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Lahti University of Applied Sciences

BENCHMARKING SUSTAINABILITY IN WIND ENERGY

Case study: Corani S.A.

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Case study: Corani

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ABSTRACT

Over the years, wind has proven to be a sustainable energy source. Its rapid deployment has increased the attention of stakeholders. More importantly, its capacity to generate clean energy triggers larger investments in the industry. Bolivia has begun the operations of wind energy to participate in the wind energy industry. Hence, a benchmarking study for Corani is of great significance on a national level.

This thesis adopts a combination of theories to research Bolivia and Denmark. The main theoretical framework is based on benchmarking and sustainable development. Benchmarking helps to find superior performance in the market, while sustainable development supports the theory with key aspects that affect the livelihood within environment. In this thesis, sector benchmarking and best-practice benchmarking are adopted. Furthermore, theory of innovation management also supports the research.

Corani S.A. is in charge of wind energy development in Bolivia. The focus of wind energy is to provide a clean source of energy to the locals. Thus, the thesis benchmarks focus areas: governmental decisions, price of energy and reliability. The findings of this thesis show that forming ambitious long-term strategies lead to the forefront of the industry as well as engagement of stakeholders. In addition, involvement of local personnel has driven the industry to prosper, and increase opportunities in economic growth.

Key words: Benchmarking, sustainable development, renewable energy, wind energy, Corani, Bolivia, Denmark.

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1 INTRODUCTION

This chapter introduces background information, research topic, and the author's motivation to introduce this study. The background information describes the significance of the topic and the reasons for the study. Then, the thesis objective and research questions are explained. The theoretical framework introduces the theories used in this work, and the research methodology describes the research stages and the process of collecting information. Lastly scope and limitations are described as well as the thesis structure, which provides a summary of the chapters in this thesis.

1.1 Background information

Nowadays, it is very important to provide energy to meet the needs of the present without compromising the ability of future generations to meet their own needs (Carroll & Buchholtz 2015, 437). The energy industry provides most of its energy from resources such as coal, petroleum, natural gas (fossil fuels) formed millions of years ago under a unique condition of temperature, pressure and biological phenomena. For many years, fossil fuels have been providing energy in societies to fulfil their needs, and yet no change has occurred. The fact that these nonrenewable resources are limited is a concern as once these are depleted, they will be gone forever. In addition, the usage of fossil fuels brings consequences such as carbon dioxide emissions, radioactive, nuclear residue, overuse scarce resources. (Tester 2012, 2-48.)

The consumption and demand of energy has a strong relationship between the level of economic development as well as environmental and human society. (Bradshaw 2014, 2-18). Gasoline for example, which is pumped out of the ground, taken to refineries is a limited resource, and therefore, when a car burns the gasoline, it produces pollution (IEA 2015).

Renewable energy sources have the ability to provide clean energy using natural elements that can be found on earth. Such energy sources can be produced from a variety of sources including solar energy, biomass, hydropower, wind, geothermal (Drake 2012, 68-70.) Fortunately, countries are concerned with the damage that fossil fuels are causing. For instance, local authorities in California, United States, are providing incentives for those owning electric cars (U.S. Department of Energy 2014). Moreover, the European Union has introduced the 20-20-20 targets, which should be met by the year 2020. The targets include a reduction of greenhouse gas emissions by 20% below the level of 1990, 20% of EU's energy consumption should be originating from renewable resources and the primary energy consumption should be reduced by 20% by improving energy efficiency. (EU 2010.) Also, the Plurinational State of Bolivia intends to deploy renewable energies in order to expand its services using environmental friendly modes of energy (World Bank 2014). Hence, Corani S.A. a company based in Bolivia, considers the deployment of clean energy crucial in order to provide means of growth. Corani is responsible for the development of wind energy and also, to connect electricity to the grid. (Corani 2015).

