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Anna Balicka
Wrocław University of Economics
anna.balicka@ue.wroc.pl

Mariola Kotłowska
Wrocław University of Economics
mariola.kotlowska@ue.wroc.pl

INTERNAL BENCHMARKING OF TECHNOLOGICAL PROCESS IN A HEATING COMPANY

Summary: The aim of this article is to illustrate the possibilities of using internal benchmarking to improve efficiency of technological process in a heating company. The research has been carried out on the basis of data from 2011 to 2013, coming from four combined heat and power plants operating within one heating company. Internal benchmarking allows for comparing the efficiency of technological process in these combined heat and power plants as well as implementing the best practices developed by a leader in the area. Separating key factors, specific to heating industry, which can be crucial in efficiency of technological process, allows one to identify the most relevant areas of business improvement in heating industry. The obtained results may be a reference point to undertake more detailed analysis.

Keywords: internal benchmarking, efficiency of technological process, heating company.

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1. Introduction

The main purpose of this article is to demonstrate the possibilities of using internal benchmarking to improve efficiency of technological process in a heating company. The appropriate type and method of benchmarking have to be applied according to the characteristics of the process in a heating company. Benchmarking is one of the methods of management, the implementation and following up of which continuously allows for developing best practices, and thus gaining the appropriate competitive position in relation to competitors. Companies operating in a competitive environment must continuously improve their business, adapt to changing environmental conditions and meet the challenges of the market.

In order to achieve the main intended purpose of this article, the following partial aims have been set:

- recognition of the specific nature of the heating industry,
- demonstration of the meaning of the efficiency of technological process in the heating industry,
- illustration of the essence of benchmarking,
- development of benchmarking method possible to employ in estimation of efficiency of technological process in a heating company,
- demonstration of the functionality of the proposed method of benchmarking.

In order to achieve these objectives the following thesis has been formulated: the use of internal benchmarking enables improvement of the efficiency of technological process in a heating company by applying the best practices identified in particular combined heat and power plants.

While writing this article, the following test methods have been applied: literature studies, analysis, synthesis and inference.

2. The specific nature of the heating industry

According to the definition by Minister of Economy Regulation, the heating company is an energy company that is engaged in the business of generating heat in sources of heat utilized by this company, transmitting, distributing and selling heat generated by these sources or purchased from another energy company [Rozporządzenie… 2007, § 2, p. 1]. These companies need to have proper infrastructure, defined as the heating system, which includes the heating network and compatible equipment or installations which generate or receive heat [Rozporządzenie… 2007, § 2, p. 21]. Heating industry has specific factors that determine the way of functioning of heating companies. They arise from two major reasons: the market where the heating company operates and the offered product.

General definition of the market defines it as a set of conditions which leads to a contract between buyers and sellers in the process of exchange of goods and services. One of the most important elements which form relations on the market is the price [Begg et al.1993, pp. 40, 82]. The price fixing is usually done by balancing the demand with the supply of the product. In case of heat, a demand is pre-determined by the demand for heat by its consumers, while supply has limits imposed by full generation capacity of the unit. Additionally, prices and free rates are determined by regulations [Rozporządzenie… 2010]. What is more, the definition of the market points out the essence of two groups of stakeholders –buyers and sellers. Access to the heat market has a lot of entry barriers which are related mainly to the costs involved in starting a business. The costs are related to construction of new generation capacity and annual concession fee. The concession fee is paid to the state budget. It is charged to the company and the amount of concession fee depends on revenues of the company in previous year. The relations between market's participants are

relevant as well. In this case, the relations are regulated by law and government authorities, represented by the Chairman of the Energy Regulatory Authority and Office for Competition and Consumer Protection. Both authorities do research and issue reports for energy market participants' good.

The product offered by heating companies, which is heat, is homogeneous and independent of its seller. However, distinct features which are characteristic only of a particular group of products are noticeable. There are limited possibilities of the storage of heat energy, therefore the production process must be kept up to date. Stopping the production, which is not related to improvements and renovations, is possible only in summer when the demand for heat is declined.

The market has to be controlled by the company as the gap between supply and demand can affect its deregulation. It may concern social (lack of heat and hot water in households and buildings belonging to enterprises) as well as economic impacts. Furthermore, it is significant to control characteristics of heat carriers – water or steam. Such parameters as temperature or pressure fluctuate, significantly lowering the quality of transported heat.

