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CORPORATE ENERGY SECURITY – CASE STUDY IN VAASA, FINLAND

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ABSTRACT:

Industry is in the heart of the developed world economy. It produces the added value for the economy. Therefore, it is very important to make the companies achieve high energy security levels. In this thesis, the concept of corporate energy security was addressed. The aim of this research was to find out what energy security means in general and for industries and corporations as well as how corporate energy security can be evaluated and measured in a company. Thorough and deep literature review was used to formulate a suitable definition for corporate energy security. Then, the needed dimensions for the adopted definition were designed and explained. After that, it was the time to test the conceptual theories of what corporate energy security is and what it includes into a real life application. Therefore, the corporate energy security index (CESI) was introduced. Capturing of needed data was done by a survey in the city of Vaasa, Finland. This survey and application of the CESI played as a case study to prove the concept of corporate energy security. Results proved the designed concepts of corporate energy security, and the importance to address this topic with the industry. Also, results showed the applicability of such concepts in real life and how to apply them to produce measureable values. Part of the results were to show the energy security level in the case study (companies in Vaasa) and to analyse them. At the end, it was concluded that this framework of conceptual design of corporate energy security is valid and practically applicable in real life situation. Also, it was concluded that CESI is a very powerful tool to measure corporate energy security for companies in Vaasa and elsewhere in the world.

KEYWORDS: Corporate, Energy security, Vaasa, Finland, Survey

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Abbreviations

CESI	Corporate Energy Security Index
EDP	Energy Defence Project

EH	Environment & Health
EU	European Union
GHG	Green House Gases
HHI	Herfindahl Hirschman Index
IEA	International Energy Agency
R&D	Research and Development
SWI	Shannon-Wiener Index
TE	Technology & Efficiency
UNDP	United Nations Development Program
VoLL	value loss due to lost load
WEC	World Energy Council

Symbols

MWh	Mega Watt Hour
$I_{i.Normalized}$	Normalized indicator
i	The rank of the company
n	Number of companies and the highest rank of all companies.
D_i	Corporate energy security value of each dimension
W_i	Weight of each indicator
$CESI_i$	Individual overall corporate energy security value
W_j	Weight of each dimension
ton CO_2 eq.	Ton of Equivalent CO_2
C Celsius	Temperature in Celsius
kWh	Kilo Watt Hour

1 Introduction

Energy security is a universal concern (Ang et al., 2015), that has received attention in many studies (Bielecki, 2002; Jun et al., 2009; Vivoda, 2010) with many fields of science (Löschel et al., 2010), energy policies (Franki & Višković, 2015), and national security (Dyer & Trombetta, 2013). As old as fire is how Valentine (2011) described the concept of energy security, however modern scientific research was considered to start around 1975 (Augutis et al., 2011). Before 2001, publications on energy security were rare (Ang et al., 2015), but the topic started to emerge afterwards (Yergin, 2006) because of many reasons. Some of the reasons are: the increased price of energy services (Vivoda, 2010), the fatal dependence of developed economies on energy (Kaare et al., 2013) as their engine for economic growth (Bielecki, 2002; Kunz, 2012). Also, the global energy supply crisis (Aparicio et al., 2006), in addition to more climate change awareness (Bang, 2010; Kim, 2014), coupled with social global developments (Augutis et al., 2011) and complex global markets (Chester, 2010; De Vos & Baken, 2004) are among the main reasons for the increased focus on energy security. It is important to refer to this emergence because energy affects every aspect of our lives (Ciută, 2010) and is vital for the persistence of a functioning industrial society (Bielecki, 2002; Sovacool, 2011b).

1.1 Aim and purpose

Because of this strong importance of energy security. There is a need to investigate the energy security within the heart of the modern developed societies: the industry. To do this, an inclusive consideration of the term energy security is required (Ang et al., 2015). There was some work done aiming to explain the nature of energy security (Vivoda, 2010), for example the work done by Ang et al. (2015), however for this thesis the aim is to investigate the energy security concept and build a suitable model for corporations and industries to measure corporate energy security. Therefore, we try to answer two main research questions:

1. What does energy security mean in general and for industries and corporations?

2. How can corporate energy security be evaluated and measured in a company?

Now in order to answer these questions many steps have to be followed. Following these steps ensures a systematic answer that can be trusted to be applied in a general level. Therefore, this thesis is constructed as follow

1. A literature review that provide state of art of how to define energy security, with a chronological analysis of previous attempts, then ending with adopting one unique definition that can be applied on corporations and industry. Different adaptation of different definition is a result of different standpoints (Narula & Reddy, 2015) or evolution over time (Chester, 2010). Therefore, the adopted definition will be from the corporation and industry standpoint.
2. Because energy security has multi-dimensions (Löschel et al., 2010; Narula & Reddy, 2015) and many parameters (Chester, 2010), the choice of suitable dimensions and parameters for corporate energy security with proper justification is to take place in the second step.
3. A detailed methodology of how to measure corporate energy security.
    a. Choice of companies and their profiles.
    b. Building the survey
    c. Survey design and data collection
    d. The mathematical design of the corporate energy security index
4. After that, results are presented with proper analytical discussion of the corporates outcome (corporate energy security) situation.
5. At the end, conclusions and recommendations are provided for ways to develop and enhance the corporate energy security level.

2 Literature review

2.1 Definition of energy security

Since energy security is not a policy by itself but rather a concept (Chester, 2010), it is very important to provide a satisfactory definition. It is a key goal of societies to enhance energy security (Dunham & Schlosser, 2016; Eaves & Eaves, 2007; Franki & Višković, 2015; IEA, 2007; Jordan et al., 2012; Sovacool, 2011a; Vivoda, 2010) that is basically due to the fact that energy security is required to fulfil basic human needs (Maslow, 1943). In Maslow's hierarchy of needs (Maslow, 1943) personal security is needed to attain freedom of choice and afterwards self-actualization.

Consequently, the important questions are "What is the desirable level of energy security?" and "How to achieve energy security?" A wide range of diverse answers is easily found in previous publications, following what approaches and assessment tools are used (Kanchana & Unesaki, 2014; Kumar, 2016; Lu et al., 2014; Phdungsilp, 2015; Sovacool, 2013). This need to measure energy security is coupled with industry to form the concept of corporate energy security.

Setting a goal to enhance energy security in industry through the corporate energy security concept needs first to clarify the concept of energy security. Though, as discussed in previous research, the concept is not clearly defined (Löschel et al., 2010; Winzer, 2012), or is defined narrowly and disparately (Bohi & Toman, 1993; Kucharski & Unesaki, 2015; Narula & Reddy, 2015) with no common consensus (Checchi et al., 2009; Kruyt et al., 2009). Definitions are polysemic in nature or context-dependent (Chester, 2010; Jonsson et al., 2015; Kruyt et al., 2009; Vivoda, 2010) and the topic is approached from different viewpoints (Ciută, 2010). Therefore, many described the term of energy security as vague, abstract, inherently difficult, elusive, or blurred (Checchi et al., 2009; Chester, 2010; Löschel et al., 2010; Narula & Reddy, 2016; Sovacool et al., 2011).

In order to formulate the concept of corporate energy security, it is needed first to form a definition for energy security that can accommodate the complexity of corporate energy security but still valid for the original concept. For doing this, a trend analysis is need, and that is coming next.

2.2 Chronological analysis of energy security definitions

Early humans needed to address energy security in their lives when searching a fire source for protection, cooking or heating (Scott Victor Valentine, 2011). Then, energy security became more complex when civilizations started to industrialize. This thesis will focus on building a corporate energy security concept, but first it needs to address the evolution of energy security concept. Although the concept of energy security has been ever-since in the consciousness of humans, documented definitions are relatively new (Augutis et al., 2011). Therefore, a study of the development with a trend analysis provides understandings into significant points of the concept, and a way to extrapolate the concept to corporate energy security.

This investigation reflects on definitions of the concept, accordingly, publications that do not define explicitly the term are not considered. Moreover, partially provided definitions will be also disqualified. For instance, "security of supply" definition (Bazilian et al., 2006; Creti & Fabra, 2007; Findlater & Noël, 2010; Grubb et al., 2006; Hoogeveen & Perlot, 2007; Jansen & Seebregts, 2010; Kruyt et al., 2009) is not investigated as it concentrates on security of supply. It is irrational to extrapolate such partial concept to corporate energy security, as it ignores dimensions e.g. environment (Narula & Reddy, 2016). The need for the full concept is essential so that it is possible to design a sub-model for corporations.

In this thesis, 10-year and 5-year intervals are used for period 1970-2000 and 2001 onward, respectively, in order to traces the development of energy security definitions. The start in this thesis is in 1970s. The first recorded definition is by Willrich (1976), just after the 1973 energy crisis. In addition, it is considered among the “environmental awakening” activities of the 1970s and 1980s. "Assurance of sufficient energy supplies to permit the national economy to function in a politically acceptable manner" by Willrich (1976) was among the early definitions grounding his view on other energy security research (Lovins, 1976; Lovins, 1979; Meadows et al., 1972). Different dimensions were discussed in the article but only economy, politics and supply were included in the definition. It seems as the author believes these dimensions are the most important ones and the rest is part of these. In addition, Miller et al. (1977) recycled the same definition but less dimensions were conversed in that publication. Afterwards, the impression of energy security as a status or circumstance rather than policy or attitude was presented by Deese (1979). As early as his time he considered the “nation” as a whole instead of looking into individuals only. Nevertheless, reflecting prevailing global conditions after the energy crisis of 1973, these two definitions focus on the availability of resources as the main idea.