The author strongly believes that the energy industry has a great significance in societies which reflects on sustainable development. Moreover, the energy industry affects several sectors including, social, economical, and environmental, livelihood and poverty. Despite the challenges, the interest towards renewable energy is seemingly enormous, and therefore, the use of clean and natural energy would safely foster development of societies in different areas. Thus, the idea of this Bachelor's thesis was adopted during the author's last semester at the university after gaining knowledge of the industry from his internship, additional courses and the media. The author' motivation is to research renewable energies from his homecountry, Bolivia, as well as his interest to research aspects associated with energy.

1.2 Objective

The objective of this thesis is to illustrate the application of benchmarking principles within one industry in two different countries. The main focus is to compare the Bolivian wind energy and the Danish wind energy, hence, to provide suggestions for improvements to Corani S.A. Corani S.A. is a company in charge of the first-installed wind turbines in Bolivia. Ultimately, studying a country's industry provides with insights to improve the current situation in another country (Camp 1989, 30). Furthermore, this thesis aims at demonstrating sufficient motives for the development of wind energy on a national level. Denmark has proven to have a strong capacity installed to generate renewables energy (CIA 2012). Therefore, Denmark suits perfectly so as Bolivia could learn from.

1.3 Research questions

The intention of the case company is to familiarize itself with the development of the industry in another country. Therefore, the question below, which is the result of a conversation with the case company's representative, intents to explain the reader the following question:

"How can Corani provide a better wind energy services in the future?"

In order to answer the key question, sub-questions are formed:

I. What is the current situation of wind energy in Bolivia? And what is the reason for its deployment?
II. What is the current situation of wind energy in Denmark? How does the government in Denmark cooperate to develop wind energy?
III. What are the potential and pitfalls of generating electricity through wind turbines?
IV. How can Corani learn from Denmark?

1.4 Theoretical framework

This thesis is a comparison of the Bolivian wind energy against best practices from the Danish wind energy. The theoretical framework is based on benchmarking wind energy and sustainability indicators. According to Camp (1989), benchmarking is the search for industry's best practices which will lead to exceptional performance through its implementation. Furthermore, innovation management is mentioned in this thesis as it is associated with growth by the creation of new ideas, and to increment competitive advantage (Bessant 2011, 4-11). The author encourages the implementation of sustainable development by using a cleaner source of energy, and by addressing indicators that reflect on the three dimensions of sustainability: environmental, economic and social. Most of the energy used nowadays causes site effects as fossil fuels provide most of the energy (Bradshaw 2014, 6). Power generation is a worldwide issue as it is associated with environmental impacts and social impacts (Espinosa 2012). Thus, the theoretical framework is based on benchmarking innovation and sustainability of wind energy in two different countries. Furthermore, this paper illustrates the current situation of the Bolivian wind energy and Danish wind energy. Providing existing experiences from developed countries would enhance Bolivia with sufficient motives to deploy wind energy. Denmark is among the top countries with high level of capacity installment of wind power (EWEA 2015). The Bolivian Ministry of Hydrocarbon (2011) presented a developing plan aiming at expanding services across Bolivia with renewable sources. Among this plan, Bolivia intends to invest in wind energy mainly for rural areas with limited resources. Rural areas present a lack access to education, infrastructure, and medical care among other services. Investing in electricity for those places would increase prosperity and a better quality of life. (World Bank 2014.)

1.5 Research methodology and data collection

Prior any investigation in any topic, it is important to decide the type of research approach to follow. Figure 1 illustrates the research methodology of this thesis.

