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Industrial Energy Management Systems and Energy-Related Decision-Making

Aida Sa [1,*], Patrik Thollander [2] and Majid Rafiee [1]

[1] Department of Industrial Engineering, Sharif University of Technology, Tehran 11155-9414, Iran; rafiee@sharif.edu

[2] Department of Management and Engineering, Division of Energy System, Linköping University, 58183 Linköping, Sweden; patrik.thollander@liu.se

* Correspondence: aida.salimnezhad@sharif.edu; Tel.: +98-914-616-0053

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Abstract: Transitions is today's debate in almost all topics both in academia and practice. Energy transitions among others, have received relatively more attention, due to the global demand for increasing energy efficiency and lowering environmental impacts. In recent decades, energy management systems, through implementing energy management programs and related practices within industrial companies, have played a vital role in enhancing industrial energy efficiency performance levels. However, still there are problems at very first step of energy management program installation, which is decision-making. Despite market and non-market failures, lack of information, inadequate knowledge, the consequent increase in the perception of risk and uncertainty can be addressed as potential reasons for mentioned problems. Another essential reason can be explained through how an energy program is characterized by people who are attending at an energy-related decision desk. Keeping in mind that allocation of the budget for any investment should not only have financial conformation, but also a strategic value for the company, this paper aims to discuss the impacting parameters on industrial energy-related decision-making and behavior patterns with respect to the critical role of industrial energy management systems.

Keywords: energy management system; energy management; industry; decision-making; Sweden

1. Introduction

Change has its own price that needs to be paid, and the very first step to this is making decisions to maintain continuous improvement. Transitions through innovation to make better decisions at different levels and to strengthen the organization's position in a competitive business world guarantee the success of projects and the earning value, and at the same time, improve the society's prosperity [1]. The design of decisions is a multi-criteria pattern that is always influenced by social, national, and international concerns, and some level of uncertainty. Uncertainties can be caused by variations of data toward various assessment methods. Moreover, the preferences of decision makers in weighting the criteria are another source of uncertainty to determine the accuracy level of the adopted energy system. Today's multi-dimensional energy plan scenarios, which are dealing with multiple objectives, criteria, and definitions, have made it difficult to sustain a system with perceptions. Making decision for an organization's energy system is not simply about maximizing or minimizing a particular element, but about multi-criteria decision making (MCDM) [2]. Many studies, through using different methods have aimed to evaluate energy systems, i.e., energy cost evaluation, thermodynamic method, and life cycle method [3]. However, these methods use a single index attempt to evaluate the energy system performance levels, and the recognition of the impacting factors in formulating such systems according to the organization's own perspective remains unattended (it should be noted that energy management

systems and related decision making events are focused on parameters that have impacts on industrial energy related decision-making and behavior, rather than using the MCDM method to propose an optimized model [4,5]. Even though this perspective is related, this paper aims to study the energy management system and impacting factors on implementing EnM practices. Proposing an optimized model for an EnMS (energy management system) is an area for future research to explore.

Increasing environmental concerns and consequently the energy related issues during the 1970s and 80s have had an impact to a great extent on developing new policies and strategic decisions to reduce energy waste, and to use it in smart and efficient ways. Reducing energy use by 20% through a 3.3% annual reduction in energy intensity for each EU member is an example of enforcing policies of energy efficiency (EE). The industrial sector, as one of major energy users [6], receives great consideration for improving its energy-related profile. This therefore, has caused increasing concern for understanding the energy status and the barriers to and the drivers for the implementation of EE programs within the company. Following that, the importance of recognizing the parameters to be included in decision making process and developing a strategy through implementing an EnMS according to each company's complexity and character, is still growing. The energy transition achievement will rely not solely on the installation of new and innovated energy-related technologies, but also on the major and in some cases radical changes in the individual's energy-related decisions and behavior patterns, resulting in a remarkable decrease in energy demand [7]. Moreover, the importance of good decision-making for managers has numerous representatives, but the questions are based around how we provide the guidance, which kinds of new knowledge and which impacting factors in decision-making matter more, in order to assist managers to be more efficient and smart in making decision [1]. To this end, this paper tries to discuss the parameters that have impacts on industrial energy related decision-making events and behaviors.

