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Leadership Competencies in Making Industry 4.0 Effective: The Case of Polish Heat and Power Industry

Anna Kwiotkowska [1], Bożena Gajdzik [2], Radosław Wolniak [1], Jolita Vveinhardt [3,*] and Magdalena Gębczyńska [1]

[1] Department of Organisation and Management, Silesian University of Technology, 41-800 Zabrze, Poland; anna.kwiotkowska@polsl.pl (A.K.); radoslaw.wolniak@polsl.pl (R.W.); magdalena.gebczynska@polsl.pl (M.G.)
[2] Department of Industrial Informatics, Silesian University of Technology, 40-019 Katowice, Poland; bozena.gajdzik@polsl.pl
[3] Department of Management, WSB University, 41-300 Dąbrowa Górnicza, Poland
* Correspondence: jvveinhardt@wsb.edu.pl

Abstract: Leadership competencies are of crucial importance in every organisation as to a large extent they determine its success. This is especially evident in the time of Industry 4.0. Given this fact, the aim of our paper is to examine the relationship between leadership competencies and 4.0 leadership effectiveness. The heat and power plants industry was chosen as the subject of our research. The fuzzy-set qualitative comparative analysis (fs/QCA) was used as the research method. It enabled us not only to analyse particular variables, competences, and typical statistical relations between them, but we also revealed the patterns of causal relationships between particular variables. The key finding of our research was the juxtaposition of leadership competencies that are indispensable for 4.0 leaders in the CHP plants. We also found out that managerial competencies were not sufficient, and they should be supported by intellectual or socio-emotional ones.

Keywords: Industry 4.0; heat and power plants; energy production; managerial competencies; leadership effectiveness; fuzzy-set qualitative comparative analysis (fs/QCA)

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1. Introduction

Industry 4.0, also known as the fourth industrial revolution, is a term that has appeared with increasing frequency in the public sphere in recent years. In general, it is a concept that describes the complex process of technological and organisational transformation of enterprises, which includes the integration of the value chain, the introduction of new business models, and the digitisation of products and services. It is changing the way we think about new industry. Industry 4.0 pertains to our understanding of leadership. Its former model, based largely on commands and tasks with imposed deadlines, is replaced by creativity and thinking about a strategic view of cyberspace. Any technological and organisational change requires support from the leaders. In Industry 4.0, leaders need to guide the organisation through digital transformation. They should indicate the direction of change, inspire employees, and support them. Given these facts, the motivation for this paper is resulting from the research gap observed in leadership competencies analysis in Industry 4.0, and it especially relates to the energy industries such as the heat and power industry.

Industry 4.0 connects the virtual world with the real one, focusing on fully automating and digitising all physical assets and integrating cooperating systems (supply, manufacturing, and distribution) across the value chain (end-to-end). Virtual networks, including employees, machinery and equipment, and IT systems are created [1–6]. Apart from the changes in production plants, it brings significant changes in the production work. In addition to change taking place in manufacturing plants, Industry 4.0 considerably alters the production process. Cyber–physical space creates a new work organisation [7,8], and the virtualisation of economic processes enables access to and use of group intelligence by initiating, creating, and applying knowledge through informal knowledge networks (e.g., open innovation, communities of practice) and collective intelligence by developing and using knowledge obtained via informal knowledge-sharing networks such as open innovation, communities of practice, and expertise without the need for external professionals [9–11]. Smart factories create new human–machine relationships, especially when one thinks about the functions of business incubators [12–14]. The employee becomes a machine teacher first and, over time, the mentor and 'friend'.

The path to digital transformation in Industry 4.0 requires a change in the long-term strategy to the digitalisation of Industry 4.0, which necessitates implementation of change in the long-term strategic planning [15]. It means that leaders who would be able to run the organisation through these changes are necessary. One of the key elements of leadership is the understanding that relates to the company's situation, employees, and their emotions during the process of constant change. Without this competence, it will be extremely difficult to guide employees through a transformation that requires a substantial change of the form of work and used tools by many of them. Another competence of the leader is the ability to analyse data. A good leader needs to know how to obtain, verify, and use it in organisational practice. In addition to hard and digital competencies, good leaders should possess a number of soft features, such as creativity; assertiveness; reliability; ability to build relationships and cooperation; communicativeness; flexibility; ability to influence; self-organising; and self-navigating. Their competencies should also include the ability to think analytically, simulate and develop know-how, and overcome problems arising in unforeseeable situations as well as the ability to cope in unpredictable situations [16,17].

The outlined challenges and changes need further research on leadership and competencies of a 4.0 leader in the sectors that will be most affected by them. We claim that the combined heat and power plants industry (CHP) in Poland belongs to one of those sectors. On the one hand, the literature on leadership rarely links this area with the currently observed digital transformation. Moreover, analysing main international databases, we did not find publications about 4.0 leadership in the heat and power plants industry, whilst Walumbwa et al. [18] state that scientific discussion on leadership and digital transformation together is topical, important, interesting, and necessary. On the other hand, this sector is facing a lot of structural changes associated mostly with the requirements of environmental protection [19] and thus lowering its harmful impact on it. Decarbonisation [20] and implementation of the circular economy [21,22] become the top priorities. Under these circumstances, the role of the leader is even more important for the company's success. The leader's function becomes even more significant for successful operation of the company. Therefore, there is a cognitive gap between contemporary leadership practice and issues related to digital transformation [23]. Given these deliberations, the aim of our paper is to examine the relationship between leadership competencies (such as intellectual, managerial, emotional) and social dimensions with the 4.0 leadership effectiveness in the combined heat and power plant industry. Our empirical research is based on Leadership Dimensions Questionnaire (LDQ), which was developed and used by Dulewicz and Higss [24] to assess leadership style in the organisational context. In our research, we also analyse the effectiveness of leadership and its relevance to 4.0 Industry in the aforementioned sector, which is called 4.0 leadership effectiveness [25].

The main contribution of the paper is associated with the identification of leadership patterns in Industry 4.0 conditions in the organisation of the energy industry. Furthermore, the contribution of the paper is the usage of the fs/QCA method in the case of leadership competencies analysis.

The rest of this paper is structured as follows. Following this introduction, the second part of this paper describes the literature review on leadership 4.0. This is followed by materials and methods used in our analysis. In the next part, we present the main results of our research. Finally, we present the Discussion section and conclusions.