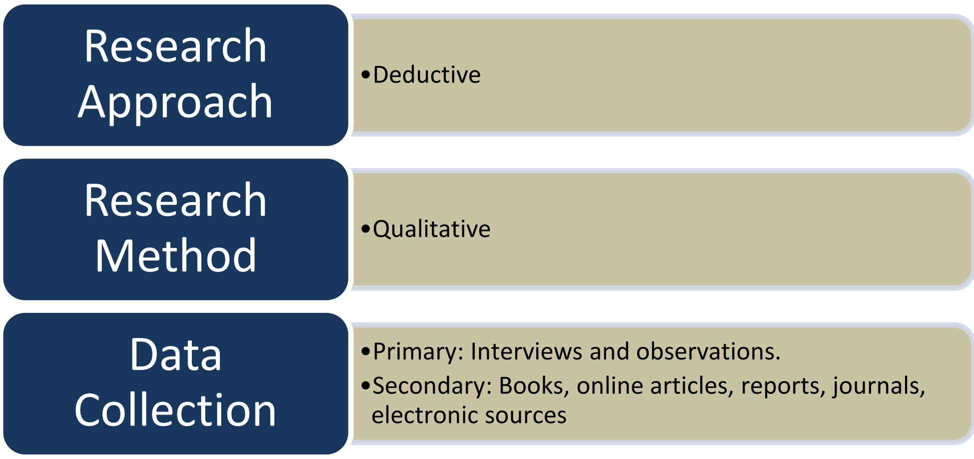

FIGURE 1. Research methodology

Research approach

There are two types of research approaches: inductive and deductive. Inductive approach involves the process of developing a theory after observing and analyzing empirical data, whereas deductive approach entails the evaluation of a theory, and a research strategy is developed to test the theory. Sometimes, a combination of both approaches is used, where inductive and deductive methods are integrated in one research. (Saunders et al. 2009, 124-127.)

Two factors shall be considered when selecting the appropriate approach: the nature of the research topic and available research time. Saunders et al. 2009, 124-127.) The author of this thesis chooses deductive approach as the nature of this study is exploratory and applied business research. This nature is combined with limited time frame which induces the author to choose deductive approach throughout the research.

Research methods

In business scientific research, there are two predominant research methods. The two methods are highly differentiated: quantitative research and qualitative research. Quantitative research is a numerical technique used widely to analyze data, whereas qualitative research is an observation of theory data focused on behavior or events that draw a conclusion out of it. Furthermore, some researches opt for a mixed-method, which consists on both qualitative and quantitative methods. (Saunders et al. 2009, 154-157.) This thesis is designed as an applied business research and carry qualitative research method as its nature is exploratory.

Data collection

The collection of data is vital to answer the research questions. Thus, the author uses two sources of information known as primary and secondary data. Primary data entails a collection of face-to-face interviews, observations and questionnaires. Secondary data is the collection of existing branding literature such as books, academic and trade journals, information databases, government publications, specialized internet sites among others. (Vrontis 2007.) The author collects primary data from the case company, as data is collected internally and unstructured interviews with stakeholders. Similarly, interviews with stakeholders from Denmark are carried out. Secondary data is applied for business research and to collect information from Bolivia and Denmark. The latter data collection is applied as the author collect information from electronic journals and local companies in charge of wind energy in the chosen countries.

1.6 Scope and limitations

The author of this thesis aims at studying the Danish wind energy sector to elaborate suggestions of better practices of wind energy for Bolivia. The evaluations of other countries demonstrate how such green energy is capable to develop, and ultimately, become a viable source of energy. The suggestions are the results of the study based on the author's desktop research, interviews with stakeholders and discussions with supervisor. Hence, the results are in need of practical applicance.

The case country is selected according upon their level of technology and investment in research and development (R&D). The author selects

Denmark as 39 % of its energy supply comes from wind energy (Danish Wind Industry Association 2015). More importantly, the European Union encourages the development of wind energy as it describes in the plan 2020 to increase the utilization of renewable energy by 20% and invest 3% of Europe’s GDP in R&D (European Commission 2015). Denmark presents a different scenario in regards of the land, population, gross domestic product, location and employment rate. Thus, providing suggestions to Bolivia limits the option to suggest new improvements for the local development.

The theory is based on benchmarking methods focusing mainly on sustainable development. All the relevant information, concerning the case company is provided by Corani as well as local government sources in order to finalize the work smoothly. The information regarding Denmark is mainly selected from secondary sources. However, lack of relevant sources about Bolivia limits the work and its finalization. Thus, part of the information gathered is carried out through interviews.