After that, Lovins and Lovins (1981) presented a definition that debated that energy security is more than keeping the oil flowing but rather with more dimensions. It was part of the 1980s few attempts to define energy security. After the Gulf War, and in general in the 1990s, Bohi and Toman (1993) defined the opposite of energy security as the loss of welfare due to alterations (e.g. oil price variations due to wars). Also, Neff (1997) provided the energy security definition with emphasis on national and regional security, to represent the concerns of that decade.

Then, more precision for the energy security terminology was noticed in the early time of the 21st century with the beginning of the 21st century due to international institutes’ involvement. The definition by UNDP (2000) provided new views within the definition of energy security about supply and import. Also, International Energy Agency provided a definition using the concept of physical availability of supplies (IEA, 2001). Further, Bielecki (2002) designed a definition to include price and supply reliability as an important part.

After two years, a new definition came include the concept of being free of risks and disruptions state (Barton et al., 2004; Lesbirel, 2004). The reason was the change in energy security perspectives after Iraq and Afghanistan wars, channelling definitions to include freedom from risks within the definition itself. Although, it was the same concept discussed earlier by Neff (1997), but it seems he did not consider it important enough to include in the definition. Building on the same notion, possible risk spurred the United Nations Development Program UNDP (2004) to modernize the definition by account a the environment in the definition.

The tendency of including more dimensions to the definition was sustained in 2005 with the insertion of infrastructure (Onamics, 2005), sustainability (Gawdat, 2005), and national power (Jan & Goldwyn, 2005).

The period 2006-2010 witnessed important progress in energy security studies. At least 21 definitions were found in the literature. The method of defining energy security by the sum of its components continued by adding more dimensions. Bruusgaard (2006) affirms the notion of the state, Hughes (2006) emphasizes to the role of governments and polices, Yergin (2006) focuses on availability and cost, Bruusgaard (2006) emphasizes the notion of the state, and Konoplyanik and Walde (2006) involved the timeframe dimension. Through the period, introduction of a variety of new extended notions of environment dimension (Müller-Kraenner, 2007), availability dimension (Costantini et al., 2007), efficiency dimension (Jansen, 2009), cost dimension (Florini, 2009), sustainable considerations (Kirchner & Berk, 2010), military dimension (Pascual & Elkind, 2010) and threats to the economy (APERC, 2007) took place.

Including more dimensions to the definition aimed to simplify the issue of energy security. However, many dimensions were still missing (e.g. technology or health), which meant the definitions are lacking. Furthermore, an important change arose with the inclusion of electricity (Rutherford et al., 2007), whereas previously oil and gas had been well-thought-out as the only source of energy to be considered.

The years after 2010 saw many diverse styles for energy security's definition formulation. In the beginning, researchers aimed to include as many dimensions as possible (Blum & Legey, 2012; Diesendorf, 2012; Georgescu, 2015; Hossain et al., 2016; Kononov, 2014; Nurdianto & Resosudarmo, 2011; O'Sullivan, 2013; Sovacool & Bulan, 2011), an extension of the preceding trend. A piece of this method is prolonging definitions, as researchers sustained including more dimensions. Another method to build the energy security definition was seen in 2012. Scholars' focus was to answer the dilemma "What is to be contained within energy security definition?" They started to generalize and simplify the definition in a way that different perspectives are all included without listing them in the definition for different sectors. The first innovative approach was introduced by Johansson and Nakićenović (2012). They provided a definition for any energy system; oil, electricity, or gas, etc. Also, they partially presented the notion of risk and threat. However, they failed to account for the producers, as their focus was limited to energy provision (services).

In 2013, Čehulić et al. (2013) attempted to simplify energy security definition by proposing: "The freedom from disruption of energy supplies for whatever reason". This description can be used for any perspective in any dimension. Jewell et al. (2013 and 2014) provided another innovative definition in two different publications (Jewell et al., 2014; Jewll et al., 2013). "Low vulnerability of vital energy systems" was their definition for energy security. However, it is considered very general, wide and vague in its constructive terms that need explanation. The connotations of vulnerabilities and energy systems need themselves to be defined to give holistic understanding. Kucharski and Unesaki (2015) had another energy security definition, "Assessing various types of risk in the energy system". They saw energy security as an action instead of a concept, and that was their drawback. Assessing the risks does not cover all aspects of energy security for example, making new laws.

Outstandingly, there was an increase in how many researchers provided definitions. Within 5 years, the count reached 29 different definitions. This number shows clearly the incongruity in the scientific community. Figure 1 shows the very clear increase in these numbers.

In addition, it is noticed that scholars approached the concept with different techniques overtime; first, definitions are general and simple. After that, scholars went to take in more terms inside the definition to account for diverse belvederes that are involved in the discussion. The last step was to simplify the definition by providing terms that are more comprehensive so sub-parameters were uninvolved whereas references to them was included.

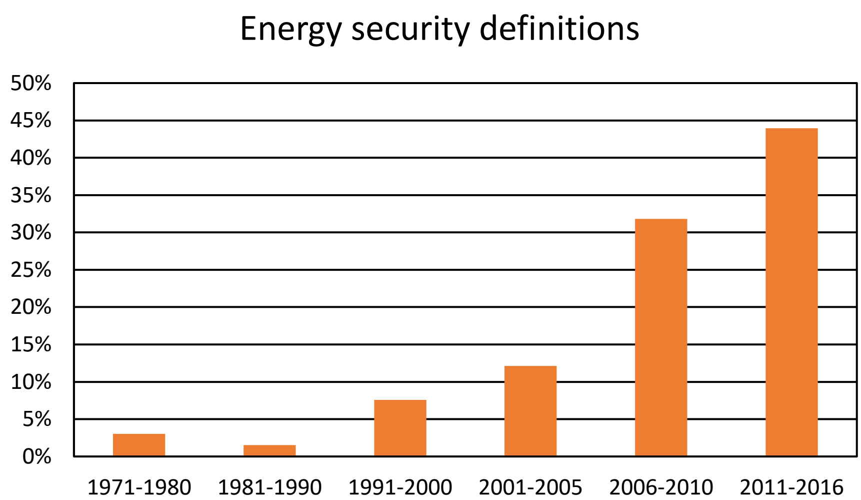

Figure 1. Scientific documents with ES definitions (Azzuni & Breyer, 2017).

As mentioned earlier, there is an evident variance between security of supply (Kaare et al., 2013) and energy security. Hoogeveen and Perlot (2007) mix the concepts when they address “Security of supply is a general term to indicate the access to and availability of energy at all times." In addition, similar constraint is established in other publications (Bazilian et al., 2006; Cabalu, 2010; Cohen et al., 2011; Creti & Fabra, 2007; De Joode et al., 2004; Findlater & Noël, 2010; Grubb et al., 2006; Hoogeveen & Perlot, 2007; Jamasb & Pollitt, 2008; Jansen & Seebregts, 2010; Joskow, 2007; Keppler, 2007; Kruyt et al., 2009;

Le Coq & Paltseva, 2009; Löschel et al., 2010). Just recently, researchers like Erdal et al. (2015) made distinction between security of energy supply and energy security with definitions for each concept.

2.3 Embraced definition

The importance of choosing a suitable definition can be seen from the old saying of Aristotle “he who controls the definition, controls the debate.” (Sovacool, 2011b). In addition to the importance, this definition has to account for some needs and be in a accordance to some criteria. It has to be as generic as possible in order to overcome the complexity of the concept of energy security (Kirchner & Berk, 2010). Therefore, the first step is to account for the three pillars of the energy system; supply, transfer and demand, since security of supply should not be the only focus of energy security (UNDP et al., 2004). Further, another important criterion is to include the concept of sustainability within the definition (Von Hippel et al., 2011). The last point of the criteria set is to include the notion of threat, risk or vulnerability (Gnansounou, 2011).

The next step, after the criteria was set, is to study the two parts of the term, “energy” and “security”. Energy is the power that can result in work, from Oxford dictionary. Energy thus can be; chemical in molecular bonds (e.g. oil or gas), electrical in electricity grid or electro-magnetic (e.g. solar irradiation), etc.

The second term “security” means: “the absence of threats to the adopted values” (Wolfers, 1952), “freedom from harmful threats” (Lesbirel, 2004) or “the state of being free from danger or threat” (Narula, 2014).

Hence, this thesis adopts the following; energy security is defined as the **feature in which companies and industries function sustainably in all possible dimensions, freely from risks**. Although, that definition is a modification of the one that was found by Azzuni and

Breyer (2017), the modification accounts for the standpoint of corporations and industries. So, by this definition, corporate energy security can be easily addressed with all needed dimensions and aspects and with all risks to be accounted for.

3 Corporate Energy Security Dimensions

After the preparation of the scene by defining energy security, it is the time to introduced the needed dimensions for corporate energy security and the threats for each of them. Previous studies provided a huge list of different dimensions of energy security that can be considered in different fields (Azzuni & Breyer, 2017) though some authors would call them dimensions (Sovacool, 2011b) whereas some others would call them aspects (Johansson & Nakićenović, 2012).