2. Literature Review

In today's economy, which is characterised by major technological advances, often referred to as Industry (or revolution) 4.0, new challenges arise for organisations and employees [6]. The role of humans is changing, as they increasingly interact with machines and robots, and the virtualisation of business processes makes the changes traceable. Access to Big Data, cloud computing, robotics and automation, collaborative robots (cobots), artificial intelligence, IoT, and IoS enable the initiation, creation, and application of knowledge that is to ensure high flexibility and efficiency of production [1]. There is no universal instruction on how to implement Industry 4.0. However, one can use certain frameworks, which are determined by basic technologies, e.g., the ones mentioned earlier [26–29].

In Industry 4.0, three types of relationships are the most important: people to people relations (P2P), people to machine relations or machine to people relations (P2M or M2P), and machine to machine relations (M2M) [30]. These relations and nexus of forces, such as the convergence of social media, mobility, and cloud computing to create new working conditions, together create the basis for cyber–physical working conditions [31]. Under these new circumstances, the profile of new leaders is being built, i.e., managers who have the ability to influence employee behavior in order to transform the enterprise into a smart factory.

It is not easy to define the concept of leadership. In our study, it is defined as a '*person's efforts toward the realisation of organisational goals*' [32]. Leadership is the ability to influence other people, inspire and motivate them, and manage their activities to achieve the goals of the organisation [33]. Therefore, some competencies are required for the successful performance of the leader's functions [34]. The leader's competencies and leadership style are key elements to achieve a company's success [35–37]. To be effective, leadership should be based on the leader's authority and power accepted by employees [38].

Leadership in Industry 4.0 has a clearly established direction, which is building cyber–physical systems functioning in a dynamic network of connections, and it is centered around a common object of interaction that is subject to constant reconfiguration depending on changing goals and conditions. To the very popular vision of its future, it is necessary to establish the directions of activities for the employees as the way of implementing Industry 4.0 solutions depends on their capabilities. Therefore, the leadership in this sector is about motivating and inspiring, as well as releasing energy in people to make the vision of a new future become a reality. Leaders must take full advantage of the capabilities and skills of all the employees to strive for Industry 4.0. In cyberspace, the implementation of leadership is facilitated by skills (leadership by skills), in particular, the increased importance of personal competencies (soft skills), because of the easy access to and accumulation of knowledge from various sources and places, almost without restriction. In the environment of Industry 4.0, the goals of many organisations are increasingly focused on creating an enterprise with strong smarts; therefore, leaders should also be open for changes and take risks in order to adapt and introduce changes. Managers, too, should be ready for change, accept it, and make risky choices, seeking to adapt to and initiate change [39,40].

A situational approach is still valid when building leadership. It assumes that the effectiveness of the leadership style depends on the specific situation. In other words, the way of influencing others should be adapted to the changing conditions of the organisation [41]. Leaders may obtain the desired behaviours from their employees by use of the appropriate leadership style in accordance with the specific situation. However, in Industry 4.0, the situational approach takes a broader meaning because there are opportunities for flexibility. Putting the values such as efficiency, flexibility, personalisation, quality, and originality into the forefront can bring organisations faster to Industry 4.0.

One should emphasise that the growth of the digital transformation requires new leadership skills, which are referred to in the literature as Leadership 4.0 or Digital Leadership. According to Oberer and Erkollar [42], digital leadership is a fast-paced, cross-sectional, team-oriented approach, with the emphasis on innovation. It is also a combination of digital competencies and digital culture that facilitates the introduction of changes and the use of new possibilities of digital technology. The personal competencies of a leader and the way of thinking, including the use of new methods such as design thinking, are regarded as a critical dimension for 4.0 leaders.

One should state that certain leadership attributes are universal and can be applied in any context, place, and time [43]. While many leadership traits are universally applicable, the specific requirements of the Industry 4.0 era cause organisations to adapt in a variety of ways, including in diverse ways such as the adaptation of specific leadership determinants and leadership competencies. Leadership styles for Industry 4.0 should be open guiding for learning and aimed at innovations as well as concentrating on knowledge improvement [44]. Industry 4.0 leaders should be self-organising managers who place especial emphasis on building trust and cooperation [45]. Characteristic features of 4.0 leaders are (1) making the right decisions even in the absence of complete information, (2) gaining the trust of the team by taking responsibility for the results achieved, (3) interpersonal skills, cooperation, and information sharing, and (4) critical thinking and conceptual skills [46]. In addition, as Albrecht [47] points out, new competencies in Leadership 4.0 are expected from executives, including lifelong learning, especially in the areas of digital technology, management skills, communication skills, cooperation skills, conflict resolution, and empathy. According to Zhu et al. [48], 4.0 leaders present five attitudes: (1) the Creative Leader, with a creative and innovative mind, formulates ideas in a given reality, (2) the Thought Leader, who can be tough in the face of market changes and competition, (3) the Global Visionary Leader, who is willing to cooperate and able to guide any change, (4) the Inquisitive Leader, with the ability to learn and deal with complex and dynamic changes, and (5) the Profound Leader, with in-depth knowledge and understanding enabling the interpretation and synthesis of information in decision making.

Gunzel-Jensen et al. [49] suggest that digital leadership is about transactional, transformational, and innovative behavior. In turn, Hüsing et al. [50] define digital leadership or e-leadership as managing human resources, changing the mindset of leaders, and using ICT (Information and Communications Technology) to achieve set goals. Furthermore, Sow and Aborbie [51] similarly suggest that adopting of such behaviour (style) may lead to success when implementing big-scale digital technologies. Then, one may state that digital leaders have a lot of options and can use one (or more) leadership approaches. In addition, different leadership styles can involve a number of other specific approaches.

Research of the ASTOR provides knowledge about the evolution of leadership in terms of building employee engagement, focusing on the picture of 'humane leadership' and 'a leader without limits' or a person with evident soft skills and a true passion who is ready for 'big tasks' by inspiring, supporting, and showing general directions of building Industry 4.0 in a company [52]. The emphasis is put on inspiring; hence, another term is used: 'inspirational leader' [53]. In studies posted on the World Economic Forum website [53], it is pointed out that leadership is the key element of strategic intelligence, and a leader's immediate environment creates technology leadership (e.g., artificial intelligence, cybersecurity, digital communications, and other technologies of the fourth industrial revolution). One should also state that people involved in the effort to build Industry 4.0 through leadership should adopt a knowledge orientation/knowledge-oriented leadership [54]. In Industry 4.0, job design can help the organisation adjust according to the specifications of the business environment characterised by change and innovation [55]. Innovations are at the core of the knowledge orientation; therefore, in the new environment, leaders should inspire employees to build dynamic capabilities for innovation [56].