This thesis intends to show the reality of the wind turbines in Denmark and Bolivia, with accurate data and up-to-date information display and conduct semi-structure interviews with stakeholders. Therefore, the author is expected to show the reader the significance as well as the drawbacks that wind turbines cause in the mentioned countries.

1.7 Thesis structure

Figure 2 introduces the structure of this thesis:

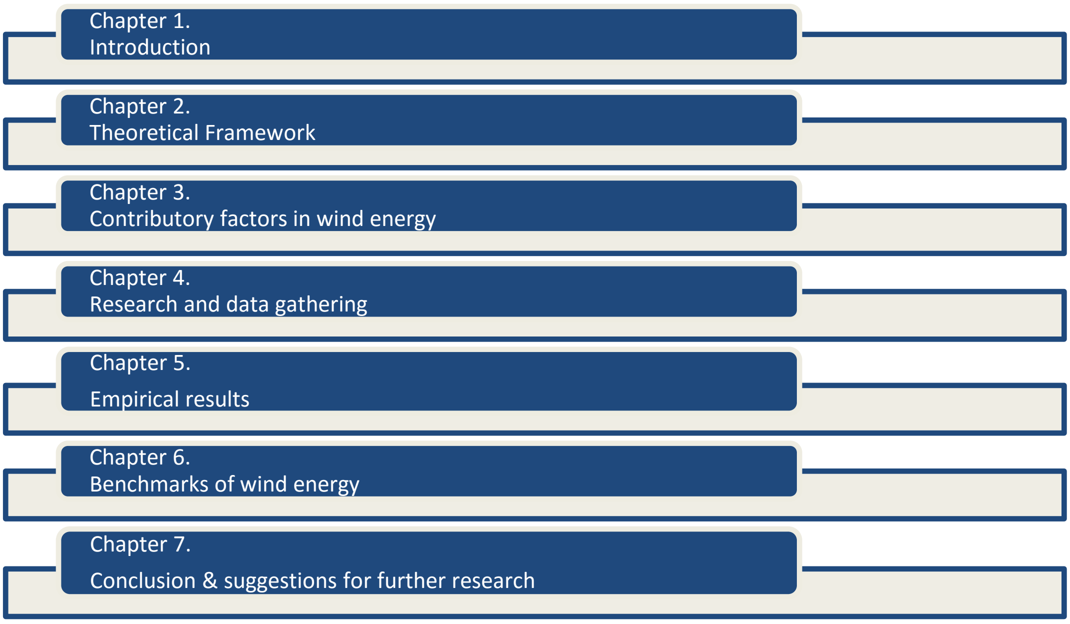

FIGURE 2. Thesis structure

Introduction of the thesis topic, objectives, and research design of the study are presented in chapter 1, which creates the basis for the work. Chapter 2 introduces a review of benchmarking practices and innovation management for sustainability indicators.Chapter 3 describes information about sustainable development and sustainable energy with factors that influence wind energy. In addition, this chapter presents information about wind energy with regards to its opportunities and challenges. Chapter 4 introduces the research method implemented with data collection and interviews. Chapter 5 introduces the empirical research which focuses on the implementation of benchmarking the two countries cases. Chapter 6 contains the benchmarks findings in wind energy. Lastly, chapter 7 presents the conclusions in addition to the author's suggestions for future research.

2 BENCHMARKING & INNOVATION MANAGEMENT

This section presents a literature review of benchmarking and innovation management, providing their definitions, types, processes and understandings. The two concepts are thoroughly explained and linked to sustainability in order to support further research.