Although many criticized including a lot of dimensions because of the need to guarantee a better assessment by not having too specific dimensions (Phdungsilp, 2015). It is obvious that any dimension with relationship to corporate energy security should be included as it was mentioned by Yergin (2006) in order “to include more dimensions” he continued “energy security discussion should be expanded”.

Corporate energy security will include a set of dimensions, it is the aim of this thesis to identify these dimensions and analyse the relationships between each of them with cooperate energy security. Then, the discussion will go through the threats to corporate energy security within each of these dimensions, that, firms and companies can take proper measures to enhance their corporate energy security level. At the end of the discussion for each dimension, an index is proposed to capture each of these dimensions within the corporate energy security analysis. The analysis will be carried principally in Vaasa Finland, as different companies are included in the survey.

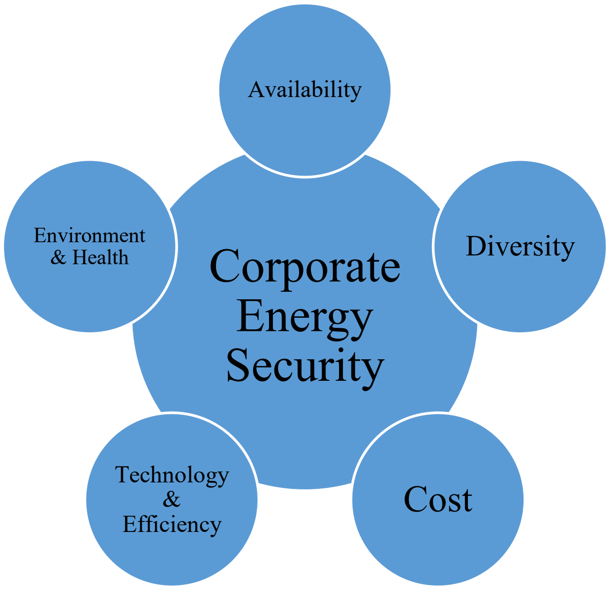

Figure 2. Corporate Energy security dimensions.

3.1 Availability

As the concept of Availability is always there when addressing energy security (Checchi et al., 2009), it is also a critical dimension for corporate energy security. For companies and firms, availability can mean the access to energy source. That can be seen as how easy their energy needs are covered. Yergin determines the importance of energy access from being a concern over the mankind history (Yergin, 1991). Easier access for corporation and companies to energy sources means more development of the business and society (Blum & Legey, 2012). Secure transport routes are essential for energy security (O'Sullivan, 2013). The threat to availability dimensions is the absence of energy sources that are needed to run companies' business. Kanchana and Unesaki (2015) suggested final energy consumption per capita as a numerical indicator to measure availability.

3.2 Diversity

Diversity is important dimension for cooperate energy security enhancement (Elkind, 2010). In the 20th century, Winston Churchill made his prominent speech where believed that energy security is in variety only (Yergin, 1991). The Diversity concept is rooted in the proverb: “Don’t put all your eggs in the one basket” (Lesbirel, 2004). Generally, extra diverse energy sources and extra different use of these sources means more secure systems (Abdo & Kouhy, 2016; Tagarinski & Avizius, 2009). In that way, as it is improbable for all fragments to stop functioning simultaneously (UNDP, 2000), if one energy source or one energy usage fails, other replacements can be used (Yergin, 2006).

Thus the influence is distributed on all of the system’s parts (Kucharski & Unesaki, 2015). Stirling (2014) presented that diversity include three main parameters; diversity of sources, diversity of fuels (energy carriers) and diversity of uses. Fuels and electricity are the main two forms of energy corporates need to use. A company that depends total on oil products is less secure than a firm that can alternate between oil products and electricity to run their business. The same is true for the sources, if the company only relies on the grid for electricity is less secure for a company that has its own generation capacity in addition to the grid connection. The last part is related to energy consumption within a company or a firm. Using all the energy to run one equipment is less secure than using the energy to run two machines. The point is in the risk management for continuous production and the corporate energy security. If one machine stops, energy can be channelled to the other one to compensate for the malfunctioning one. Further, the use of renewable energy bring more diversity to the energy system (Ren & Sovacool, 2015).

Energy dependency is one term that is discussed often in literature (Ciută, 2010). Where users (companies) are dependent on one source or type of energy carriers. Although energy-independence (having all needed sources owned by the company) is merely a myth (Kanchana & Unesaki, 2015). No company can manage all the supply chain by itself to acquire energy independence from all other players and even if it does it is not a guarantee (Haghighi, 2007) to have higher corporate energy security. Also, total dependency on one source (national grid) is not always a zero level of corporate energy security performance (Fattouh, 2007).

For corporations, many indexes can be used to measure diversity; the diversity of energy sources for the company, own electricity generation (Jewell et al., 2014), Herfindahl Hirschman Index (HHI) (Narula & Reddy, 2016), or Shannon-Wiener Index (SWI) (Phdungsilp, 2015).

Although diversity is important, it is insufficient by itself to enhance the corporate energy security without considering costs or compatibility (Kucharski & Unesaki, 2015). Therefore, there is a need to address cost and technology side by side with diversity and thus they are the next dimensions.

3.3 Cost

Although the cost dimension is very important but it often treated unfairly. Many researchers would call this dimension as affordability (the price to be paid for energy). However the cost dimension has two parts, the first is the energy price and the second is the cost of disruption. For companies and firms, there is a tight connection between profitability (economy) and energy prices (Scott V. Valentine, 2011).

In terms of companies, a cheaper energy price means higher corporate energy security because it can increase industrial production, and profitability (Elkind, 2010). However, the issue with cheaper energy prices for corporates is the burden on future planning (Konoplyanik & Walde, 2006). Companies need to plan the future expenses to make proper plans, but funds allocated for investment become scarce and thus have a structural impact on future budget control (Bahgat, 2006a) and thus corporate energy security. On the long term planning, cheap energy prices can lead to false sense of instant security (Lakić, 2013). That can happen to companies that cannot control the cheap prices to continue for the future which makes them vulnerable to any price shocks (Elkind, 2010).

Furthermore, to assure corporate energy security, companies need to address two important concepts; price volatility (Jansen, 2009) and stability of energy prices (Yao & Chang, 2014). Many would consider volatility of energy prices as the main challenge for corporate energy security (Jun et al., 2009); a sudden unpredicted energy price change can disturb the whole budget planning and calculations (Edenhofer et al., 2013). For this, volatility has a serious ambiguity about future economic planning for companies (WEC, 2015). In that logic, renewable energy is a key for stable energy prices in the future where sustainability is deemed to be achieved (Schellnhuber et al., 2016).

The second point of the cost dimension is how much supply disruption (Jun et al., 2009) costs companies if there is energy cuts or blackout. The companies will have less level of corporate energy security if higher costs are to be paid for disruptions. Different estimates are made for the counties' level for how much it can cost, for example, American economy will lose 323 bUSD1980 for oil disruption of 10 MB/D for one year (EDP, 1980). Also, another example is brought by Hedenus et al. (2010) where cost of oil disruption can reach between 29.5 and 31.6 b€/a for EU25.

The threat to this dimensions in the view of corporate energy security is the inability to calculate failure probabilities (Lovins & Lovins, 1981) due to rapid change of prices Finally, to calculate this dimensions for corporate energy security, many indexes are proposed; market costs of energy in €/MWh (Franki & Višković, 2015), price volatility (Narula & Reddy, 2016) or value loss due to lost load (VoLL) (Rutherford et al., 2007).

3.4 Technology & Efficiency

Corporate energy security has a strong relation to technology and efficiency because utilizing energy needs technological equipment (Yao & Chang, 2014). For that, new technological solutions can enhance corporate energy security (Elkind, 2010). In the future, advanced renewable energy sources can be vital for a more corporate energy security (Ren & Sovacool, 2014; Schellnhuber et al., 2016).

In addition to the importance of using newer and advanced technological solutions, efficiency of these technologies needs to be on a high level within the firms (Sovacool & Brown, 2010). Therefore, efficiency consideration should be included in the study of corporate energy security (Kumar et al., 2016). Basically, for a long time, it was known that enhancing efficiency by technological development levels up energy systems in corporation (Augutis et al., 2015; Brown et al., 2014; IEA, 2007; Lovins, 1976), and pave the path for a double-win for the climate traits (Refaat, 2009). Maximizing the output unit per input units (Rutherford et al., 2007; Sovacool & Brown, 2010) is the essence of efficiency increase. That is done usually with improving the performance (Brown et al., 2014). For corporate energy security, performance is usually sought to be improved in R&D departments.

Another way to measure the efficiency, instead of output/input ratio, energy intensity is use to capture the efficiency nature for corporate energy security evaluation(Badea et al., 2011). On the national level energy intensity is how much energy is required to produce one unit of GDP (UNDP, 2000). This can be used in companies as how much energy is used up in order to yield added value (Bahgat, 2006b). Therefore, to improve corporate energy security, there should be reduction in energy intensity (reducing the dependence of the economics of the company on energy) (UNDP, 2000).