2. Energy Management System

In EE literature, energy management (EnM), through its practices and its systematic approach, is recognized as a supporting function for the industrial energy system. Despite the great potential, EnM is not fully applied in practice. This reason can be explained through the interdisciplinary nature of EnM, due to involvement of multiple criteria and knowledge, such as technological, political, social, financial, and managerial aspects. Moreover, all of the practices and processes to improve EE, which is embedded within an EnM program, needed to be implement and supervised. To this aim, it is of importance to have an implemented EnMS that maintains the mentioned desires, and this is a step that is misunderstood in majority. The interaction of researchers and practitioners to cover the mentioned gap calls for further investigation.

Energy-related decision-making literature can be seen through two major perspectives. A number of scholars [8–11] argue about the importance of financial conformation for any investment, including EE programs. However, some others [12–15] believe in the critical role of contextual factors, e.g., knowledge and mindset, as well as external elements such as policy and energy price. Meanwhile, earlier researchers [13–19] have addressed the importance of strategic links between any investment with the organization's core business and goal. Nowadays, the critical and impacting role of EnM to improve the industrial EE from an engineering perspective is understood more clearly than before. However, how to put this in practice through theoretical models and understanding the difference between EnM and energy management system (EnMS) calls for further research, in order to develop a clear understanding [20]. According to [21], EnM can be defined as the procedures by which a company works strategically on energy, while an EnMS is a tool for implementing these procedures. Developing EnMS, therefore, can be an essential solution to extend improvements in the industrial sector. Nevertheless, the strategic role of top managers, people who decide for such changes and implementations, to maintain this system within the company is crucial, and it should not be under-estimated. To be sustainable in energy related strategies, companies need to stablish a management system [22] in which they could define a policy and a set targets, identify key

performance indicators for EE in their organization, and finally are committed to implementing the adopted EE programs. The more strategic the implementation, the more EE improvement and financial performance would bring for the organization.

3. Methodology

Reviewing the literature and communicating with key personnel to identify and classify the most commonly used parameters and the related weights for decision making have been conducted accordingly. On January 2018, 15 requesting emails were sent to industrial companies located in Sweden. A total of 10 out of 15 companies showed interest in participating within the research. A mixture of a structured questionnaire and an interview was used to validate the EnMS and decision-making structures of 10 Swedish energy-intensive industrial companies. The companies were medium and large in size (five companies from each size). Questions were classified into three main sections, namely: (1) Companies' environmental strategies and motives for implementing EE practices; (2) EnM use case assessment (industry's requirements); and (3) Decision-making support and investment behavior. Moreover, questions related to the integration level of the EnM into the company and the promotion of the efforts and celebrations of success are asked from the interviewees. A Likert scale was used to analyze the respondents' answers. The scale was expanded from 1 to 7 (1 = Strongly Disagree, 4 = Neither Agree nor Disagree, 7 = Strongly Agree) for the first section, and (1 = Irrelevant, 4 = somewhat relevant, 7 = highly relevant) for the second section, and (1 = not at all, 4 = moderately, 7 = great extent) was used to rank the questions in section three. The outcome of this study exploited conclusions concerning the main parameters to be considered, along with evaluation of the decision-making parameters leads amongst others, to boost the choices for maximizing the continuous EE enhancements within industrial sectors.

4. Results and Discussion

4.1. Companies' Environmental Strategies and Motives for Implementing Energy-Efficient Practices (EnMS Assessment)

Characteristics of EE measures have significant impacts on companies' EnM program adoption rates [23]. Table 1 delivers the results on the opinion of the top manager and the energy manager of studied companies, about their environmental strategy and motives. The results show that there is a difference between large- and medium-sized companies in considering the voice of the customer, governmental regulation, social responsibility, competitors, and the reduction of environmental impact through setting the energy strategy of the company. These differences, which can be seen in Table 1 and more precisely in Figure 1, for large size companies, showed up with high importance in comparison to medium size companies, and they can be explained, especially for governmental regulation and social responsibility, through relatively high pressure from government on large companies comparing with small- or medium-sized companies in industry. For both sizes, it is evident that they ranked low ratings for competitors in their sector. The reason can be explained through lack of information and/or sharing of success stories in the field [19].

Table 1. Results for energy management system assessment (EnMSA) for both medium- and large-sized companies (1 = Strongly Disagree, 4 = neither Agree nor Disagree, 7 = Strongly Agree).