2.1 Benchmarking

Robert C. Camp is referred as the creator of benchmarking. Xerox Corporation intended to improve its services. The firm sent a group to visit a Japanese organization considered to have a superior processes. (Camp 1989, 7.) Robert C. Camp was employed by Xerox who helped the firm expanding benchmarking in all Xerox units, ensuring customer satisfaction and business results improved by incorporation of best practices in product service and business processes. (Nelson 2008 & Blakeman 2002.) The purpose of benchmarking remains as finding the industry best leaders and to incorporate the best of the best. In other words, to learn from leaders, know where they are and where they are heading and emulate best practice. (Camp 1995, 14.) The theory of benchmarking may have various definitions, but Camp defines benchmarking as an ongoing process used to improve business performance by analyzing and understanding various methods and practices by other organizations (Camp 1989,14). Benchmarking refers to the continuous analysis of strategies, functions, processes and products compared within or between best-in-class organizations by obtaining information through appropriate data collection methods, with the intention of assessing an organization's current standards and thereby carry out self-improvement by implementing changes to exceed those standards. (Anand 2008.) Regardless of the various definitions, benchmarking is frequently cited as a management tool enabling understanding own advantages in comparison with competitors. Yet, Amaral (2009) selects several definitions by academics and practitioners in which benchmarking is defined in four elements:

1) A continuous process, tool or structured approach

2) To measure, evaluate, improve and learn about products, services, performance and practices
3) To compare against the best-in-class world leaders
4) And to achieve superior performance, compete and apply knowledge.

In addition, benchmarking should add products and functions used in product planning, designing and development expressed as product goals and technology design practices (Camp 1995, 16). Furthermore, a clear difference between benchmark and benchmarking is set out. Benchmark is a repeatable input process, combined with a certain steps and outputs, whereas benchmarking is a continuous process of improvement that measures productivity, services and practices against competitors. (Camp 1995, 18.)

There are four different types of benchmarking: internal, competitive, functional and generic. A clear distinction is made between internal and external benchmarking. Internal benchmarking studies the best performers inside an organization. Internal benchmarking helps the company managers identify their strengths, weaknesses, opportunities and threats (SWOT) and improving the economy efficiency of the organization. While external benchmarking helps organizations compare themselves to other organizations such as competitor firms in the same industry (Competitive benchmarking), non-competing firms in another industry (functional benchmarking). Competitive benchmarking deals with direct competitors comparing themselves in an industry. This investigation shows the comparative advantages and disadvantages between direct competitors. Functional benchmarking investigates competitors or industry leaders in certain areas to benchmark regardless of the industry. This type of benchmarking is productive as the data and information may be the interest of other firms. In addition, the best practice is selected in order to achieve superior performance. Generic benchmarking cover business functions or processes regardless of the dissimilarities of industries. This type evaluates the business performance of the sector for improvement. (Camp 1989, 60-65.) However, Anand and Kodali (2008) suggest that there are two different kinds of benchmarking: Internal and external. Internal benchmarking is considered as it has been established since its origin, and its form has helped organizational scope and complexity. External benchmarking entails details in order to satisfy benchmarking's critis.

As this thesis' objective is to compare industry leaders and business processes, the author selects functional and generic benchmarking. Table 1 below illustrates the scope, objective, advantages and disadvantages of the functional and generic benchmarking named in the table as best-practice benchmarking and sector benchmarking (Wober 2002).

TABLE 1. Types of benchmarking

<table>
<tr><th>Approach</th><th>Scope</th><th>Objectives</th><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>Best-practice benchmarking</td><td>Any organization regardless of the sector and location</td><td>Identify best management practice</td><td rowspan="2">-Possibility of breakthroughs
-Broadness corporate perspective
-Stimulate challenges
-Less sensitive to ethical and political reservations
-Relative ease of access to data
-Relatively low threat
-Industry trends easier to assess</td><td>Relatively difficult to access data Change ramifications are greater</td></tr>
<tr><td>Sector benchmarking</td><td>Specific or similar sector or industry branch</td><td>Identify sector strategies Disseminate information on best practice</td><td>Data also accessible to competitors Difficult to derive specific recommendations</td></tr>
</table>

Benchmarking may be pursued in two different ways: problem-based approach and process-based approach. Problem-based approach is used when there is no specific plan for benchmarking, and thus, the benchmarking activity is uncontrolled and only used when problem arises. On the contrary, process-based approach is put into practice when pursuing a continuous improvement, and normally the benchmarking activity is managed and therefore the improvement is applied to the business process. (Camp 1995, 17.) The table below describes the benefits of benchmarking as key to success factors when benchmarking is implemented and what a firm may attain when doing benchmarking.