Leadership styles need to be combined. It is especially important to combine the transformational style and transactional style [57,58]. Both styles enable leadership that is strongly oriented toward the knowledge and innovation of Industry 4.0 (Figure 1).

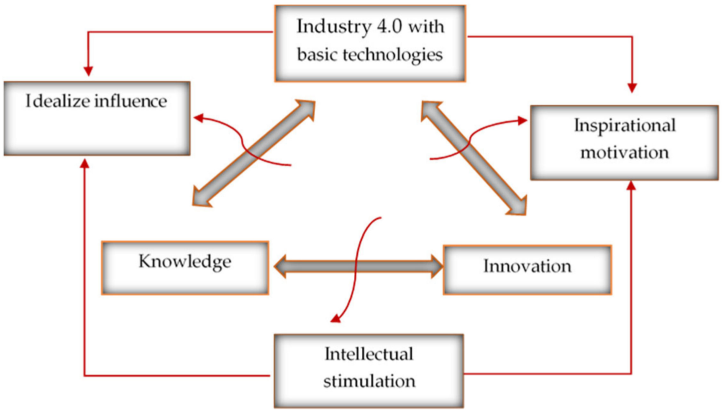

Figure 1. Framework of leadership leading to the compatibility with Industry 4.0. Source: own study.

The deliberations presented indicate that the issue of leadership in the conditions of Industry 4.0 is a complex matter that is analysed from different perspectives and different points of view. The problem still evolves, and new approaches appear all the time. The researchers add new competencies that should be possessed by the 4.0 leaders. It is the result of the dynamic nature of Industry 4.0. For example, one also underlines authenticity as a characteristic of the Industry 4.0 leader. This is because it is difficult to inspire employees to implement Industry 4.0 projects if they themselves are not authentic in these activities. Of course, the authenticity of a leader must be adapted to the conditions in which the leader operates [59]. Key characteristics of authenticity can include knowledge of key Industry 4.0 technologies and the ability to use tools to influence employees [60]. This may not seem like enough, so each environment should identify the authenticity traits of the leader. However, authenticity alone is not enough, and Herold [61] goes even further, describing the leader in Industry 4.0 as a 'networked leader'. One should remember that many powerful leaders are an element of a larger team (huge supply networks). The leaders contact the employees of many companies in the value chain, such as other producers, distributors, consumers, service suppliers, government representatives, project office staff, and R&D staff and other institutions [62–64]. Some powerful leaders also work in smaller teams (e.g., industrial heat, power). Therefore, the core competencies, beside the ones characterised for the managers, also include supervisory skills [65]. These facts confirm the complex nature of the phenomenon. Nevertheless, there is no doubt that the skills of the leader are acquired together with professional experience.

In our paper, we concentrated on the Polish heat and power industry. Related industries also operate in other European Union countries. For example, it is worth mentioning the Finnish CHP (heat and power) industry. Finland is a leader in the combined production of heat and power. CHP plants are built in Finland for financial gains. The high acquisition cost of the energy is connected with increased profitability for companies and also communities to invest in cogeneration, which saves energy. The achievement of high-efficiency CHP facilities is connected with the use of expensive, as well as inferior, fuels [66]. Digitalisation and decarburisation influence the increased use of CHP in Finland. A significant part of heated building stocks which are situated in cities, towns, and densely populated municipalities are now connected to district heating network. CHP electricity now accounts for one-third of Finland's electricity production. The Finnish long-term strategy aims to achieve decarbonisation of the current building stock by 2050. The targets that are taken into consideration are used to build additional policy measures required to decarbonise the Finnish building industry [67].

ICT plays a very important role in the CHP industry nowadays. For example, its role is evident in the process of initiating and enabling EU to fulfil its energy environmental targets. ICT can provide a very good basis, which is useful to achieve efficient energy strategies and evaluation of it is implementation. In addition, ICT technology can address the complexities in the case of measuring energy performance at a system level. In this situation, one can use appropriate software tools that can provide useful information and data on how to better configure the various elements of the whole system to optimise it. The optimisation of the system can be used to achieve a better level of overall energy performances in a cost-effective way [68]. For example, ICT technology can be used to forecast energy consumption. Andre describes the case of total consumer power forecasting using ITC methods [69].

The implementation of ICT in the CHP industry can be done in several ways. Smart grids belong to the most important methods of its implementing. Smart grids and also smart power systems can have a major impact on improving energy distribution and optimising energy usage. New, advanced components used in grids are useful for more efficient energy supply, better availability, and reliability of power. Those components can include conductors and improved electric storage components. Other components are advanced power electronics and new materials. There are also smart sensors and smart sensors networks in the CHP industry. Those sensors are used along the grids as transformers and substations [70–72]. One should also add that a new form of producer and customer is built, i.e., "prosumer". Although, the term "prosumer" has been in operation since the 1980s (Alvin Toffler's dictionary, 1980) [73], in the CHP industry, it is more and more popular. The policy of green economy and global trends of sustainability cerate the instruments for producers and consumers to be prosumers. The industrial age with new technologies of Industry 4.0 create a Cyber–Physical System (CPS) with different forms of energy for industries (toward Renewable Energy Sources, RES) [74]. Cooperation structures in industry (coopetition networks) [75] are sources of knowledge in the field of productivity and resources intensity. In modern markets, there are strong cooperative relationships in the field of energy saving in particular sectors of industries.

3. Materials and Methods

3.1. Basic Assumptions and Research Model

Based on research conducted by Dulewicz and Higss [24] and a critical literature review, we selected the following factors of leadership in our study: (i) intellectual; (ii) managerial; (iii) emotional and social dimensions which influence 4.0 leadership effectiveness (Figure 2).