Functioning of heating companies (and the entire energy market), defined in Act on Energy Law, concerns ensuring energy security, rational and economical use of fuel and energy as well as taking into account environmental protection requirements [Ustawa z 10 kwietnia 1997, Art. 1, p. 2].

3. The efficiency of technological process in a heating company

Technological process in a heating company relates to the generation of heat which is used to commercial purposes or for the company's use. Heat plants and combined heat and power plants may function as a part of a heating company. The difference between them concerns the effectiveness of functioning and energy losses. Fuels used in the production process, which involves generation of both electricity and heat in CHP, are converted to larger quantity of secondary energy in comparison with separation technology used in heat and power plants.

The production process of heat and electricity comprises four cycles: combustion, work, cooling and the one connected with electricity. In the combustion process a chemical reaction takes place. It uses fuel such as brown coal, hard coal, gas, oil, biomass or coke. They have different calorific value, which defines net efficiency. The net efficiency is expressed in percent. The calorific value determines the value of the generated electricity and heat (in MWh) per 1 MWh of fuel used. Side effects as ash or exhaust fumes (carbon dioxide, sulfur dioxide, nitrogen oxides and particulates) occur in the combustion process. In accordance with the EU Directive [2010/75/EU], the limit of pollutant emissions has been specified. It has to implement one of the energy policy objectives concerning protection of the environment. The work phase involves extraction of mechanical energy by expanding boiler-generated steam. As a result, heat is generated, and then transported to heat consumers by heat

pipes. The work phase is directly associated with the cooling phase. In the cooling phase we may observe removal of heat unsuitable for conversion into mechanical energy from circulation. This process includes condenser and evaporating towers. In CHP plants, the last production process is to generate and transport electricity to final heat consumers.

The company must bear a number of fixed costs associated with maintaining a unit on various stages of production. These costs include maintenance and repair, salaries for employees and rental property. Production process in the heating company is ongoing. Therefore, any unplanned stopping of production means economic losses which are related to repair production infrastructure: the costs of materials, spare parts and purchase of repair services. These costs, defined as unavailability costs, also include costs of reignition after production stoppage and lost revenues from sale. It is intensely relevant to ensure full efficiency of machines and equipment, on which the subcontractors performing any repairs and modernization have impact.

Efficiently performed activities should have characteristics as the factors demonstrated above. Among them one can find ensuring required level of quality, high productivity which enables the company to compete successfully on the market, and eliminating all sources of waste, such as downtime, shortages or under-utilization of generation capacity [Łunarski 2012, p.189]. Generally speaking, the efficiency is when the processes can implement plans, while improving the quality of processes, increasing the productivity and reducing costs. This way, it is possible to manage resources rationally, mainly by maximizing outputs from given inputs or minimizing input use in the production of given outputs [Krumbhakar, Lovell 2004].

4. The essence of benchmarking

The origins of benchmarking can be found in ancient times [Codling 1992, p.12]. R.C. Camp, manager of benchmarking at Xerox, was the precursor of benchmarking and a person important for scientific development of benchmarking. This method of management was pioneered by Camp, both in theory and in practice. He created one of the basic definitions of benchmarking, which reads as follows: “Benchmarking is the search for industry best practices that lead to superior performance” [Camp 1995, p. 28]. Over the years, the definitions of benchmarking have reflected various points of view of their authors on this method. Some of them are listed in Table 1.

Benchmarking is classified by subject, time, reference standards, environment, field and the nature [Kisperska-Moroń 2000, p. 18]. T. Bendell and L. Boulter distinguish four types of benchmarking: internal, competitive, functional and generic. Internal benchmarking includes comparisons within the company (departments, affiliates, group of companies, divisions). Competitive benchmarking concerns comparisons with other companies, mainly in the same sector. Functional benchmarking is the comparison of specific business functions with specific business functions in companies from different sectors. Generic benchmarking compares

processes connected with various activities of the company across non-related industries [Bendell, Boulter 2000, pp. 85, 86].