TABLE 2. Benefits of benchmarking (Camp 1989, 30)

Without benchmarking	With benchmarking
Defining customer requirement	
Based on history or gut feel	Market reality
perception	Objective evaluation
Low fit	High conformance
Establishing effective goals and objective	
Lacking external focus	Credible, unarguable
Reactive	Proactive
Lagging industry	Industry leading
Developing true measure of productivity	
Ignores market development	Solving real problems
Strengths and weaknesses not understood	Based on best industry practice
Route of least resistance	
Becoming competitive	
Internally focused	Understanding of competition
Evolutionary change	New ideas of proven practices
Low commitment	High commitment
Industry best practice	
Not invented here	Proactive search for change
Few solutions	Many options
Average of industry progress	Business practice breakthrough
Frantic catchup activity	Superior performance

In order to apply benchmarking into a product or process, there should be a process to follow up. However, a benchmarking process must identify organizational competencies, gauge their values according to consistent metric and establish how these competencies contribute to the sustainability of the organization. More importantly, a benchmarking process is effective if it identifies the potential for improvement. (Moriarty 2011.) The external world may provide a great value in learning from industry best practice. Therefore, uncovering industry best practices through benchmarking is the route to superior performance (Camp 1989, 34).

In order to apply benchmarking to this work, the author combines Amaral's (2009) Johnson's (2001) and Camp's (1989) benchmarking processes in regards to the case study and the wind energy industry:

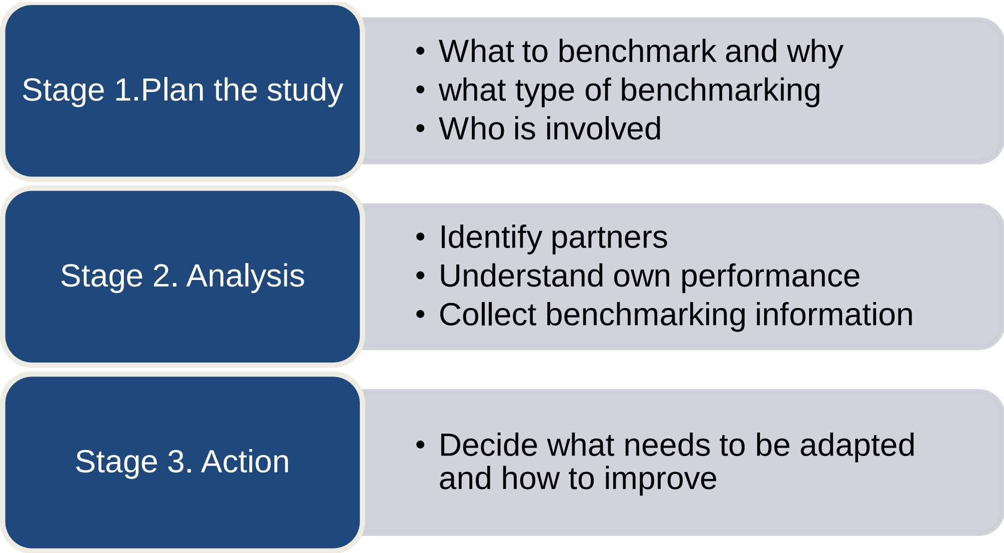

FIGURE 3. Benchmarking process (Modified from Amaral 2009 & Johnson 2001 & Camp 1989)