For all of these aspects, there are some threat. The first threat to enhancing corporate energy security is the cultural obstacles to exploit new technologies (Sovacool, 2009). The second threat is the rebound effect. To explain the rebound effect it can be put simply as follows; when technology advancement results in more efficient equipment that uses less energy, human behaviour tends to push for more use of this equipment (it is known also as backfire) (Berkhout et al., 2000). Usually, the rebound effect is articulated as energy loss ratio to projected benefit for employing the advanced technology (Grubb, 1990).

Many scholars tried to quantify the effect of technology and efficiency on energy security, it is considered a difficult task (Elkind, 2010). Share of machines with expired service life to the running ones (Kononov, 2014), expenditure on research and development (Sovacool, 2013) and energy intensity (Badea et al., 2011; Erdal et al., 2015) are among the numerical indicators that can be used to measure this dimension.

3.5 Environment & Health

As companies and firms operate in this world, their relation to environment and people's health is undeniable. Therefore, corporate energy security has to include the environment and health dimension (Yao & Chang, 2014). For corporation, they have to be liable for the result of their energy usage. The most visible effects from the energy use in companies are CO2 and GHG emissions, global warming (Meadows et al., 1972), heavy-metals emission, water contamination (Sovacool & Bulan, 2011), climate change (Munich Re, 2014; Von Hippel et al., 2011), air pollution (Brown & Dworkin, 2011), acidic rain (Von Hippel et al., 2011), and indoor-suffocation (Islam et al., 2014). Having all these possible results from companies' energy use, a higher corporate energy security means less environmental impacts. In addition, firms operating in tough climate conditions that are a result of human-made climate change are considered to have lower level of corporate energy security. These conditions worsen the energy systems in companies, profoundly (Elkind, 2010). Also, these conditions can deteriorate to a point where nations (and companies) reach the point of collapse (Brown et al., 2014), with no possibility for humans to anymore live outside (Pal & Eltahir, 2016). Therefore, climate patterns and conditions are a major concern for corporate energy security in the global community (WEC, 2015).

The second part of this dimension is the people's health. Healthy life is a universal human desire (Meadows et al., 1972). For companies and firms, healthier workers have a higher productivity (Baicker et al., 2010; Pritchett & Summers, 1996) and thus enhance corporate energy security. For companies, for having a higher level of corporate energy security, effects on workers in energy industries should be included in the strategic planning of all companies as it is considered the second biggest health impact globally (Johansson & Nakićenović, 2012). Moving on, emissions resulting from corporation's energy use result usually in cases of suffocation and long term cancer (Pacesila et al., 2016) especially for their own employees. The last affected group by companies' use of energy is the society. More than 5 million deaths per year plus 5% of global health are attributed to the current energy system (Johansson & Nakićenović, 2012).

Risks to this dimension can be seen in the effects of climate change, for instance, storm surges (Elkind, 2010). In 2016, it was found that the most threatening risks for years to come are the ones that are associated with climate change (WEF, 2016). Another risk in this dimension is the unawareness of the connection between corporate energy security and environment, as some would debate (Jewell et al., 2014; Luft et al., 2011). However, the major stream of scientists stand for a strong affiliation between the energy system and the environment (Kowal, 2011; Mietelski et al., 2014; Møller & Mousseau, 2011; Povinec et al., 2013). As it was stated "No form of energy production or use is without environmental impact" (Jun et al., 2009). The same lack of awareness between health issues and corporate energy security is regarded to be a threat to corporate energy security. The lack of awareness was attributed to subsidies as summarized by Coady et al. (2015).

Lastly, in addition to number of sick leaves, indicators to evaluate this dimensions range from carbon intensity, i.e. CO2 production per energy consumption (kWh) (Badea et al., 2011; Grigoroudis et al., 2015) emissions per capita (employees) (Buonocore et al., 2016; Epstein et al., 2011; Phdungsilp, 2015).

3.6 Summary of the corporate energy security dimensions

After going through this literature, corporate energy security dimensions and their parameters are summarized in Table 1. They are used after this point with their short name, which is put inside brackets. Each of the dimensions are afterwards referred with names as shown in Table 1.

Table 1. Dimensions, parameters and their abbreviations.

Dimensions	Parameters
Availability (A)	Existence of resources (A1)
	Existence of consumers (A2)
	Existence of means (access) (A3)
Diversity (D)	Diversity of sources (D1)
	Diversity of energy (D2)
	Diversity of Usage (D3)
Cost (Co)	Energy cost (Co1)
	Cost of disruption (Co2)
	Energy cost volatility (Co3)
Technology & Efficiency (TE)	New technology solutions (TE1)
	Energy efficiency (TE2)
	Energy intensity (TE3)
Environment and Health (EH)	Impact on the environment (EH1)
	Environment conditions (EH2)
	Impact on employees (EH13)

4 Methodology

Reliability in the results needs sensible methodologies and tools to examine the input data. Therefore, in this thesis, methodology was well taken care of. The methodology was chosen to be a suitable way to capture information and to be easily reflected and interpreted. Thus, nomothetical approach with both theoretical and numerical parts was applied. In the nomothetical methodology, the focus is on how things are currently, and as the aim is to evaluate and measure current corporate energy security levels, the choice is methodology approach is justified.

The methodology that was chosen in this thesis comprises of many aspects in order for the results to be robust, reliable and coherent. The first aspect of the methodology was to determine its domain of application. As the aim was to build model of corporate energy security index, and apply it on a case study (city of Vaasa), corporates in the city of Vaasa were identified to be target for collecting data. Companies in Vaasa were chosen randomly but with some criteria. That, all the chosen companies have these criteria, but not all the companies with these criteria were chosen.

The next aspect of the methodology was the building of the survey. The survey was meant to capture all the identified dimensions of the corporate energy security. These dimensions were identified and explained in details previously.

The next aspects of the methodology are questionnaire builder, how the questionnaire was built, the survey distribution and data collection. Then the last, aspect is the building of the corporate energy security index. In the following sections, more details about each of these methodological aspects is provided.

4.1 Companies profiles

The city of Vaasa has many promising and interesting companies that can be chosen to be the subject of this research. These companies can be a good representative for the rest of the companies in the city. Therefore, companies were chosen randomly but with certain criteria.

The first criteria was the location. All chosen companies are located in Vaasa or at least have running branches in Vaasa. The second criteria for choosing a companies into the companies list of targeted companies was the strong connection to the energy field. Many companies are either in the energy industry as a mainline of work or contracted and affected by the energy industry. The energy-related industry in Vaasa consists of many leading companies and some of these were put in the list. The third criteria was the industrial production relationship. These companies have to be affiliated to industrial production. This criterion was set to make sure that the answers that are received are applicable to other industries and cover all the dimensions of corporate energy security. The last criteria was the ease of communication. Identified companies had to have online websites and contact emails. Putting together all these criteria, the selected companies and their corresponding emails that were used in the communications are listed in Appendix 1.

4.2 Survey

The survey was built to capture the important data according the detailed design of the corporate energy security index. The first was the need to have a preliminary knowledge about what energy security is defined for each company, and whether they have some tools or index to measure their energy security level. Therefore there had to be a genera section in the survey under which, two questions were listed.

1. What is energy security for you as a company?
2. Do you measure energy security in your company? How?

The second part of the survey was to capture all the parameters that affect each of the five defined dimensions of corporate energy security. It was determined that each dimension will have three parameters and thus suitable questions were drawn out. Table 2 summarizes all the used questions in the survey to capture the corporate energy security data for each company. Same table can be found in Appendix 2.

Table 2. Questions that are used in the survey.

Dimensions	Parameters	Numerical indicators	Questions
(A)	(A1)	Total energy consumption	How much energy kWh, in total, was consumed by your company in 2018? (kWh)
	(A2)	Energy use per capita	How much energy kWh per capita, on average, was consumed by your company in 2018? (kWh/person)
	(A3)	Electric energy use as a percentage of total energy use	How much electric kWh, in total, was consumed by your company in 2018? (kWh)
(D)	(D1)	Number of energy sources	How many different energy sources does your company receive energy from?
	(D2)	Percentage of self-produced energy	How much energy was self-produced in 2018? (kWh)
	(D3)	Number of applications	How many applications, in your company, is energy used for?
(Co)	(Co1)	Energy cost	How much does energy cost? (euros)
	(Co2)	Financial loss of one hour energy blackout	How much, on average, would it cost the company if there is an energy blackout for one hour? (euros)
	(Co3)	Percentage change of energy cost over the last 5 years	What is the percentage change of energy cost over the last 5 years as absolute value?
(TE)	(TE1)	R&D department budget as a percentage of the total budget	What is the R&D department budget as a percentage of the total budget?
	(TE2)	Average energy efficiency of all equipment	What is the average energy efficiency (energy input/work output) of all equipment?

	(TE3)	Energy intensity	What is the energy intensity (kWh/€ profit)
(EH)	(EH1)	Total GHG emissions, 2018	What was the total GHG emissions level from your company in 2018?
	(EH2)	Average temperature in 2018	What was the average temperature, in 2018, in the city your company operates in?
	(EH3)	Hours of sick leaves, in total, 2018	How many hours of sick leaves, in total, did your employees take in 2018?