Table 1. Selected definitions of benchmarking

Authors	Definition of benchmarking
M.J. Spendolini	Benchmarking is a continuous, systematic process for evaluating products, services and work processes or organizations that are recognized as representing the best practices, for the purpose of organizational improvement.
B. Karlöf, S. Östblom	Benchmarking is a continuous, systematic process based on confronting (comparing) one's own efficiency measured by productivity, quality and experience with the results of organizations which could be considered as models of excellence.
R. Pieske	Benchmarking is a method of searching for standard manners of conduct, enabling the achievement of the best possible results by learning from others and using their experience.
American Productivity and Quality Centre	Benchmarking is the process of comparing and measuring your organization against others, anywhere in the world, to gain insights into measures, performance, and practices in a way that can rapidly improve the journey to world-class performance.
G.J. Balm	Benchmarking is the ongoing activity of comparing one's own process, practice, product, or service against the best known similar activity so that challenging but attainable goals can be set and a realistic course of action implemented to efficiently become and remain best of the best in a reasonable time.
R. Kowalak	Benchmarking is a very important method of management. It is used to implement the best practices by comparing with best practices employed in other organizations.

Source: own study on the basis of [Karlöf, Östblom 1995, p. 7; Kisperska-Moroń 2000, p. 10; Kowalak 2009, p. 19; Nazarko i in. 2008, p. 17; Węgrzyn 2000, p. 82].

A. Węgrzyn classifies benchmarking according to the object criterion. He distinguishes: strategic benchmarking, performance benchmarking and process benchmarking. Strategic benchmarking is the comparison of processes and procedures involving long-term strategies, as is the case with the choice of product, market, strategy, investment trends, etc. Performance benchmarking focuses on comparison of data, which demonstrates economic and operational efficiency of the company. In contrast, process benchmarking compares processes and procedures in various companies [Kowalak 2006, p. 280].

With reference to the criterion of the subject, one can distinguish internal and external benchmarking. Within external benchmarking, there are competitive benchmarking and functional benchmarking. Internal benchmarking focuses on comparisons within the same organization, between departments, affiliates or

divisions. It is relatively easy to implement and it may be used as an introduction to other types of benchmarking. External benchmarking may be divided into functional benchmarking (also known as overall, intersectoral and horizontal) and competitive benchmarking. Functional benchmarking is the comparison and implementation of innovative ways thanks to exchange of information and experience with companies from different sectors. It has to be pointed out that the type of activity is insignificant. The aim is to achieve a competitive advantage on the market. On the other hand, competitive benchmarking is the comparison between competitors from the same sector. It is relevant not only to determine the position of the company on the market, but also to compare it with the leader, which allows the company to be ahead of other competitors [Węgrzyn 2000, pp. 86–92].

Time is the criterion for benchmarking which is frequently ignored. According to this criterion we can distinguish one-time benchmarking and systematic benchmarking. One-time benchmarking is one-time exchange of experiences in order to achieve a certain level of efficiency. When efficiency is increased, one-time benchmarking is no longer employed. Nevertheless, when the company's situation deteriorates it is applied again. Systematic benchmarking is applied constantly in order to improve the effectiveness of the company [Doradca Consultants 2001, p. 7].

5. Benchmarking in a heating company

In units operating in heating industry, workers are frequently unaware that they can improve technology as well as organization in the company. Managers may do not know that the particular unit operates improperly as there is lack of comparisons between units with similar activities [*Heating system*…] There is a need for exchange of information between units in heating industry. It is supported by the fact that the project "Development and Dissemination of Benchmarking for Increasing Cost-efficient District Heating" has been created. The aim of this project is to create benchmarking platform for the heating companies in the Baltic Sea Region [Regulski 2004, p. 4]. The authors of the project decided that process benchmarking is the most appropriate in the heating industry as the activities of the heating companies are specific [Koc 2005, p. 4].

This article demonstrates the possibility of using benchmarking in combined heat and power plants operating within one heating company. The most appropriate types of benchmarking, which can be used in this case, are: process benchmarking, internal benchmarking and systematic benchmarking. Type of benchmarking, its characteristics and criteria are cited in Table 2, which is illustrated beneath.