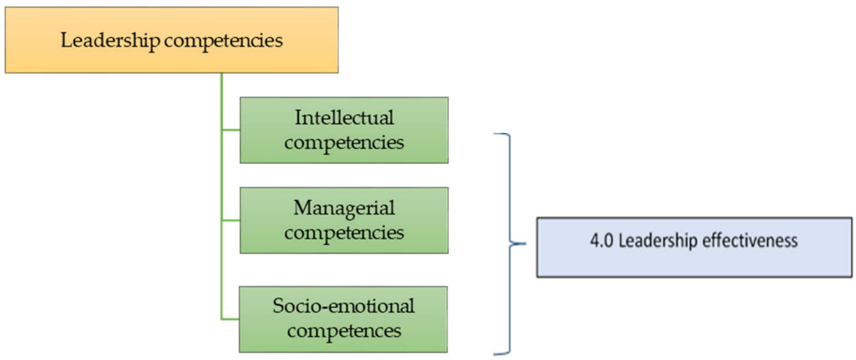

Figure 2. Diagram of the research model based on key structure of leadership competencies. Source: Own study.

3.2. Variables

Table 1 shows the key variables used in our study. In our research, we used the Leadership Dimensions Questionnaire (LDQ) by Dulewicz and Higgs (2004) [24]. The LDQ comprises three competencies: intellectual (Cronbach's alpha = 0.83), managerial (Cronbach's alpha = 0.81), emotional and social (Cronbach's alpha = 0.76) dimensions. The definition and operationalisation of each dimension are presented in [24].

Based on research conducted by Sarwono and Bernarto (2020) [25] and Ansari et al. [76], 4.0 leadership effectiveness was measured with two dimensions: managers' performance and workers' satisfaction (Cronbach's alpha = 0.82). To measure managers' performance, a four-item scale was used, which was developed on the basis of 4.0 leader performance indicators, which are also proposed by other authors e.g., [77,78]. Example items are 'My leader always asks input before making a decision' and 'My leader has the ability to trigger a change in this company'. Workers' satisfaction was measured with a three-item scale adapted from Mulki et al. [79]. Examples of items are 'We are satisfied with the fairness demonstrated by our leader' and 'We are satisfied with the promises that are always delivered by our leader'. All the items were measured on a 5-point Likert scale where 1 means strongly disagree and 5 means strongly agree. All the items used to assess leadership competencies and leadership 4.0 effectiveness in the heat and power plants industry are presented in Appendix A.

Table 1. Key variables used in the research.

<table>
<tr><th colspan="2">Variables</th><th>No. of Items</th><th>References</th><th>Cronbach's α</th></tr>
<tr><td colspan="5">Leadership competencies</td></tr>
<tr><td rowspan="2">Intellectual competencies</td><td>1. Critical analysis and self-vision</td><td>7</td><td>The Leadership Dimensions Questionnaire (LDQ) Dulewicz, Higgs (2004) [24]</td><td>0.83</td></tr>
<tr><td>2. Strategic perspective</td><td>4</td><td></td><td></td></tr>
<tr><td rowspan="3">Managerial competencies</td><td>1. Communication, managing resources, and achieving</td><td>5</td><td>The Leadership Dimensions Questionnaire (LDQ) Dulewicz, Higgs (2004) [24]</td><td>0.81</td></tr>
<tr><td>2. Developing team</td><td>2</td><td></td><td></td></tr>
<tr><td>3. Empowering team</td><td>4</td><td></td><td></td></tr>
<tr><td rowspan="4">Socio-emotional competencies</td><td>1. Self-awareness and intuitiveness</td><td>4</td><td>The leadership dimensions questionnaire (LDQ) Dulewicz, Higgs (2004) [24]</td><td>0.76</td></tr>
<tr><td>2. Sensitivity</td><td>2</td><td></td><td></td></tr>
<tr><td>3. Influence (including motivation and conscientiousness)</td><td>5</td><td></td><td></td></tr>
<tr><td>Outcome</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">4.0 Leadership effectiveness</td><td>1. Managers' performance</td><td>4</td><td>Ansari et al. (2004) [76]</td><td>0.82</td></tr>
<tr><td>2. Workers' satisfaction</td><td>3</td><td>Mulki et al. (2015) [79]</td><td></td></tr>
</table>

Source: own study.

3.3. Sample

The research sample included employees and managers from seven CHP plants in the Silesia region in Poland. In order to obtain the data for the survey, a peer review and pilot survey were conducted prior to the study. The selection of the sample was based on personnel from departments that have a direct impact on the operation of the CHP plant. The majority of these managers participating in the survey had many years of experience. Data were collected for the last quarter of 2019 and for January and February 2020. The field study includes information from 232 surveys with employees and managers of these plants. After excluding incomplete surveys, the data for analysis include 188 valid surveys, representing a response rate of 81.03%. The basic characteristics of the sample are illustrated in Table 2.

Table 2. Characteristics of the research sample. Source: own study.

Firm Level	CHP Plant age	≤20 (14.3%) 21–30 (57.1%) ≥31 (28.6%)
	Legal form	Joint-stock company (71.4%) Limited liability company (28.6%)
	Technical data	Thermal power: ≤380 MWt (42.9%) 390–475 MWt (42.9%) >475 MWt (14.2%) Electric power: ≤100 MWe (42.8%) >100 MWe (57.2%)
Respondent Level	Age	Mean: 58.3 years
	Gender	Female (13%) Male (87%)
	Position	Management positions (68%) Other employees (32%)
	Working experience of respondents	≤10 years (19%) 11–20 (29%) More than 20 years (52%)

CHP plants were chosen based on random selection. We have chosen a random sample of CHP plants and in each plant random sample of employees and managers according to the amount of employment size in each plant. The survey reliability has been checked using Cronbach's alpha test. The test values were sufficient to decide that the survey is reliable and can be used in the research.

3.4. Method

This study uses a fuzzy-set qualitative comparative analysis (fs/QCA), i.e., a set-theoretic technique that enables the analysis of the constellations of the causal conditions that lead to 4.0 leadership with high effectiveness. The primary purpose of fs/QCA is to show some patterns supporting the existence of causal relationships rather than to prove them [80–83]. In this type of analysis, causal patterns are tracked by focusing on the relationships between subsets. In fs/QCA, 'Boolean algebra' is used to derive some simplified expressions leading to the analysed outcome [84]. Importantly, unlike regression and correlation methods, in which linearity is assumed, fs/QCA takes into account equifinality and the interrelationships of variables, enabling the obtaining of outcomes resulting from a wider range of studies. This technique refers to scenarios in which '*a system can reach the same final state from different initial conditions and by a variety of different (or multiple) paths*' [85]. This study follows the assumptions of the QCA method regarding the requirements for complex causality and non-linear relationships. For this purpose, the fs/QCA program was used, which defines the interrelatedness between 4.0 leadership effectiveness and leadership competencies configurations.