		Medium Size							Large Size				
Strategies and Motives	**Code**	**A**	**B**	**C**	**D**	**E**	**Tend to**	**Tend to**	**F**	**G**	**H**	**I**	**J**
Receiving support from the top manager(s)	EnMSA1	7	7	6	7	7	6.8	6.4	7	6	6	7	6
Environmental concern	EnMSA2	5	4	5	4	4	4.8	4.8	4	5	6	4	5

Table 1. *Cont.*

		Medium Size							Large Size				
Strategies and Motives	**Code**	**A**	**B**	**C**	**D**	**E**	**Tend to**	**Tend to**	**F**	**G**	**H**	**I**	**J**
Voice of customer	EnMSA3	3	5	2	3	3	3.2	5.8	6	6	5	6	6
Governmental regulation	EnMSA4	4	5	4	4	4	4.2	6.2	7	6	6	6	6
Increasing market share	EnMSA5	7	7	7	7	7	7	6.4	7	6	7	6	6
Cost saving	EnMSA6	5	6	6	5	5	5.4	6.4	6	7	7	6	7
Increase in sale	EnMSA7	5	4	5	5	4	4.6	4.8	5	5	4	6	4
Social responsibility	EnMSA8	2	3	4	2	2	2.6	4.6	4	4	5	5	5
Competitors	EnMSA9	1	2	1	3	2	1.8	3	3	3	2	4	3
Energy efficiency as an integrated factor within company's strategy	EnMSA10	6	6	5	6	6	5.8	5.4	6	5	5	6	5
Reduce environmental impact	EnMSA11	3	3	3	4	3	3.2	6	5	7	6	6	6

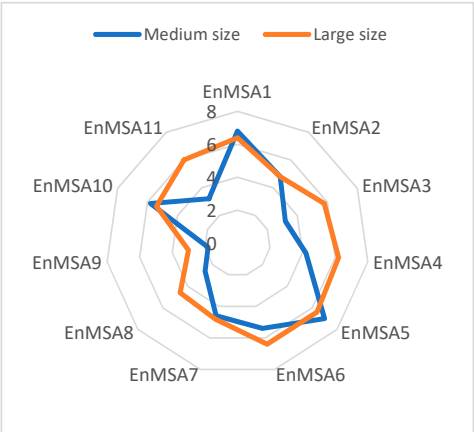

Figure 1. Comparing the results extracted from Table 1.

4.2. Energy Management Assessment

EnMS, as an efficient and robust tool in overcoming the barriers for implementing EE programs, has requirements for implementation within companies. The most important requirements extracted from the literature and listed below (Table 2), were asked and ranked, from the view of the relevance of such factors to each organization, from 1 to 7 (1 = Irrelevant, 4 = somewhat relevant, 7 = highly relevant). The results in Table 2 and, more clearly, in Figure 2 illustrate that the sample companies differ in paying attention to the EE of the companies' building envelope, in the time monitoring system, the existence of a full-time energy manager, using smart grids, calculation of energy costs, identifying significant deviations, monitoring of the energy footprint of production, implementation of a certified energy management system, and forecasting the future carbon emission trading and energy demand. However, this difference for some cases (e.g., EnMA2, EnMA4, EnMA11, EnMA12 and EnMA14) was relatively high between both sized companies. EE improvement targets will not be achieved through only upgrading the technology [24]. It is vital, therefore, to look at energy-related targets as a system. Only through systematic efforts can measurement organizations achieve considerable improvements. This system needed to include all aspects from suppliers, the building envelope, and processes to any small tasks and energy-related behavior within an organization. Energy targets should be seen as a systematic and continuous task. It is like a chain by which the following step depends on the previous one, and vice versa.

Table 2. Results of energy management assessment (1 = Irrelevant, 4 = somewhat relevant, 7 = highly relevant).