It was possible to carry out internal benchmarking because there are four combined heat and power plants, where the same technological process is conducted, within the analyzed company. The main advantages of internal benchmarking are [Bendell, Boulter 2000, pp. 102, 103]:

- easier flow of information – communication within one company,

Table 2. Characteristics of various types of benchmarking employed in technological process in heating company

Criteria	Type of benchmarking	Characteristics
Object	Process benchmarking	Evaluation of efficiency of technological process in heating company
Environment	Internal benchmarking	Comparisons of four CHP plants operating within one heating company
Time	Systematic benchmarking	Quarterly comparisons

Source: own study.

- the possibility of positive relationships between employees – earlier cooperation,
- understanding a unit's culture by employees,
- the possibility of direct observation of good practices employed by other entities,
- reducing problems connected with maintaining confidentiality.

The confidentiality of the information provided is extremely significant in the heating industry, which is why internal benchmarking is the best tool.

Systematic benchmarking is characterized by systematic comparisons and implementing the best practices and solutions. Thanks to this method of benchmarking, we can monitor previous changes [Doradca Consultants 2001, p. 7]. Process benchmarking can be also applied by virtue of specific nature of heating industry and technological process, which decides about the quality of CHP plant's operation.

Four entities, which operate within one heating company, have been compared: CHP Alpha, CHP Beta, CHP Gamma, CHP Delta[1]. Factors specific to heating industry and characteristic metrics has been distinguished, as is demonstrated in Table 3.

To compare the cost structure of CHP plants a modern tool – benchmarking matrix, has been used. The simplified calculation procedure reads as follows [Badiru, Ayeni 1993, pp. 54, 55]:

1. Determination of the number of analyzed metrics in benchmarking – at least 4 (n).
2. Calculation of the angle which the metrics take ($360°/n$).
3. Metrics standardization – scale from 0 to 10.
4. Plotting the standarized metrics on the radar chart – forming polygons on the chart.
5. Calculation of the polygon area on the radar chart.
6. Calculation of the circle area.
7. Determination of the contribution of the polygon area to the circle area.

By using a radar chart, one can make measurements in a given period of time and create a performance map, which illustrates changes that have taken place. It can

[1] For confidentiality reasons, fictional names are used.

Table 3. Factors, metrics, units and characteristics selected for analysis

No.	Factor	Metrics	Unit	Metrics characteristics
1.	The use of fuels in the production process	net efficiency	[%]	Stimulant
2	Pollution and environmental protection	emissions of carbon dioxide	[t/MWh]	Destimulant
3	Fixed costs related to operation of combined heat and power plants	fixed costs	[zl/MWh]	Destimulant
4	Downtime of machinery and equipment	unavailability costs	[zł/MWh]	Destimulant
5	Modernization and development of generation capacity	value of involved assets	[zł/MWh]	Stimulant
6	Labour efficiency and productivity	the number of production workers	[person/MWh]	Destimulant
7	Costs related to purchase of external services	value of purchase of external services	[zł/MWh]	Destimulant

Source: own study.

be possible when one puts the results of the analyses from several quarters on one chart. In this way, one can observe what is the most effective way of implementing improvements [Bogan, English 2006, pp. 91, 92].

6. Benchmarking as a tool to evaluate efficiency of technological process in heating company

Efficiency of technological process of particular combined heat and power plants has been evaluated on the basis of quarters in the years 2011–2013. The combined heat and power plants have been compared on the basis of subject and time. The comparison was possible thanks to the analysis of the results illustrated on radar charts (Figures 1 and 2) and the contribution of the polygon areas calculated by mathematical method (Table 4).

Closer observation of the results suggests that it is impossible to determine one leader among CHP plants for the whole period considered. This results mostly from the specific nature of heat market as the need for heat is seasonal, which means that the weather conditions and temperature have great influence on the distribution of heat to final heat consumers. Therefore, CHP Alpha is the leader in the winter as it uses scale effect in technological process. Using full generation capacity, which results from the possibility of sale of a huge part of generated heat (and electricity),