In this study, fs/QCA was first used to assess the attributes that make up subsets of leadership competencies, and in the next step, it identifies combinations of conditions (leadership competencies) that are associated with high leadership 4.0 effectiveness. To reduce a large number of complex causal conditions to a limited set of configurations leading to the outcome that is in the field of our research, fs/QCA uses Boolean algebra and certain algorithms. According to the research of Ragin [85] and Schneider and Wagemann [80], fs/QCA has three phases. The first phase deals with the calibration of conditions (leadership competencies) and the outcome. The variables describing the conditions and the outcome were coded to be included in the analysis on a continuous scale from 0 to 1. Subsequently, a direct coding method was utilised to code individual case data points.

As Ragin [85] points out, the direct method is based on three qualitative anchors that determine the degree of membership to the focus set. These are (1) the threshold for full non-membership; (2) the threshold for full membership; and (3) the crossover point, where there is some ambiguity about membership.

For most calibration needs, the calibration function available in the fs/QCA program is sufficient, where one of the flexible function classes for the concept of positive endpoints is given in Equation (1).

$$\mu_s(b) = \begin{cases} 0 & \text{if } \tau_{ex} \geq b \\ \frac{1}{2}\left(\frac{\tau_{ex}-b}{\tau_{ex}-\tau_{cr}}\right)^p & \text{if } \tau_{ex} < b \leq \tau_{cr} \\ 1-\frac{1}{2}\left(\frac{\tau_{in}-b}{\tau_{in}-\tau_{cr}}\right)^q & \text{if } \tau_{in} < b \leq \tau_{cr} \\ 1 & \text{if } \tau_{in} \geq b \end{cases} \quad (1)$$

The variable b is the base variable, the threshold for full exclusion from the set S is denoted by τ_{ex}, the crossover threshold at the point of maximum ambiguous membership in the set S is denoted by τ_{cr}, and τ_{in} denotes the threshold for full inclusion in S. The degrees of concentration and dilation are controlled by the parameters p and q.

In our study, for each outcome and conditions (leadership competencies and 4.0 high leadership effectiveness), the observed scores that fall within the 90th percentile are considered to represent full membership. The complete absence of members, full non-membership, is indicated by the 10th percentile as the threshold value, and the crossover point is the median. Table 3 presents the process of calibration and transformation into fuzzy terms, both of the outcome—4.0 high effectiveness of leadership, and the conditions—leadership competences.

Table 3. Calibration of outcome and conditions into fuzzy sets. Source: own study.

Outcome and Conditions	Coding	Threshold Values		
		Full Non-Membership (0.05)	Crossover Point (0.5)	Full Membership (0.95)
4.0 Leadership effectiveness	L	0.23	2.34	4.31
Intellectual competencies	I	0.30	3.06	5.29
Managerial competencies	M	0.24	2.49	4.81
Socio-emotional competencies	S	0.30	3.05	5.78

The second phase of research includes an analysis of necessary conditions.

The necessity analyses moved from observing values under the outcome set Y—written Y{ν_1}—to observing values in the condition set X—written $\mathbf{X}\{\nu_1\}$. To perform a necessity inclusion analysis, the key question remains the extent to which objects are members of $\mathbf{X}\{\nu_1\}$ and Y{ν_1} relative to their overall membership in Y{ν_1}. In the case where the necessity inclusion is sufficiently large, this implies that the proof is consistent with the hypothesis that $\mathbf{X}\{\nu_1\}$ is necessary for Y{ν_1}. The formula for determining the necessity inclusion $Incl_N(\mathbf{X}\{\nu_1\})$ is presented in Equation (2).

$$IncI_N(\mathbf{X}\{v_1\}) = \frac{\sum_{i=1}^{n} \min(\{v_1\}x_i, \{v_1\}y_i)}{\sum_{i=1}^{n}\{v_1\}x_i} \quad (2)$$

A condition is necessary when its consistency score exceeds the threshold value of 0.9 [78]. In this study, due to the necessity test conducted, it was found that no condition exceeded the consistency threshold of 0.90 for the necessity condition. The next analytic phase is a sufficiency analysis, considering causal configurations of conditions and the outcome, which are explained in turn by truth tables.

The sufficiency analyses moved from observing values under X to observing values under Y. To perform a sufficiency inclusion analysis, a key question remains the extent to which objects are members of $\mathbf{X}\{\nu_1\}$ and $Y\{\nu_1\}$ relative to their overall membership in $\mathbf{X}\{\nu_1\}$. If the sufficiency inclusion is high enough, it means that the evidence is consistent with the hypothesis that $\mathbf{X}\{\nu_1\}$ is sufficient for $Y\{\nu_1\}$. The formula for determining the sufficiency inclusion $Incl_S(\mathbf{X}\{\nu_1\})$ is presented in Equation (3).

$$IncI_S(\mathbf{X}\{v_1\}) = \frac{\sum_{i=1}^{n} \min(\{v_1\}x_i, v\{1\}y_i)}{\sum_{i=1}^{n}\{v_1\}x_i} \tag{3}$$

A classic instrument for analysing sufficiency relations is the truth table. This table is a key tool in fs/QCA and contains 2^k rows (k is the number of causal conditions considered in the analysis). Each row in the table is a logically possible combination of conditions, not representing individual cases, but logical configurations strongly associated with an outcome (with three conditions, given $2^3 = 8$ logical configurations). The next step in the analysis is to reduce the number of rows in the truth table, where in the case of fs/QCA, this is done mostly with the Quine–McCluskey algorithm.

In turn, the causal conditions that are most closely related to the outcome are analysed. Which causal combinations distinguish these configurations is examined. Before this is done, configurations that are theoretically plausible but not empirically present, so-called logical remainders, are considered. Including them in the analysis leads to a complex solution. In turn, excluding them from the analysis allows for a parsimonious solution. Between them, there is also a third solution, the so-called intermediate solution that allows for the selective inclusion of logical remainders in the analysis [85]. It is worth noting that although logical remainders lead to different solution formulas, all these formulas are logically true, as they do not contradict the empirical data in the truth table [86]. The fs/QCA 2.5 software was used in this study. In this research, the parsimonious and intermediate solutions are analysed.