4.3 Survey design, distribution and data collection

To build the survey, an online platform was needed. Many options were examined but finally Google Forms was the best option. The criteria that led to the choice of Google Forms for the survey designs are as follow:

1. Online platform that is shared through email address. This lead to the elimination of any paper based survey builder. It also, eliminated all the options where survey could only be reached through mobile apps.
2. Platforms that do not need any registration. Some survey builders require the participants to register. This was against the anonymity policy followed in this thesis. It was very important to make the survey 100% anonymous without any personal data. Thus, all survey builders that required any kind of identification were discarded.
3. Free platforms with all options available. Most of the online platforms to design surveys are not totally free. They are either free for very limited options of the type of questions to be included or they are very limited on how many responses can be collected. This led to the exclusion of most of the platforms
4. Familiarity and ease to build the needed questions. This led to the choice of Google Forms as the authors have previous experience with them.

After choosing Google Forms to be the platform, questions were built and the survey was designed to get all the needed information. The survey consisted 9 sections. The first section included the description and introduction to the survey. It also informed the participants of all needed information to complete the survey. Section 2 included the General two questions mentioned above. Section 3 was directions to inform the participants that the following 5 sections will include questions for corporate energy security, a section for each dimension. Each of the sections 4,5,6,7 and 8 included questions for the dimensions of Availability, Diversity, Cost, Technology & Efficiency and Environment & Health, respectively. These questions were listed in Table 1. The last section (Section 9) included a thanking statement for the participants.

After the survey was designed and built, the link to the survey was generated and made ready for distribution. The survey link was sent to the identified receivers and potential participants from the university student email. The survey was sent many times as the later attempts were reminders for the participants to fill the survey. In total there were 6 emails sent on the following dates 24/9/2019, 17/9/2019, 11/9/2019, 3/9/2019, 29/8/2019 and 22/8/2019. The deadline was postponed after the second email, as there was only one response. Postpone of the deadline was from 10/9/2019 to 30/9/2019.

With these attempts total of 3 responses were collected from 3 different companies. Data was collected automatically in the platform. Google Forms allows the collected data to be shown and presented visually. It is also possible to download all the responses and collected data in an excel file. That what exactly was done. The collected data was then arranged in an excel sheet to make them more informative.

4.4 Design of the corporate energy security index

As was seen before in Table 1, there are 5 dimensions for corporate energy security, and there are 3 parameters for each of the dimensions. For each parameter, a numerical indicator was assigned from the answers of the survey. The numerical data that was collected from the survey plays as the input data for each of the parameters. For each parameter one indicator is used. After that, all indicators are normalized by a Max-Min approach (Al Shalabi & Shaaban, 2006; Jain & Bhandare, 2011; Yu et al., 2009). Companies are ranked based on their indicators. The best value of the indicator for corporate energy security is given the full mark of 100%. The worst value is then the full mark 100% divided by the number of companies participated in the survey. Therefore, for each company the normalized indicator can be calculated from equation (1)

$$\mathrm{I}_{\mathrm{i\,.Normalized}} = \frac{\mathrm{i} * 100\%}{\mathrm{n}} . \qquad (1)$$

where $I_{i.Normalized}$ is the normalized indicator, i is the rank of the company, n is the number of companies and the highest rank of all companies.

After that, all normalized indicators are put together to form the value of their respected dimension. The corporate energy security aggregated values for each dimension is a sum of all normalized indicators multiplied by their respected weight. In this research, all indicators are given equal weights within their dimension, because there is not enough data to support otherwise. The equal weighting is the safest when there is no enough data to support using different weights. In order to be able to use different weights for each parameter within the each dimensions, there should be supporting data for such differentiation. Furthermore, many previous studies have used equal weighting when aggregating their energy security index (Cabalu & Alfonso, 2013; Kamsamrong & Sorapipatana, 2014; Wu et al., 2012). Equation (2) describes the calculation of the value of each dimension.

$$\mathrm{D_i} = \sum_{i=1}^{n} W_i \cdot I_{i.Normalized} \cdot \qquad (2)$$

where Di is the corporate energy security value of each dimension, Wi is the weight of each indicator. In this thesis, the weight of each indicator within the dimension is 0.333. After the value of each dimension was calculated, the overall corporate energy security index is formulated by the same technique. All dimensions are summed up after they are multiplied by their respected weight. The same argumentation for using equal weights for all indicators is also applied for the dimensions. The equal weighting is the safest when there is no enough data to support using different weights (Cabalu & Alfonso, 2013; Kamsamrong & Sorapipatana, 2014; Wu et al., 2012). In addition, there is no enough data to support otherwise. Equation 3 describes the calculating of the corporate energy security index (CESI)

$$\mathrm{CESI_i} = \sum_{i=1}^{n} W_j \cdot \mathrm{D}_i \, . \qquad (3)$$

where $\mathrm{CESI_i}$ is the overall corporate energy security value, $\mathrm{W_j}$ is the weight of each dimension. In this thesis, the weight of each dimension is 0.2.

4.5 Methodological procedure

After all the data was collected, and the calculation methods were ready to set, the remaining was to use excel in order to compile the data. All the calculations are made in excel where it was made possible to change the weighting of the indicators or the weighting of the dimensions. This excel file can be used for any corporate in Vaasa region to calculate their corporate energy security value. Further, if more data is collected worldwide then this index is robust and flexible at the same time to provide good results about the corporate energy security levels. This s for future research, not included in this thesis.

Furthermore, some typical issues for the survey approach were faced, for example, respondents might answer what they think they are expected to say or that they do not actually have too much knowledge or experience on the domain. However, these issues were in the mind when designing the survey. Thus, there were enough instructions in the survey so the real answer is gotten instead of what respondents might think they need to answer. Also, the choice of the respondents was done in a way to assure that respondents have enough knowledge in the domain. In addition, they were instructed to consult their colleagues in the company who might have the needed knowledge.

5 Results and Discussion

In total, there were three companies, which participated in the survey, and their respected data was used to aggregate the CESI. In this section, the results of each dimension is presented and analysed. The collected data is presented in their absolute values and then the determination of the best among them is explained and discussed. The results and discussions are to follow a dimension-by-dimension procedure. That each dimension's results are discussed separately. Then after that, the overall result of corporate energy security level is explained with thorough discussion.

5.1 Availability

The three parameters of Availability dimension were presented in Table 1 and their representative indicators were presented in Table 2. Furthermore, for the summary of the responses from the three companies regarding the numerical indicators for Availability dimension is shown in Table 3.

The effects of the Availability indicators on corporate energy security are different. The "Total energy consumption" affects the availability dimension proportionally, more energy consumption means the company has access to more energy and thus more secure on the availability dimension. The second indicator "Energy use per capita" provides information on the number of consumers within the company. Less energy use per capita means higher ratio of employees and users of this energy, which means higher level of corporate energy security. On contrast, higher values of energy per capita means less users of the energy and more machine consumption. Thus, the relationship is reverse proportional. The third indicator "Electric energy use as a percentage of total energy use" has a proportional relationship to corporate energy security. Higher share of electric energy means easier transport of energy and thus a more secure system on the availability dimesons.

Table 3. Companies' responses for Availability dimension.

Company	Numerical indicators	Input values	Normalized parameter	Dimension values
A	Total energy consumption	1924125 (kWh)	66.67%	66.67%
	Energy use per capita	5500 (kWh/per-son)	100.00%	
	Electric energy use as a percentage of total energy use	71%	33.33%	
B	Total energy consumption	875194 (kWh)	33.33%	55.56%
	Energy use per capita	22000 (kWh/per-son)	33.33%	
	Electric energy use as a percentage of total energy use	100%	100%	
C	Total energy consumption	2756121 (kWh)	100.00%	77.78%
	Energy use per capita	8000 (kWh/per-son)	66.67%	
	Electric energy use as a percentage of total energy use	74%	66.67%	

As can be seen from Table 3, companies A, B and C secured a corporate energy security value of the Availability dimension of 66.67%, 55.56% and 77.78%, respectively. Company C stands to be the highest achiever in this dimension because of its rank in the three indicators. It scored highest in one indicator and second highest in the other two indicators. On contract, company B scored the lowest score in two dimensions and the highest in one. The overall visual representation of the Availability dimension is shown in Figure 3.

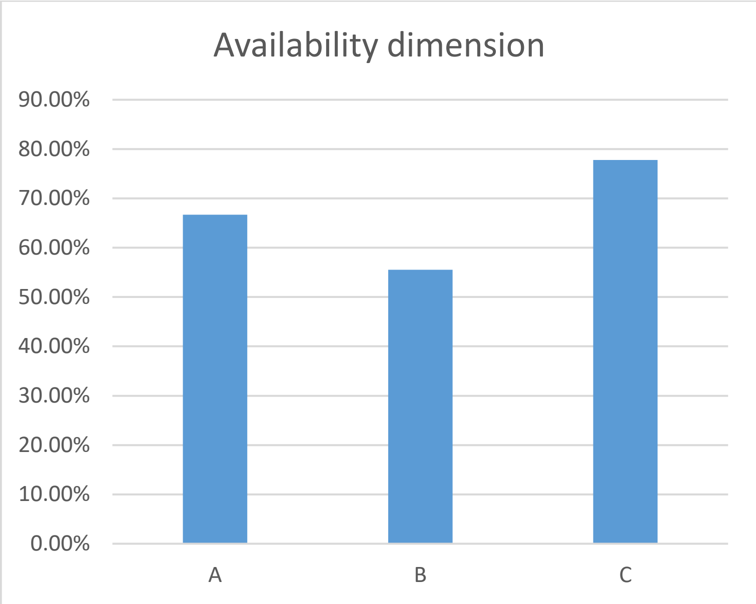

Figure 3. Companies' values for Availability dimension.