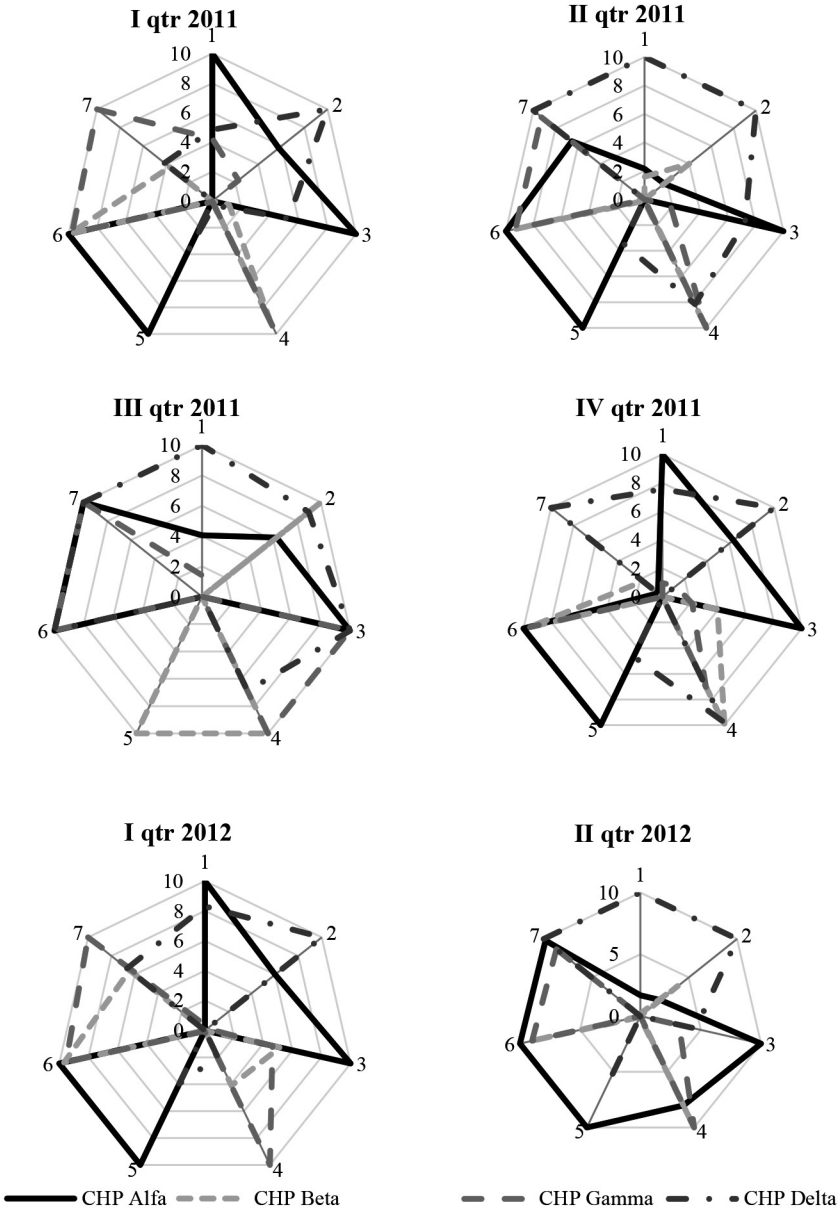

Figure 1. Radar charts demonstrating the efficiency of technological process of CHP Alpha, CHP Beta, CHP Gamma and CHP Delta in the years 2011 and 2012, comparing seven metrics characteristic to heating company

Source: own study.