4. Results

The results from the parsimonious and intermediate solutions can be summarised using a configuration chart (Table 4). Based on the Ragin [85] and Fiss [87,88] notation system, the columns in Table 4 indicate the configuration of the conditions associated with the outcome, i.e., 4.0 leadership effectiveness. The presence of a condition is indicated by a full circle (•) and an empty space means 'don't care'. The large circles represent the core conditions, and the small ones represent the peripheral (or contributing) conditions. As indicated by the results, there are two alternative causal combinations or causal recipes which are numbered S1 and S2, respectively.

Table 4. Configurations for 4.0 leadership high effectiveness based on the CHP plants research sample.

Leadership Competencies	Solutions	
	S1	S2
Intellectual competencies	•	
Managerial competencies	⬤	⬤
Socio-emotional competencies		•
Consistency	0.89	0.91
Raw Coverage	0.51	0.63
Unique Coverage	0.01	0.13
Solution Consistency	0.91	
Solution Coverage	0.74	

Note: ⬤ = core causal condition present; • = peripheral causal condition present. Source: own study.

In short, consistency indicates the degree to which cases in which a condition occurs are compatible. Raw coverage measures the total coverage of a combination that can be covered with other combinations. Unique coverage reflects coverage that is uniquely through the combination. Solution consistency represents the degree to which membership in the solution is a subset of membership in the outcome. Finally, solution coverage expresses the combined coverage of all combinations aimed at an outcome [77]. Table 4 indicates that there is one core condition associated with 4.0 leadership high effectiveness in the heat and power plants industry, namely, the presence of managerial competencies in each of the two solutions. The results show that in terms of overall coverage, the solution accounts for 74% of membership in the outcome, which presents an acceptable fit. Furthermore, all two configurations show high consistency values: 0.89 in solution S1 and 0.91 in solution S2, with the overall solution consistency at 0.91. The overall solution for 4.0 leadership high effectiveness implies equifinality of solutions. As for the peripheral conditions related to 4.0 leadership high effectiveness, the analysis indicates that in solution S1, the core conditions are complemented by intellectual competencies and in solution S2 by socio-emotional competencies.

By applying set-theoretic analysis, it is possible to formulate the expression of statements using Boolean notation. In the current study, the outcome of interest is achieving 4.0 leadership high effectiveness (L), and the conditions of interest are intellectual competencies (I), managerial competencies (M), and socio-emotional competencies (S). The set of obtained results (X) using Boolean notation is presented in Equation (4):

$$(X)\text{: IM} + \text{SM} \rightarrow \text{L} \quad (4)$$

where the '+' sign represents the logical 'or'; the arrow is the logical sign of implication.

The first leadership competency configuration suggests the presence of high-level scores of managerial competencies and intellectual competencies (solution S1—column A in Table 4). The second configuration indicates the presence of managerial competencies and socio-emotional competencies (solution S2—column A in Table 3). From the two configurations leading to 4.0 leadership high effectiveness, managerial competencies are found to be pervasive and may offer initial evidence to managerial competencies as a necessary condition for 4.0 leadership high effectiveness in the CHP plants. The study also reveals that managerial competencies are not sufficient to predict 4.0 leadership high effectiveness in the CHP plants. Depending on the context, two other leadership aspects (intellectual and socio-emotional competencies) could be essential to explain the variation of 4.0 leadership effectiveness. It should be emphasised, referring to the research model presented in this study, that the analysed research results in defining the intellectual aspects of leadership are not based on traditional psychometric scores but use self-description in the following issues: 'critical analyses', 'self-vision', and 'strategic perspective'. The result also suggests a reasonably significant role of socio-emotional competencies as a 4.0 leadership high effectiveness predictor. Thus, 'self-awareness and intuitiveness,' 'sensitivity', and 'influence' seem to have an important effect on 4.0 leadership high effectiveness in the CHP plants. This result confirms the thesis that it is insufficient for an effective leader to be limited to managerial roles emphasising planning, organising, executing, and controlling, especially in the area of resource/team management. This discovery confirms the extended perspective of 4.0 leadership that takes into account at least three key aspects: intellectual, managerial, and socio-emotional competencies, which are in line with the leadership competency school of thought.

QCA enables the extension of the research and analysis of the inverse of the outcome, i.e., determining which configurations may lead to the low 4.0 leadership effectiveness or to the absence of 4.0 leadership high effectiveness. This analysis is an important advantage of QCA and enables the development of the concept of causal asymmetry [77]. In general, this concept indicates that the causal conditions or their configurations leading to the occurrence of the test outcome can often differ significantly from those that lead to the absence of that outcome [88]. Therefore, in this research, we additionally analysed both the lack of high 4.0

leadership effectiveness and the presence of low 4.0 leadership effectiveness. However, the analyses showed that none of the obtained configurations exceeded the acceptable level of consistency (threshold 0.75). This leads to a conclusion confirming the existence of causal asymmetry, with two configurations being sufficient for 4.0 leadership high effectiveness, but no configuration being associated with the absence of 4.0 leadership high effectiveness or 4.0 leadership low effectiveness.

The use of fs/QCA in the present study made it possible to adopt a specific perspective of analysis triangulation. Using a limited research sample, a systematic review of the cases included in the sample was possible. The study examined a current and interesting social phenomenon concerning a combination of variable conditions that affect the outcome under study, in this case, 4.0 leadership high performance [89–91]. In this study, this concept was presented for a set of data from the heat and power industry in which positive configurations can be achieved through the configuration of high managerial and intellectual competences or high managerial and socio-emotional competences.

5. Discussion

Many researchers have found the positive relation between personal competencies of the leader and the effectiveness of organisation, e.g., [9,25,59,77–79,92–96]. For example, Fraser has found that special personal skills of leaders have an impact on the effectiveness of managers in the construction industry [89]. In our study, we have analysed the relations between leader competencies and effectiveness of organisations in the heat and power plants industry. Our analysis has shown that one needs at least two types of competencies to successfully manage the CHP plants in Industry 4.0 conditions. The first one links managerial competencies with intellectual competencies, and the second one links managerial competencies with socio-economical competencies.

