

Due to a number of activities conducted to date that have been associated with the idea of sustainable development, implemented, among others, as part of carbon efficiency projects, there do exist identifiable values and attitudes consistent with the CE concept at coal power industry enterprises. However, those result chiefly from the legal obligations stemming from the climate and energy policy implemented by Poland. The economic benefits associated with the ability to reduce costs and the environmental protection aspect have been assessed as the key elements which presently encourage power industry enterprises to conduct the CE implementation activities. Moreover, enterprises do not associate the CE implementation with an opportunity to gain competitive advantage, nor do they see the CE as a threat to their market position.

From the perspective of the processes being implemented and the waste being generated, they see the greatest potential associated with circular economy in coal combustion by-products. The respondents indicated that they undertake waste management cooperation activities. However, their cooperation on the CE implementation is hindered by the fact that

raw materials recovered from waste find no purchasers. This state of affairs reflects the lack of social approval for the use of recycled products. Therefore, as stressed by the respondents, in order for the sector to become fully consistent with the CE concept, activities supporting the development of awareness and of the right attitude toward coal combustion products other than electric and thermal energy are expected from the authorities. Successful implementation of the CE is conditional upon provision of proper conditions which would integrate all economic operators: the authorities, enterprises and consumers. It is necessary to create consistent foundations based upon awareness, willingness to act in accordance with its principles, and intensification of the present activities.

## **6. Conclusion**

The interviewees showed through their responses that the transformation from the system of linear economy to the circular one entails doubts connected with the necessity of making considerable financial outlays on the investment activities. However, it is the investment and modernisation actions (directed at, among others, improving the energy efficiency) that are identified as the presently realised actions consistent with the CE. The financial support for the investment activities (besides the changes in legal regulations) is the most stressed expectation towards the authorities.

From the study it follows that the implementation of the CE principles in the plants takes time and needs to be supported by the authorities both on the level of regions and the state. Changes in the present economy may be achieved through such actions as painting a reliable picture of the present state of affairs, constituting the basis for verification of what has been accomplished so far and what is to be undertaken in the future. Additionally, one of the basic tasks for institutions promoting the CE in Europe and in the World is showing the financial benefits coming from the implementation of solutions based on the CE, along with providing and implementing new business models. This, in turn, will depend on many external and internal factors influencing the development of the energy sector in Poland and in Małopolska Region. They may certainly be exemplified by the possibility of an efficient cooperation of science and business with the support of the local, regional and state authorities and the availability of financial resources allocated to the transformation and lowering the risk connected with the transformational processes of the sector in accordance with the premises of the CE.

## Acknowledgement

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 665778.



This project has received funding from the National Science Centre, Poland. POLONEZ funding programme (project registration number 2015/19/P/HS4/02098).

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## **ZASTOSOWANIE GOSPODARKI CYRKULACYJNEJ W SEKTORZE ENERGETYCZNYM REGIONU MAŁOPOLSKIEGO – KORZYŚCI I WYZWANIA**

### Streszczenie

Gospodarka obiegu zamkniętego (cyrkulacyjna) jest nowym trendem w **rozwoju** zrównoważonym, skierowanym na ograniczanie zużycia zasobów oraz minimalizację produkcji odpadów. Uznając postulaty Komisji Europejskiej dotyczące wdrażania gospodarki cyrkulacyjnej, autorki stawiają sobie za cel stwierdzenie czy elektrownie działające na terenie Województwa małopolskiego są świadome pojęcia gospodarka obiegu zamkniętego, czy są gotowe myśleć i działać w zgodzie z jej regułami, oraz jak udowadniają że ich obecne działania wpisują się ten nowy trend. Wyniki niniejszego opracowania ukazują sektor energetyczny w kontekście przechodzenia z gospodarki liniowej do cyrkulacyjnej oraz kształtowania się podstaw dla dalszego rozwoju, jak również intensyfikacji działań związanych z wdrażaniem gospodarki obiegu zamkniętego.

**Słowa kluczowe:** gospodarka obiegu zamkniętego (cyrkulacyjna), sektor energetyki opartej na węglu, Województwo małopolskie

**Kody JEL:** O13, O44, Q49, Q56

**<https://doi.org/10.25167/ees.2018.45.5>**