Therefore, for any company, in order to be able to get higher corporate energy security values in the availability dimension, more energy has to be consumed, more staff are to be employed and more use of electricity rather than fuel is to be realized. Following these steps will help companies to achieve high in the Availability dimension.

5.2 Diversity

The three parameters of Diversity dimension were presented in Table 1 and their representative indicators were presented in Table 2. Furthermore, for the summary of the responses from the three companies regarding the numerical indicators for Diversity dimension is shown in Table 4.

Table 4. Companies' responses for Diversity dimension.

Company	Numerical indicators	Input values	Normalized parameter	Dimension values
A	Number of energy sources	1	33.33%	33.33%

	Percentage of self-produced energy	0%	33.33%	
	Number of applications	3	33.33%	
B	Number of energy sources	1	33.33%	55.56%
	Percentage of self-produced energy	0%	33.33%	
	Number of applications	10	100%	
C	Number of energy sources	2	100.00%	88.89%
	Percentage of self-produced energy	5%	100.00%	
	Number of applications	2	66.67%	

There are different effects of the Diversity indicators on corporate energy security. The "Number of energy sources" affects the Diversity dimension proportionally, higher number of sources means a diverse set of sources thus higher security level on the Diversity dimension. The second indicator "Percentage of self-produced energy" provides information on how much the company is dependent on external resources, their dependency level. Therefore, a higher share of self-production means less dependent on external factors. This means a higher level of corporate energy security. However, if the share grows more than the share of other energy sources then corporate energy security deteriorate. The third indicator "Number of applications" has a proportional relationship to corporate energy security. More applications that are in use means different ways to use the energy and thus a more secure system on the Diversity dimesons.

The reasons behind the high achievement of company C in this dimension is using self-produced energy source that accounted as 5% of the total energy consumption. This meant a more diverse situation and thus a higher corporate energy security level. Although company C was ranked second in the number of applications they use this diverse energy for, but that did not make them to lose their lead. On contrast, companies A and

B relied totally on external resource, which makes them more vulnerable. However, company B achieved a higher corporate energy security level in the diversity dimension because of the diversification of usage where the number of applications is higher. Figure 4 visualizes the results for the Diversity dimension for the three companies.

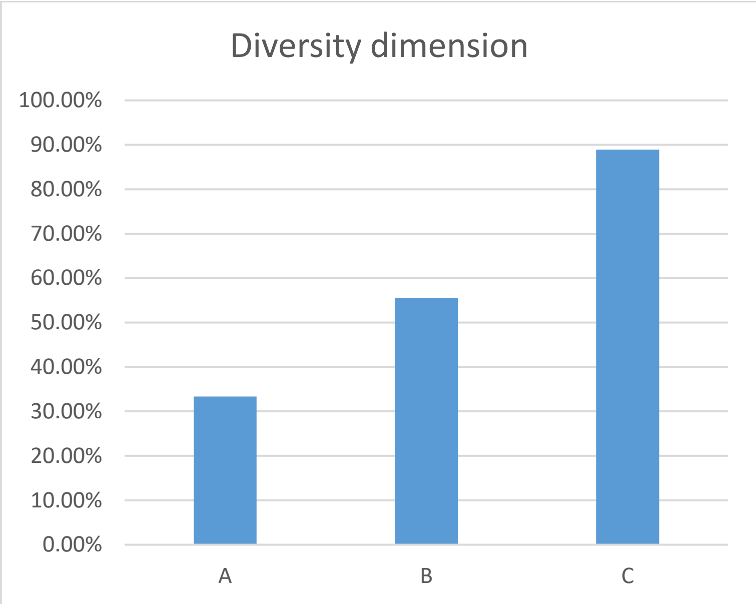

Figure 4. Companies' values for Diversity dimension.

Therefore, for any company, in order to be able to get higher corporate energy security values in the Diversity dimension, higher number of energy sources has to be utilized, more energy to be self-produced and to increase the number of applications they use the energy for. Following these steps will help companies to achieve higher level of corporate energy security in the Diversity dimension.

5.3 Cost

The three parameters of Cost dimension were presented in Table 1 and their representative indicators were presented in Table 2. Furthermore, for the summary of the responses from the three companies regarding the numerical indicators for Cost dimension is shown in Table 5.

Table 5. Companies' responses for Cost dimension.

Company	Numerical indicators	Input values	Normalized parameter	Dimension values
A	Energy cost	30000 (Euro)	100.00%	55.56%
	Financial loss of one hour energy blackout	6000 (Euro)	33.33%	
	Percentage change of energy cost over the last 5 years	15%	33.33%	
B	Energy cost	96000 (Euro)	33.33%	77.78%
	Financial loss of one hour energy blackout	1200 (Euro)	100.00%	
	Percentage change of energy cost over the last 5 years	5%	100.00%	
C	Energy cost	50000 (Euro)	66.67%	66.67%
	Financial loss of one hour energy blackout	3000 (Euro)	66.67%	
	Percentage change of energy cost over the last 5 years	11%	66.67%	

There are different effects of the Cost indicators on corporate energy security. The "Energy cost" affects the Cost dimension in a reverse proportional relationship; more expensive energy cost means less energy security, because companies need to pay more on the energy rather than using that money on their development or elsewhere. The second indicator "Financial loss of one hour energy blackout" provides information on how much the company loses financially for each one-hour blackout of energy. More loss means lower corporate energy security level. The third indicator "Percentage change of energy cost over the last 5 years" has a reverse proportional relationship to corporate energy security. More change in the energy cost means higher volatility and thus lower corporate energy security. When the energy prices are more volatile, uncertainty increases and makes the system to be more vulnerable.

What can be seen in the Cost dimension is that companies A, B and C score very close to each other. This indicates that their results within the indicators are distributed. However, there are two remarks about the highest and the lowest, B and A, respectively. Company B achieved the highest in two of the indicators, that their financial loss is the least for each one hour of energy blackout. This means their revenue generation is less dependent on energy and that their business has less energy intensity as will be seen later. Also, company B maintained a profitable business for the last 5 years as their energy price volatility level was lower than the other two companies. Company A is the total opposite of company B in all of its indicators. Although company A payed the least for energy cost and was ranked highest for this indicator, still, the low results of the other two indicators made it to be ranked the lowest in this dimension (Cost dimension). Figure 5 visualizes the results of the Cost dimension for the three companies.

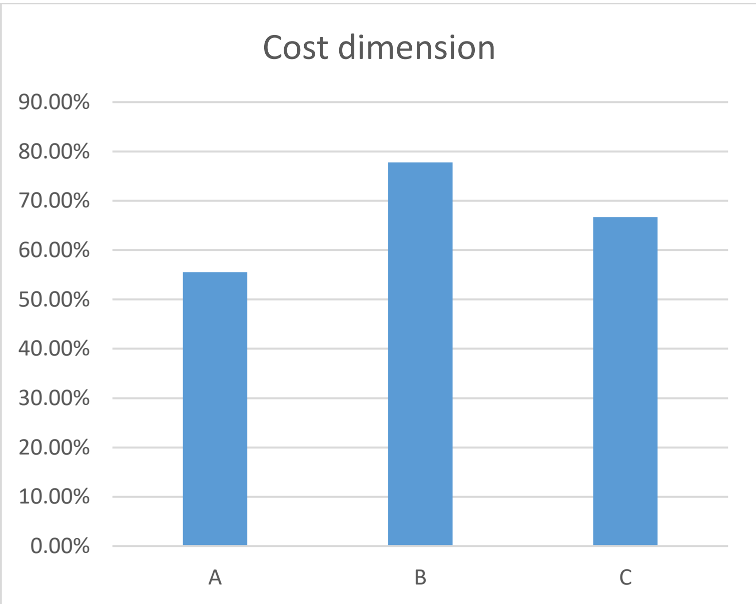

Figure 5. Companies' values for Cost dimension.

For any company, in order to be able to get higher corporate energy security values in the Cost dimension, energy cost has to minimized, revenue generation portfolio shall have lower energy intensity and further, more reliable energy sources are to be used instead of the ones with high price volatility over the years. Following these steps will help companies to achieve higher level of corporate energy security in the Cost dimension.

5.4 Technology & Efficiency

The three parameters of Technology & Efficiency dimension were presented in Table 1 and their representative indicators were presented in Table 2. Furthermore, for the summary of the responses from the three companies regarding the numerical indicators for Technology & Efficiency dimension is shown in Table 6.

Table 6. Companies' responses for Technology & Efficiency dimension.