Size		**Medium Size**							**Large Size**				
Use Case	**Code**	**A**	**B**	**C**	**D**	**E**	**Tend to**	**Tend to**	**F**	**G**	**H**	**I**	**J**
Improvement of the energy efficiency of process machinery	EnMA1	7	6	6	7	7	6.6	6	5	6	7	6	6
Energy efficiency of buildings	EnMA2	7	4	6	5	7	5.8	2.8	2	3	4	2	3
Reuse of heat, combined heat, and power plant, use of renewable energies	EnMA3	3	2	3	3	4	3	2.8	4	3	2	3	2
In time monitoring system	EnMA4	7	6	5	7	6	6.2	2.6	4	2	3	2	2
Total understanding about the people who are working within the company	EnMA5	6	6	7	5	6	6	6	6	7	6	5	6
Existent of a defined target	EnMA6	5	5	6	5	5	6	6.6	6	6	7	7	7
Existent of a full-time energy manager	EnMA7	7	2	1	1	7	3.6	5.2	4	4	7	4	7
Root-cause analysis	EnMA8	6	7	7	7	6	6.6	6.4	7	6	6	7	6
Monitoring and alarming	EnMA9	7	4	4	7	5	5.4	5.2	4	4	5	6	7
Reduce energy consumption in critical situations	EnMA10	7	7	7	7	7	7	6.6	7	6	6	7	7
Smart-grid functionality	EnMA11	1	1	1	4	1	1.6	4.6	4	5	1	6	7
Calculation of energy costs	EnMA12	1	1	1	4	1	1.6	4	5	1	4	5	5
Post calculation: identify significant deviations	EnMA13	1	3	3	3	1	2.2	3	1	5	3	3	3
Energy footprint of production	EnMA14	1	2	3	1	1	1.6	5	3	5	6	5	6
Implementation of a certified Energy-Management-System according to ISO 50001 as requested by public bodies or customers	EnMA15	1	1	1	1	4	1.6	4.6	4	3	5	4	5
Establishing services to support Carbon-Emissions Trading (forecast, sourcing)	EnMA16	1	2	1	1	1	1.2	3	2	3	4	2	4

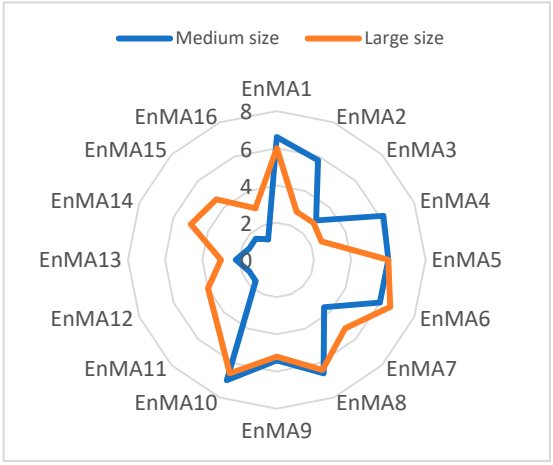

Figure 2. Comparing the results extracted from Table 2.

4.3. Decision-Making and Investment Behavior

Industries not only need to implement more energy efficient technologies and updated strategies, but also changes in an individual's behavior and decision-making patterns; how to do this in detail is equally important if EnM is to succeed [8]. Understanding the most dominant factors and/or identifying characteristics that influence managers' decisions is an important challenge. A study in USA showed that motivation for any investment, including energy-related investments, goes far from an economic one only. Organizational and institutional aspects are examples of those aspects which have greater impact on a firm's investment behaviour [25]. These aspects are, also, stressed in other studies (see [26,27]).

In the literature, making an investment decision is described as a process, and not as a single occurrence point in at a particular time [27]. Mintzberg et al. (1976, p. 246) [28], discussed about three main aspects of the decision-making process, namely: identification, analysis, and final selection, which should work together with the commitment to action. The three aspects mentioned in Mintzberg et al.'s definition have also been stressed in other researchers' publications (see [26,27,29]). Moreover, the importance of working on procedures and patterns within an organization are essential, which is in line with EnMS's target and responsibility. For an organization with an EE goal, it is important to motivate its staff to be sensitive to, and committed to improving EE [20]. For the importance of EE in overall budgeting decision, the results in Tables 1 and 3 reveal that in the firms' own view and perception, there is no under- or overestimation. This, therefore, will increases the chance of additional energy saving through incorporating EE as a decision variable. This inference was empowered by asking firms about their future strategies and investment budgeting behaviour. It turned out that most firms, particularly medium size companies (look the results for DM6 in Table 3), expect the total budget for investments to remain largely constant or to increase slightly. This additionally holds, but to a lesser extent, for investments that are strictly geared toward increasing EE. However, the importance of EE in investment decisions is foreseen to increase albeit slightly.

The results in Table 3 and, more clearly, Figure 3 show there is a relatively homogenous opinion between both sized cases, except in DM18, which is the willingness to reduce labors through EE activities for medium-sized company is relatively higher than large size companies.

Apart from the contextual aspects of any investment, which are discussed above, financial analysis is a fundamental and key phase throughout the investment decision-making flow. Common capital investment evaluation methods include the net present value (NPV), the internal return rate (IRR), and the pay-back time (PB) method. Empirically, PB is the most frequently applied evaluation tool by firms [17,30]. Other findings also reveal that firms in some cases apply the PB method by NPV or IRR [26,31].