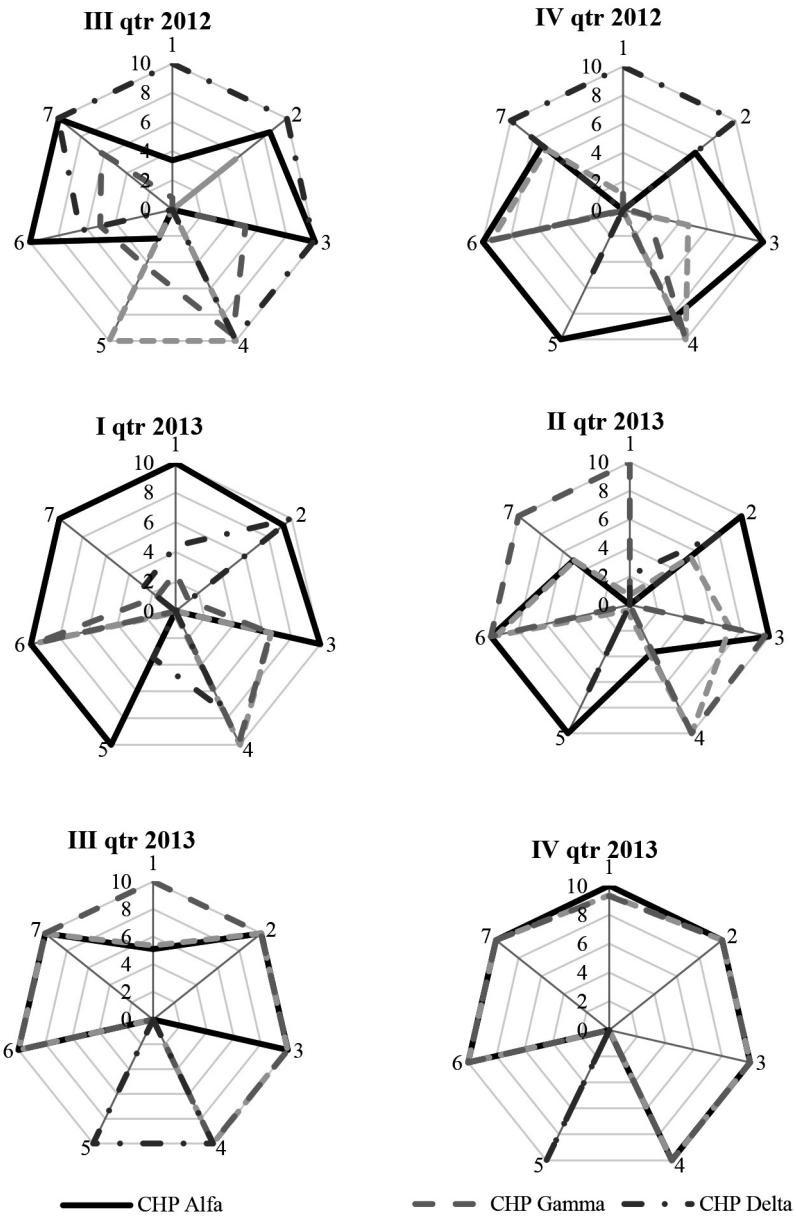

Figure 2. Radar charts demonstrating the efficiency of technological process of CHP Alpha, CHP Beta, CHP Gamma and CHP Delta in years 2012 and 2013, comparing seven metrics characteristic to heating company

Source: own study.

Table 4. The comparison of the contribution of the polygon areas of the CHP plants in the years 2011–2013, in relation to the base surface area

Quarter	CHP Alpha	CHP Beta	CHP Gamma	CHP Delta
I qtr 2011	**30.74%**	6.79%	21.46%	17.73%
II qtr 2011	28.71%	1.19%	14.95%	**51.36%**
III qtr 2011	32.67%	14.29%	30.58%	**64.04%**
IV qtr 2011	**33.60%**	8.05%	2.69%	28.00%
I qtr 2012	**31.40%**	11.89%	21.08%	20.88%
II qtr 2012	**57.02%**	0.39%	15.75%	35.14%
III qtr 2012	38.39%	14.29%	21.14%	**65.90%**
IV qtr 2012	**57.38%**	16.88%	2.83%	28.57%
I qtr 2013	**69.40%**	9.68%	13.49%	11.69%
II qtr 2013	**46.20%**	24.86%	42.46%	2.36%
III qtr 2013	43.11%	58.06%	**71.36%**	14.29%
IV qtr 2013	**71.43%**	69.54%	69.40%	0.00%

Source: own study.

results in lower costs per 1 MWh of generated energy. The increase of metrics value regarding net efficiency connected with the combustion of fuels in the production process is also extremely significant. It affects efficiency of technological process and higher, than in other entities, final results. In addition, CHP Alpha has lower, than other combined heat and power plants, fixed costs in the period considered.

In summer, when the production process is reduced, efficiency of technological process in all combined heat and power plants declines. CHP Delta is a leader in II and III quarters in 2011 and 2012. It has strong position as it is not completely stopping the production and it purchases outsourced services at low costs. In this case, fixed costs related to the functioning of CHP plants, salaries for employees and property maintenance are not immensely high when we convert them to 1 MWh of generated energy. It has to be mentioned that combined heat and power plants, which are extremely effective in the heating period, have increased repair work in the summer. Therefore, the costs of spare parts and repair and refurbishment services from external companies increase.