Company	Numerical indicators	Input values	Normalized parameter	Dimension values
A	R&D department budget as a percentage of the total budget	3%	66.67%	77.78%
	Average energy efficiency of all equipment	90%	100.00%	
	Energy intensity	1.64 (kWh/€ profit)	66.67%	
B	R&D department budget as a percentage of the total budget	1%	33.33%	55.56%
	Average energy efficiency of all equipment	10%	33.33%	

	Energy intensity	1 (kWh/€ profit)	100.00%	
C	R&D department budget as a percentage of the total budget	7%	100.00%	77.78%
	Average energy efficiency of all equipment	90%	100.00%	
	Energy intensity	2.1 (kWh/€ profit)	33.33%	

The effects of the different Technology & Efficiency indicators on the results of their respected dimension are interesting. The first indicator "R&D department budget as a percentage of the total budget" affects the Technology & Efficiency dimension in a proportional relationship; higher R&D expenditure means higher corporate energy security level because it allows for more advanced technology solutions. Advancement in technology solutions will make the business more advanced and more efficient. The second indicator "Average energy efficiency of all equipment" provides information on efficiency of the company. Efficiency is measured in percentage as the energy input used in the company and the output work produced from the machines. The relationship of this indicator to corporate energy security is proportional; higher energy efficiency means higher corporate energy security level. The third indicator "Energy intensity" has a reverse proportional relationship to corporate energy security. Higher energy intensity means lower level of corporate energy security. When one Euro profit relies on more energy consumption then the company loses its tail on the corporate energy security perspective.

The results of the Technology & Efficiency dimension for the three companies has a unique feature apart from all other dimensions. Two companies (A and C) scored the same level of corporate energy security level of the Technology & Efficiency dimension, although they reached this achievement in different paths. Company C scored the highest in the R&D expenditure and average efficiency. This means their technology development lead them to have a more advanced and efficient solutions to their needs. On contrast, both companies A and C fall behind the third company (company B) in the energy intensity indicator. Company B uses less energy to generate revenue and this is more secure in this regard, but the sad news are for the other two indicators that need to be taken care of more. Figure 6 visualizes the results of the Technology & Efficiency dimension for the three companies.

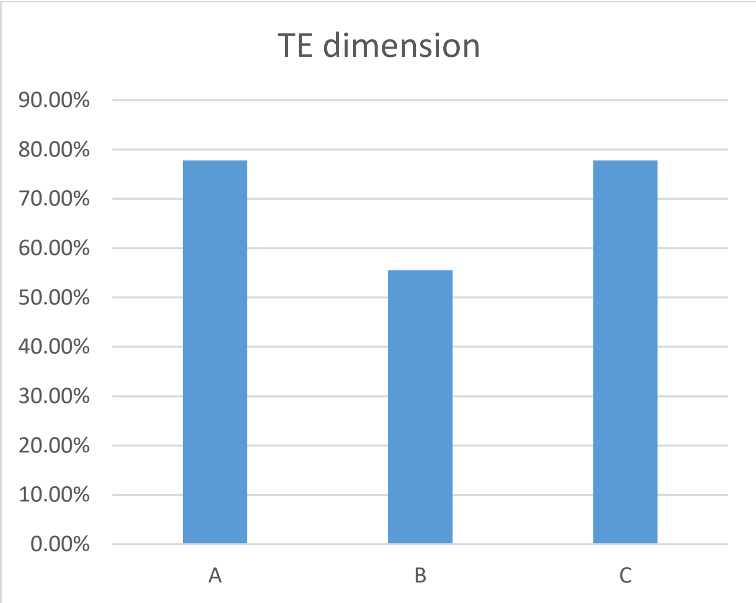

Figure 6. Companies' values for TE dimension.

For any company, in order to be able to get higher corporate energy security values in the Technology & Efficiency dimension, more R&D budget has to be increased, more efficient equipment have to be in use and less energy intensity for generating profit has to be achieved. Following these steps will help companies to achieve higher level of corporate energy security in the Technology & Efficiency dimension.

5.5 Environment & Health

The three parameters of Environment & Health dimension were presented in Table 1 and their representative indicators were presented in Table 2. Furthermore, for the summary of the responses from the three companies regarding the numerical indicators for Environment & Health dimension is shown in Table 7.

Table 7. Companies' responses for Environment & Health dimension.

Company	Numerical indicators	Input values	Normalized parameter	Dimension values
A	Total GHG emissions. 2018	714.2 (ton CO_2 eq.)	100.00%	77.78%
	Average temperature in 2018	5 (C Celsius)	33.33%	
	Hours of sick leaves in total 2018	300 (Hours)	100.00%	
B	Total GHG emissions. 2018	1000 (ton CO_2 eq.)	33.33%	55.56%
	Average temperature in 2018	15 (C Celsius)	100.00%	
	Hours of sick leaves in total 2018	1000 (Hours)	33.33%	
C	Total GHG emissions 2018	900 (ton CO_2 eq.)	66.67%	66.67%
	Average temperature in 2018	10 (C Celsius)	66.67%	
	Hours of sick leaves in total 2018	800 (Hours)	66.67%	

There are many effects of the Environment & Health indicators on the results of their respected dimension. The first indicator “Total GHG emissions. 2018” affects the Environment & Health dimension in a reverse proportional relationship; higher GHG emissions means more negative impacts on the environment and therefore lower corporate energy security level. The effect of GHG emissions on Environment & Health vary from global warming and desertification to floods and air pollution. These effects reduce the workers ability to work and the number of healthy consumers who use the company services. The second indicator “Average temperature in 2018” provides information on the environmental effects on business operational conditions. It is assumed that the optimal ambient temperature for businesses to operate is 25 C. In this temperature less energy is used for either cooling or heating, less capital insulation cost is needed and more comfortable environment conditions for workers. Therefore, the closer the ambient temperature is to this optimal, the higher the corporate energy security level can be achieved. The third indicator “Hours of sick leaves in total 2018” has a reverse proportional relationship to corporate energy security. More hours of sick leaves means lower level of corporate energy security. More sick leaves reduce the companies’ productivity and thus profitability.

The results of the Environment & Health dimension for the three companies show a clear ranking of their corporate energy security level, companies A, B, and C achieved 77.78%, 55.56% and 66.67%, respectively for this dimension. Company A achieved the highest due to its lower GHG emissions and less hours of sick leaves of its employees. Although it is operating in a relatively low temperature where it was ranked the worst temperature among the three companies, the overall results for this dimension is high. On contrast, company B operates in the best temperature conditions among the three companies, but still achieves the lowest corporate energy security level in this dimension because of the other two indicators where GHG emissions are very high and many productive hours are lost as sick leaves. Figure 7 visualizes the results of the Environment & Health dimension for the three companies.

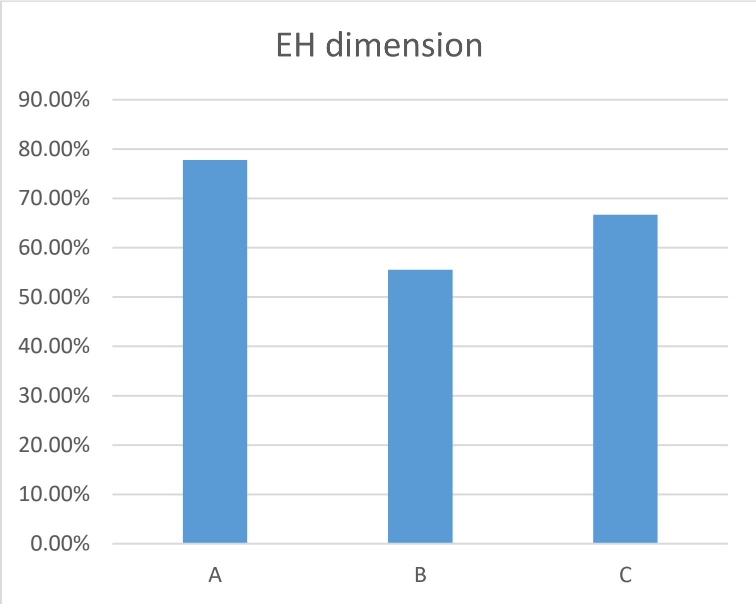

Figure 7. Companies' values for EH dimension.

As a result, for any company, in order to be able to get higher corporate energy security values in the Environment & Health dimension, lower GHG emissions should be released to the environment, choice of an optimal ambient temperature location should be considered and better health care and work conditions should be provided for employees. Following these steps will help companies to achieve higher level of corporate energy security in the Environment & Health dimension.

5.6 Overall CESI

In this section, the analysis and discussion for the overall corporate energy security levels for the three companies in presented. Table 8 summarizes the achievement of the three companies in each of the dimensions and the total overall Corporate Energy Security Index (CESI).

Table 8. CESI results for all companies and their respected dimensions values.

Companies	(A)	D	(Co)	(TE)	(EH)	CESI
A	66.67 %	33.33 %	55.56 %	77.78 %	77.78 %	62.22%
B	55.56 %	55.56 %	77.78 %	55.56 %	55.56 %	60.00%
C	77.78 %	88.89 %	66.67 %	77.78 %	66.67 %	75.56%

The overall results of the CESI have some interesting aspects to be discussed. First of all, although there is a clear ranking of the three companies where company C has the most secure business, company A and company B achieve very close results of their corporate energy security levels. However, the path of which each of these two companies followed to achieve this comparable result is very different.

Company B achieved the lowest corporate energy security level among the three companies. However, it is noticeable that none of the five dimensions of corporate energy security was less than 55.56%. In fact, four out five dimensions have the same results. This indicates the achievement of company B in most of the dimensions is similar. The efforts of company B to have all the dimensions equal is not enough to bring the company to achieve corporate energy security. Therefore, companies should not aim to perform similarly in all of the corporate energy security dimensions but rather to focus on performing better for each of the dimensions individually.