Previous results present a required PB period of 3.5 years [17]. However, periods of three years or even less also reported as companies' preference period of time for PB [25,30,32,33]. Comparing the results (Code: DM1, DM2, DM3, DM4, and DM5) of Table 3, they are largely in line with the results of a study, indicating that shorter PB periods for EE investments is an essential and required criteria for firms [34]. Considering PB as an assessment tool for investment decision-making EE investments, this pattern is frequently used for any investments in general [18,31]. However, it has been criticised in academia (see [35]). Moreover, from profitability point of view, results (look codes: DM20 and DM21) reveal that the willingness for long-run profitability is relatively high, and somehow the same for both size. However, not is only the long-run profitability highly demanded among medium size companies, but short-run profitability is also demanded as well. Since the motive behind investments may impact the next investment process, it calls for further exploration of the measure of the mentioned impact.

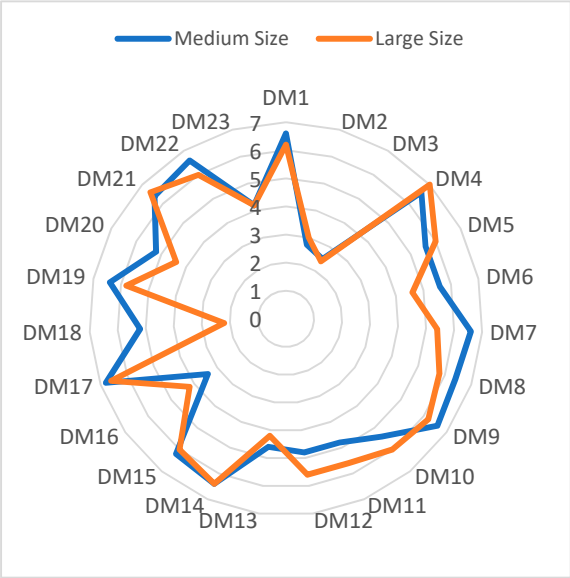

Figure 3. Importance percentage of each impacting factor.

Last but not least, adequate knowledge is an important requirement before any investment decision making. The absence of a proper information would cause failures in optimal investment behaviour. According to the respondents, the main source to obtain knowledge, for example on suitable technologies, are the industrial board and colleagues, publications, and suppliers. Government and energy-related agencies play a minor role only to provide the required energy-saving information for the organizations. Results in code DM16 indicate that both sized companies are suffering from a low rate of relevancy in including R&D within their organization system.

Table 3. Results for decision-making support and investment behavior (1 = not at all, 4 = moderately, 7 = great extent).

Size		**Medium Size**							**Large Size**				
Use Case	**Code**	**A**	**B**	**C**	**D**	**E**	**Tend to**	**Tend to**	**F**	**G**	**H**	**I**	**J**
Payback time is the main criteria	DM1	6	7	6	7	7	6.6	6.2	6	6	7	6	6
Internal return rate is the main criteria	DM2	No answer	3	4	2	2	2.75	3	3	3	2	2	2
Payback time and internal return rate both have the same importance	DM3	No answer	3	3	2	2	2.5	2.4	2	2	3	2	3
Projects with a pay-back of two years and less can be selected to be implement	DM4	7	6	6	7	7	6.6	7	7	7	7	7	7
Projects with a pay-back of more than two years and less than five years can be selected to be an implement	DM5	5	5	6	6	6	5.6	6	6	6	6	6	6
strategy in budgeting for energy efficiency for future	DM6	6	5	6	6	5	5.6	4.6	5	6	6	6	6
Improvement of the product quality, along with energy saving	DM7	7	7	7	6	6	6.6	5.4	6	7	7	7	7
Increase of the capacity along with energy saving	DM8	7	7	7	6	5	6.4	5.8	5	7	5	6	6
Cost and benefit analyses have an impact on program implementation	DM9	7	7	7	6	6	6.6	6.2	7	6	6	6	6
Emission reduction programs	DM10	7	5	4	6	5	5.4	6	6	5	7	6	6
Waste reduction programs (in terms of energy) have a positive impact on decision-making	DM11	5	4	4	5	6	4.8	5.6	5	6	6	5	6
Implementing programs to fulfil the continuance improvement target regarding energy efficiency at the process level	DM12	5	5	4	5	5	4.8	5.6	5	6	6	5	6
Implementing programs to fulfil the continuance improvement target regarding energy efficiency at the site level	DM13	5	5	5	4	4	4.6	4.2	4	4	4	4	5
Increase the transparency of the results of any implemented program and fosters decision-making process for future programs	DM14	6	6	7	7	6	6.4	6.4	6	7	7	6	6
Willingness	DM15	6	7	7	5	6	6.2	6	7	6	5	6	6
Research and Development (R&D)	DM16	4	3	2	4	4	3.4	4.2	4	3	4	3	4
Competition with the competitors	DM17	7	7	6	7	7	6.8	6.6	7	7	7	6	6