It is crucial to managers to constantly monitor the results of CHP plants, whose contribution of the polygon area does not exceed 5% in relation to the base surface area. Thanks to comparisons with other entities, managers can learn from the leaders and thus improve the actions and activities in the company. They can identify the best practices which affect the improvement of effectiveness in the processes. Therefore, such practices may be also implemented in other CHP plants. It is possible by applying internal benchmarking.

Internal benchmarking allows to analyze the combined heat and power plants on the basis of time, in this case – quarters and years. Noticeable differences in the results for individual CHP plants allow for drawing conclusions that the functioning of the enterprise, based on the experience of previous years, becomes more effective. CHP Alpha is the best example as the contribution of the polygon area reached 30.74% in relation to the base surface area in I quarter in 2011. In addition, two years later, in the same quarter, it increased to 69.4%. It is the result of improvement works which have a great influence on effectiveness of technological process (more than twice). It helps achieve the best results in almost all analyzed factors. Modern machinery park and automation have an impact on the reduction in employment in CHP Alpha. All of this has a great impact on increasing the quality of the offered product – energy. Unavailability costs are the only exception as its structure mostly depends on random incidents.

The analysis of CHP Delta over the quarters demonstrates decreased efficiency of technological process. It is connected with limited modernization activities, such as repairs and improvements of machinery and equipment. Moreover, it affects lower fixed and unavailability costs, which resulted in high results of analyzed metrics of heating company in summer. However, due to refraining from taking any actions to reduce failures in technology park, the increase in costs in particular quarters affected the contribution of the polygon area of CHP Delta. It has been reduced to 2.36% in relation to the base surface area in II quarter in 2013. However, in the same quarter in 2011, CHP Delta was a leader, it reached 51.36%.

These extreme situations demonstrate that internal benchmarking allows for noting how improvements in combined heat and power plants influence the results, in the analyzed periods. Furthermore, it allows for continuing the actions when they are successful or to stop them in case of the negative effects of introduced changes.

7. Conclusions

This analysis should lead to deeper studies of technological process in the analyzed heating company. This mainly results from relatively poor results which were obtained. On the one hand it is suggested that it is possible to optimize processes, while on the other, more detailed analysis, including the possibilities of the system, the costs and the efficiency of technological process, should be carried out. Making a more detailed analysis will have an impact on the improvement of processes in an enterprise. Recognition of these will allow for increasing the efficiency of the technological process. This will be enabled by knowledge of the best practices taking place in individual, analyzed plants.

It may be concluded that internal benchmarking allows for improving the results of combined heat and power plants by increasing the quality, reducing the costs and minimizing the time of realization. It is also possible to allocate resources (human,

financial, tangible and intangible) between all units of the company. In that way, they can yield their full potential and increase the value of the company at the same time.

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BENCHMARKING WEWNĘTRZNY PROCESU TECHNOLOGICZNEGO W PRZEDSIĘBIORSTWIE CIEPŁOWNICZYM

Streszczenie: Celem artykułu jest przedstawienie możliwości wykorzystania benchmarkingu wewnętrznego w doskonaleniu efektywności procesu technologicznego w przedsiębiorstwie ciepłowniczym. Badania zostały przeprowadzone na danych z lat 2011–2013, pochodzących z czterech elektrociepłowni funkcjonujących w ramach jednego przedsiębiorstwa ciepłowniczego. Zastosowanie benchmarkingu wewnętrznego pozwala na porównanie efektywności procesu technologicznego zachodzącego w badanych elektrociepłowniach i wdrożenie najlepszych praktyk wypracowanych przez lidera w danym obszarze. Wyodrębnienie kluczowych czynników, specyficznych dla branży ciepłowniczej, decydujących o efektywności procesu technologicznego, umożliwia zidentyfikowanie najważniejszych obszarów doskonalenia działalności jednostek branży ciepłowniczej. Uzyskane wyniki przeprowadzonych badań mogą stanowić punkt odniesienia w dokonywaniu bardziej szczegółowych analiz.

Słowa kluczowe: benchmarking wewnętrzny, efektywność procesu technologicznego, przedsiębiorstwo ciepłownicze.