Company A was ranked second in CESI among the three companies because of its high achievement in the TE and EH dimensions. However, the contribution of the Diversity dimension lowers its CESI. In addition, considering the fact that CESI of company A is not far from company B, it can be noticed how sever the impact of one dimension on the overall CESI. Therefore, if companies want to design their own strategies to enhance corporate energy, they should not forget about any of the dimensions in their planning. Neglecting improvement for any of the dimensions will affect the CESI negatively.

The last remark is about company C. Company C achieved the highest corporate energy security level among the three companies. This high achievement should not make companies to copy company C strategies as the CESI is affected by the number of the sample. Thus, companies should aim to enhance each of the dimensions and indicators individually. Furthermore, the very high performance of company C is attributed to many factors but one of the noticeable factors is the Diversity dimension. Unlike the other two companies, company C uses renewable energy that is self-produced in-house. Therefore, for strategy planners, it should be clear that more use of renewable energy is to enhance their corporate energy security. Also, a balanced independent-dependent energy production (self-produced and external) mix should be sought. Finally, company C did not achieve the lowest in any of the dimensions. This shows the implication of preforming better in all of the indicators and the need for developed plans for enhancing and developing of all indicators. Figure 8 visualizes the CESI results for the three companies.

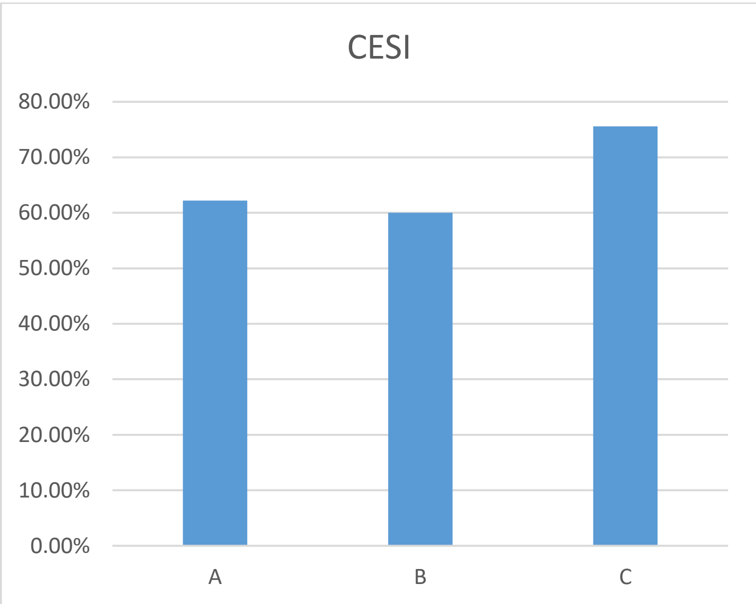

Figure 8. CESI, Corporate Energy Security Index for companies A, B and C.

6 CONCLUSIONS

After going through this journey about corporate energy security, it can be concluded that this topic is very important for the companies in Vaasa and in the whole world. In addition, CESI can be used in the future to determine the corporate energy security level of any company, simply by adding their values in the modelled index and reading the results.

In order to get to these conclusions we tried to answer the main two research questions of what energy security means for corporations and how to evaluate and measure it. Therefore, a conceptual development of what to consider for corporate energy security was done in a qualitative method from literature. This method helped to answer the first research question, but quantitative methods were needed to answer the second research question. Thus the development of the CESI took place. First by introducing suitable indicators for each of the predefined dimensions, then by capturing these indicators values from a case study. The case study was companies and industries in the city of Vaasa, Finland. The case study was to apply the conceptual design of the CESI in real life.

The results were on the point of answering the research question. It was found that corporate energy security is the feature in which companies and industries function sustainably in all possible dimensions, freely from risks. After that, 5 dimensions were identified to be needed for corporate energy security analysis (Availability, Diversity, Cost, Technology & Efficiency and Environment & Health). Then for the quantitative part of the thesis, many indicators were proposed to capture data for these dimensions. Hereafter, data was collected through a survey. But data without a framework was not enough, therefore, the design for Corporate Energy Security Index took place. The last step was to apply this index on the respondents of the survey and present their corporate energy security levels. That included the results and discussion section of the thesis.

Furthermore, it can be concluded from the results that this thesis work was able to measure what was intended to be measured (corporate energy security). This makes the validity level of this work on the high end. In addition, what is astonishing about the results is their reliability, that, same results can be obtained shall the research be repeated. The reason is the structural design of the methodology that takes the researcher systematically from preliminary literature towards mature results.

On the other note, there were some limits for this research because of the number of respondents to the survey. In order to have a better representation of any region, more respondents will be helpful. Hence, more research is needed by following the same methodologies but focus should be in the communication of and data collection.

Lastly, it is recommended that this index (CESI) is used to evaluate individual company's profile and its achievement in the field of energy security. Simply, any company in Vaasa or even in the whole world, can use this CESI by inputting their data into the proper tables presented in this thesis and calculate their corporate energy security values. However, the closer the company meets the set criteria mentioned in the methodology section, the more accurate the results will be. A limitation might arise for companies that have very different profile than these criteria. That is for each individual company to decide. For the researcher, more use and application of this work to benefit the society is admired and encouraged.

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Appendices

Appendix 1. List of companies and their contact details

- **ABB** : contact.center@fi.abb.com
- **Ad-electronics oy** : Jukkarantala@gmail.com;
- **Crimppi oy** : sales@crimppi.com; Aapo.Valli@crimppi.com
- **Elekrometalli** : jukka.koponen@elektrometalli.fi
- **Epv tuulivoima** : Raine.Laaksonen@epv.fi; Frans.Liski@epv.fi;
- **Escarmat oy** : veikko.junttila@escarmat.com; nora.mottonen@escarmat.com
- **Incap oy** : communications@incapcorp.com; info@incapcorp.com;
- **Jmc engine oy** : rekry@jmcengine.fi; mikko.lassila@jmcengine.fi
- **Kgn tool oy ab** : KGN@KGNTOOL.COM;
- **Leimec** : leimec@leimec.fi;
- **Leinolat Oy** : leinolat@leinolat.com; rauno.honkamaki@leinolat.com
- **Merinova** : johan.wasberg@merinova.fi; kaj.sandberg@merinova.fi; anna-kaisa.valkama@merinova.fi;
- **Plastweld oy :** leena.vatilo@plastweld.fi; arto.alho@plastweld.fi; ismo.kajaala@plastweld.fi;
- **Primo finland oy :** andre.sandberg@primo.com; mika.kantola@primo.com;
- **Prohoc :** Ilkka.Palola@prohoc.fi; Sesilia.Alhainen@prohoc.fi;
- **Schneider electric finland oy :** asiakaspalvelu.fi@schneider-electric.com
- **Sop-metal oy** : jarkko.jamsa@sop-metal.fi; sami.kuntola@sop-metal.fi;
- **Steelcomp** : ari.koski@steelcompvaasa.fi; timo.viitanen@steelcompvaasa.fi
- **The switch** : Reijo.Takala@theswitch.com; Pertti.Kurttila@theswitch.com;
- **Työkaluvalmistus Nisula Oy :** nisula@nisulaoy.fi; chatrine@nisulaoy.fi;
- **Uwira Oy :** info@uwira.fi;
- **Vamp Ltd :** sales@vamp.fi
- **VEO** : Visa.Yliluoma@veo.fi; Fredrik.Grankull@veo.fi; Jari.Vataja@veo.fi

- **Wärtsilä** : Thomas.Lerstrand@wartsila.com; Jonas.Carlsson@wartsila.com; Johan.Bertula@wartsila.com; Harri.Makela@wartsila.com
- **We tech solutions** : marten.storbacka@wetech.fi; Solutions@wetech.fi;

Appendix 2. Questions that are used in the survey

Dimensions	Parameters	Numerical indicators	Questions
(A)	(A1)	Total energy consumption	How much energy kWh, in total, was consumed by your company in 2018? (kWh)
	(A2)	Energy use per capita	How much energy kWh per capita, on average, was consumed by your company in 2018? (kWh/person)
	(A3)	Electric energy use as a percentage of total energy use	How much electric kWh, in total, was consumed by your company in 2018? (kWh)
(D)	(D1)	Number of energy sources	How many different energy sources does your company receive energy from?
	(D2)	Percentage of self-produced energy	How much energy was self-produced in 2018? (kWh)
	(D3)	Number of applications	How many applications, in your company, is energy used for?
(Co)	(Co1)	Energy cost	How much does energy cost? (euros)
	(Co2)	Financial loss of one hour energy blackout	How much, on average, would it cost the company if there is an energy blackout for one hour? (euros)
	(Co3)	Percentage change of energy cost over the last 5 years	What is the percentage change of energy cost over the last 5 years as absolute value?
(TE)	(TE1)	R&D department budget as a percentage of the total budget	What is the R&D department budget as a percentage of the total budget?
	(TE2)	Average energy efficiency of all equipment	What is the average energy efficiency (energy input/work output) of all equipment?
	(TE3)	Energy intensity	What is the energy intensity (kWh/€ profit)
(EH)	(EH1)	Total GHG emissions, 2018	What was the total GHG emissions level from your company in 2018?
	(EH2)	Average temperature in 2018	What was the average temperature, in 2018, in the city your company operates in?
	(EH3)	Hours of sick leaves, in total, 2018	How many hours of sick leaves, in total, did your employees take in 2018?