Table 3. *Cont.*

Size		**Medium Size**							**Large Size**				
Use Case	**Code**	**A**	**B**	**C**	**D**	**E**	**Tend to**	**Tend to**	**F**	**G**	**H**	**I**	**J**
Reduction of labors	DM18	7	5	4	5	5	5.2	2.2	3	3	2	2	1
Reduction of energy costs	DM19	6	6	6	7	7	6.4	5.8	7	4	6	6	6
Short run profitability of energy-related projects	DM20	5	5	5	6	5	5.2	4.4	5	4	4	5	4
Long run profitability of energy-related projects	DM21	7	6	6	6	7	6.4	6.6	7	7	6	7	6
Improvement of the environmental image	DM22	5	5	5	6	6	6.6	6	5	7	6	6	6
Increase in sales	DM23	3	3	4	5	3	4.2	4.2	4	4	3	5	5

5. Conclusions

Although the potential is vast, EnM programs are not fully implemented and/or adopted by industries. The reasons for this are numerous, and they can be partly explained through different scenarios, but one or more possible reasons can be explained through the existence of one narrow perception of EnM. EnM would not work if one considers it as an input and output machine. It is vital to know that to have success in any energy-related program contextual factors (e.g., mindset, individuals' behavior) matters. To help companies to improve their EnM maturity levels and, as a consequence, to enhance the energy system, this paper, in three sections, and through developing questions for each section, aimed to understand the most dominant factors that should be considered in developing a successful EnM program. According to the results, there are differences in setting energy-related strategies and EnM assessment criteria between large- and medium-sized companies, but results did not show any huge differences in the impact factors for strategic energy-related decision-making behaviors for both samples in terms of size.

According to the results, projects with a pay-back of two years or even less, and an improvement of the product quality, along with energy saving, received a high weight from the respondents. The most obvious result that also confirms the results of a research in 1998 and published in 2001, is that the most effective and important driver to initiate managers to decide on energy-related programs is the potential to save costs, along with energy-related programs [16]. Moreover, companies, in both sizes, are more eager if, through an energy-related program, they could achieve other strategic improvements, which are in line with their core business strategy, like increasing organization's capacity, improving product quality, waste reduction, and labor reduction. According to the discussions with managers and results here, programs aiming purely at EE only receive accordingly low interest from manager committees. Furthermore, according to the results in Figure 3, some categories receive highly positive consideration from managers. Programs with DM4, DM, DM8, DM9, DM10, DM17, DM18, and DM21 characteristic roles among others received 90 percent of managers' interest (see Figure 4). The outcome of this study exploits the conclusions concerning the main parameters to be considered, along with the evaluation of the decision-making parameters amongst others, to boost choices for maximizing the continuous EE enhancements within industrial sectors. Perhaps a study with a larger sample size, which was the limitation of this study, can complete the findings and give a much more holistic view about the pattern of the industries' energy-related decision making behaviors.

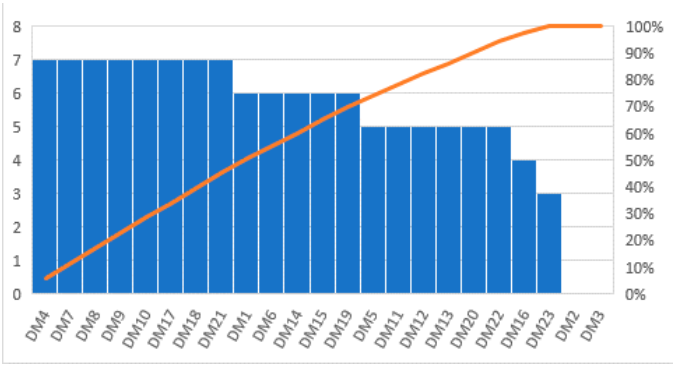

Figure 4. Comparing the results extracted from Table 3 (cumulated data).

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