We found that the most important leader competencies in the analysed industry are the managerial competencies. Our results are in line with many other studies, for example [25,97–100]. However, not only the managerial competencies are important. The key to achieve success is the juxtaposition of various competencies. This juxtaposition is crucial for achieving the success in the Industry 4.0 environment for the CHP plants managers. As we found, the emotional and social dimension of leadership competencies are very important to achieve Leadership 4.0 effectiveness in the heat and power plants industry. These results are in line with previous findings of Bolte et al. [93]. The importance of social and especially cognitive skills was also pointed out by Guzman et al. [95]. According to their research, skills such as speaking and active listening are very important for leaders to communicate and also to disseminate information. This is especially important in digital and agile environments in the COVID-19 pandemic era when many business activities are fully digitalised and it is not easy to manage a team in fully remote work conditions.

We also found that intellectual competencies with managerial competencies can be a sustainable and sufficient combination for 4.0 effective leaders in the heat and power plants industry. This finding concurs with the results of Guzman et al. [95], who have found that many intellectual competencies are important for leaders. According to them, the important intellectual competence is the active learning skill needed to prepare and act in today's fully digital environment [96–100].

We analyse three groups of leadership competencies among managers in the heat and power plants industry: managerial, intellectual, and emotional. The best for the successful 4.0 leader in this industry would be to have competencies in all three dimensions, but is not always possible and it is not always easy. On the basis of our research, we found that is sufficient to concentrate on two of three dimensions: managerial and intellectual competencies or managerial and emotional competencies.

We think that intellectual and socio-emotional skills are very important among the 4.0 leadership skills. They can be useful in many aspects of Industry 4.0 implementation [39]. For example, the managerial training that aims at increasing many Industry 4.0-related skills is based on intellectual and socio-emotional skills [40,41]. We think that especially in education, those two types of skills are indispensable.

We found that the two combinations can be compared with the leadership 4.0 dimension proposed by Oberer and Erkollar [42]. They described the 4.0 leadership matrix with four dimensions: 4.0 social leadership, 4.0 digital leader, 4.0 freshmen leader, and 4.0 technological leader. We opine that our first combination (managerial and socio-economical skills) is similar to the 4.0 social leader dimension. The 4.0 leader should concentrate on the ability to create the appropriate atmosphere for employees within the organisation. The second combination (i.e., managerial and intellectual competencies) are similar to the 4.0 technological leader conception. Those types of leaders should concentrate on the ability to use the new technology in appropriate ways to deliver an increase of value to the organisation.

6. Conclusions

The key finding of our research was the juxtaposition of leadership skills that are indispensable for 4.0 leaders in the heat and power plants industry. Using the fuzzy-set qualitative comparative analysis (fs/QCA), we analysed not only particular variables, dimensions, and typical statistical relations between them, but we also revealed patterns about causal relationships between particular variables and dimensions. Based on our research, we found that a 4.0 leader in the heat and power plants industry should have two out of three potential leadership competencies: intellectual, managerial, and socio-emotional. Managerial competencies are the most important, as without them, it is not possible to be an effective leader in Industry 4.0 conditions. However, managerial competencies are not sufficient, and they should be supported by intellectual or socio-emotional competencies. It is not necessary to have all three types of competencies. The best for leaders in the heat and power plants industry is to have one of two types of combinations: managerial and intellectual competencies or managerial and socio-emotional competencies. The organisation in the heat and power plants industry should concentrate on those combinations in the process of recruiting potential managers.

The obtained results allow us to contribute not only to the development of theory in the context of the role of leadership competencies in companies operating in the conditions of Industry 4.0 but also to the practice thereof. Given the results achieved, our findings offer important implications for industrial practices by showing the mechanisms for improving organisational performance. Moreover, these implications can be applicable to a broader scope of organisational configurations. Moreover, it also opens the door for the further research in this area. For example, an interesting field of the research in the future can be the analysis of which of the two combinations analysed in the paper is better-adjusted to the industry conditions. Moreover, it could lead to research not only in the heat and power plants industry organisations but also others, especially the ones dealing with energy production.

The appropriate leadership is connected with the effectiveness of all CHP industry. In the case of the Finnish CHP industry, the positive effects of it are achieved among others because of appropriate leadership and leadership skills [101–103]. In addition, structural changes are happening in other CHP markets in European Union countries. For example, in Sweden, the trend is most evident, and we can spot the fast growth of wind power production and also nuclear power [104]. France is implementing CHP solutions as well, for example connected with wind power. France has ambitious targets in renewable energy—they want to achieve 32% of total national energy use from renewable resources and 40% of electricity from renewable resources by 2030 [105].

New technologies of Industry 4.0 build new relationships between people and machines [106–110], so new leaders are needed. In the energy and power sector, as in other key industrial sectors, Industry 4.0 technology is being implemented to improve efficiency and reduce resource intensity [107,108]. Leaders at the strategic level are expected to be creative in building Industry 4.0, while leaders at the operational level, i.e., technical staff above all, are expected to be able to apply technology [109,110]. Companies operating in different sectors require different skills of their employees, as these sectors differ in terms of the implementation of Industry 4.0 [111]. Each energy sector—the various sources of energy—has its own leaders; for this reason, the competence profiles are different, especially at the level of technical competence backed up by specialist knowledge. Trends of energy intensity are different in particular branches of industries [112].

Examples of skills are as follows [113]: (i) knowledge of working with technology related to the generation, delivery, and use of heat and power and operation with modern technology (including KETs—Key Enabling Technology Industry 4.0); (ii) working to improve knowledge of and ability to use computers, mathematics, and electric power and energy technologies; (iii) identifying energy (heat and power) savings opportunities and making recommendations to achieve more efficient operation; (iv) participation in development programs, assisting drafters in developing the structural design of products using drafting tools or computer-assisted design (CAD) or other equipment and software; (v) conducting technological and energy audits and conducting jobsite observations, field inspections, or sub-metering to collect data for energy (power) conservation analyses; (vi) analysis of information from basic systems (Information and Communication Technologies—ICTs); (vii) monitoring and analysing heat and power consumption and monitoring the progress of improvement programs of energy intensity and quality in manufacturing processes [114].

Many power leaders are part of the large team (huge supply networks). The leader contacts the employees of many companies in the value chain. The leader contacts producers, distributors, consumers, servicers, government representatives, project office staff and R&D staff, and other institutions [63,115,116]. Some power leaders also work in smaller teams (e.g., industrial heat, power).

Skills needed for teams in the energy sector include [113] (i) cooperation with large teams and working cooperatively with others; (ii) cooperation with engineers at different levels of the plant, e.g., mechanic, electrician, operators, designer, environmental engineer, quality control engineer; (iii) communicating effectively verbally and through writing and understanding the importance of hard work and having a positive attitude; (iv) anticipating what needs to be done and taking action to identify and solve problems in a systematic way; and (v) providing feedback to engineers on customer (stakeholder) problems and needs, with integrity and following the standards of the companies in the sector.

The core competences that are needed by engineers in this industry, in addition to technical (engineering) competence, are critical thinking, problem solving, print reading, project planning, teamwork, knowledge and application of new technologies, knowledge of legislative and regulatory functions and industry standards, troubleshooting, teamwork, communication skills, new project design, development of short- and long-term plans, and supervisory skills [65,117]. The skills of a leader are acquired together with professional experience.

Organisational change management is not efficient without gaining and sharing knowledge by the leaders of the enterprise. There is a constant need of improvement and of shaping competences and distribution of knowledge in the enterprise. Key programs and models of building knowledge are used in enterprises of particular benches of industries (e.g., SECI acronym: Socialisation, Externalisation, Combination, and Internalisation) [118,119].

In our research, we did not find the configuration consistently associated with the absence of 4.0 leadership effectiveness. It is also a very interesting field of future research, as the greater part of the international research concentrates on managerial competencies that are important for the leaders. There is a very small amount of research concentrating on analysis of leadership competencies with a negative impact on effectiveness. We did not find a study about negative leadership competencies in the Industry 4.0 environment. We think it creates a field for future research.

Of course, our study is not free of limitations. One of them is the size of the sample and the operationalisation of variables. The sample of the research was rather mediumsize because we could not obtain additional information from organisations from the heat and power plants industry. The analysis of the other particular branches (possible on larger samples) from that point of view could be a potential future field of research. The operationalisation of variables is only one of many possible solutions. Despite these limitations, we believe that our study presents the real picture of the situation in the analysed industry.

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Appendix A. Measurement Items for Leadership Competencies and 4.0 Leadership Effectiveness in the Heat and Power Plants Industry

Intellectual competencies
Critical analysis and vision

1. My leader has a critical faculty that probes the facts, identifies advantages and disadvantages, and discerns the shortcomings of ideas and proposals.
2. My leader makes sound judgments and decisions based on reasonable assumptions and factual information, and is aware of the impact of any assumptions made.
3. My leader is imaginative and innovative in all aspects of one's work.
4. My leader establishes sound priorities for future work.
5. My leader has a clear vision of the future direction of the organisation to meet business imperatives.
6. My leader anticipates the impact of external and internal changes on one's vision that reflect implementation issues and business realities.
7. My leader sees the wider issues and broader implications.

Strategic Perspective

8 My leader explores a wide range of relationships and balances short- and long-term considerations.
9 My leader is sensitive to the impact of one's actions and decisions across the organisation.
10 My leader identifies opportunities and threats.
11 My leader is sensitive to stakeholders' needs, external developments, and the implications of external factors on one's decisions and actions.

Managerial competencies
Communication, managing resources and achieving

12 My leader clearly communicates instructions and vision to staff.
13 My leader's communication style expresses approachability and accessibility.
14 My leader plans ahead, organises all resources, and coordinates them efficiently and effectively.
15 My leader regularly and effectively monitors and evaluates staff performance and provides sensitive and honest feedback.

16 My leader selects and uses actions that bring the greatest benefit to the organisation and increase productivity.

Developing team

17 My leader believes that others have the potential to take on ever more-demanding tasks and roles and encourages them to do so.
18 My leader develops subordinates' competencies and invests time and effort in coaching them to work effectively and grow.

Empowering team

19 My leader knows the strengths and weaknesses of his direct reports.
20 My leader gives autonomy and encourages them to take on personally challenging and demanding tasks.
21 My leader encourages problem solving, innovative ideas and proposals, and the development of his vision for his area and the wider vision for the company.
22 My leader encourages a critical faculty and a broad perspective and encourages the challenging of existing practices, assumptions and policies.

Socio-emotional competencies
Self-awareness and intuitiveness

23 My leader has an awareness of one's own feelings and the ability to recognise and deal with them in a way that gives them a sense of control.
24 My leader has a degree of confidence in his or her ability to manage emotions and control their impact in the work environment.
25 My leader arrives at clear decisions and drives their implementation when presented with incomplete or ambiguous information.
26 My leader uses both rational and 'emotional' or intuitive perceptions of key issues and implications.

Sensitivity

27 My leader is aware of the needs and views of others and takes them into account when making decisions and proposing solutions to problems and challenges.
28 My leader demonstrates a willingness to think openly about possible solutions to problems and to actively listen to and consider the reactions and contributions of others.

Influence (including motivation and conscientiousness)

29 My leader persuades others to change views based on an understanding of their position and a recognition of the need to listen to this perspective and provide a rationale for change
30 My leader has the drive and energy to achieve clear results and make an impact and, also, to balance short- and long-term goals with a capability to pursue demanding goals in the face of rejection or questioning.
31 My leader balances the needs of the situation and task with the needs and concerns of the individuals involved.
32 My leader demonstrates a clear commitment to the chosen course of action in the face of challenges and matches 'words and deeds' in encouraging others to support the chosen direction.
33 My leader demonstrates a personal commitment to finding an ethical solution to a difficult business issue or problem.

Leaders' performance

34 My leader has the ability to trigger a change in enterprise in the heat and power industry.
35 My leader has had a significant impact on increasing networking with other enterprise.
36 My leader has had a significant impact on increasing effectiveness in enterprise in the heat and power industry.

37 My leader has had a significant impact on increasing profitability in enterprise in the heat and power industry.

Workers satisfaction

38 We are satisfied with facilities provided by our leader.
39 We are satisfied with the fairness demonstrated by our leader.
40 We are satisfied with the promises that always delivered by our leader.

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