It is crucial to identify what shall be benchmarked in order to identify key business functions. Customer requirement normally determines the reason for benchmarking, which needs improvement (Camp 1995, 31). Moreover, output deliverables build a solid base of a starting point to find specific items to be benchmarked. (Camp 1989, 40-44.) The analysis part is entirely a comparison of own performance against others. Finally, the action stage is when the firm identifies external practices and ultimately applies those. (Johnson 2001, 97-104.) Such external practices are identified as performance gaps whether they are negative gaps, parity or positive gap. Negative gaps are called when external practices are superior and the benchmark is based on external findings. Parity is identified when there is no significant practice difference in the benchmarking. Positive gap is when the firm has a superior performance than others. (Camp 1989, 122-123.)

Even though there is a vast amount of literature of benchmarking theory, it is worth evaluating the theory prior to its implementation. Moreover, it is recommended spending enough time in researching which companies might make relevant partners. High level of leadership in an industry is desirable which could be valid for a broad range of companies. More importantly, many firms may be reluctant to grant access to independent researchers as sensitive aspects on a firm's operations and information is shared and compared other competitors. (Wober 2002.) The cost of benchmarking might be a fairly expensive process. The time spent in labor time, indirect costs as well as employees devote in searching for exceptional companies, information, and data base cost (Sekhar 2010). In addition, benchmarking requires education and travel cost to implement benchmarking and educate the persons in charge of the benchmark (Blakeman 2002). On the other hand, the success of benchmarking lies in understanding the best practice and the process of implementing them. Furthermore, benchmarking help assessing a firm and generate new ideas and practices to improve its functioning (Sekhar 2010). Above all the benefits, one of the most important is finding innovative approaches, assist in setting targets, planning and strategy but all this is sustained by a self-analysis and understanding own processes. (Scott 2011.) When the self-analysis, understanding own process and innovative approaches are carried out, a key driver is to set an action plan to induct the identified betterments, as well as to motivate employees for effective implementation of the process benchmarking (Sekhar 2010).

2.2 Innovation Management

Innovation is considered the motor improvement in creating value in economy turning ideas into products. Hence innovation is associated with growth as businesses are created by new ideas in order to increment competitive advantage whether expressed in employment, sustainability or improvement of social welfare. (Bessant 2011, 4-11.) Drucker (1985) defined innovation as a specific tool for entrepreneurs by which they seek opportunities for a different business or service. Innovativeness is defined as the combination of newly gained, distant knowledge with familiar knowledge. Chesbrough (2005) mentions innovation as an invention implemented and taken to the market, but it requires an innovative product offering. Particularly, distance knowledge has the greatest significance for breakthrough in innovation. Moreover, gaining access to such knowledge allows organization to differentiate themselves from their competition. (Dahlander 2015.) OECD countries invest $700 billion/year on Research & Development (Bessant 2011, 4). The main focus of innovation is to increment wealth and social value in order to explode new technology markets, provide growth and build a solid portfolio to sustain business and engage stakeholders (Bessant 2011, 12). The distinction of invention and innovation is that innovation determines factors of commercialization whether such factors are success or failure (Botarelli 2008) Davila (2014) recognizes two types of innovations: incremental innovation and breakthrough innovation. The figure below displays the definition and differences of the two types of innovation.

Incremental innovation

- Manages knowledge, improves current strategy leading an edge over competitors. Hence it runs under low uncertainty and it operates with an extensive knowledge and amount of information.

Breakthrough innovation

- Manage ignorance as it provides with low level of knowledge and high level of risk and uncertainty. But when breakthrough succeed, it might cause a revolution in a short time period.

FIGURE 4. Innovation types (Adapted from Davila 2014, 5-6)

Bessant (2011, 16) identifies four core themes in order to steer and control innovation process: recognize ideas, finding the resources, developing the venture and creating value. Hence, the innovation process begins with the generation of ideas and early R&D activity, which could turn out a new products or processes when implemented. The second process is the acquisition of full knowledge on the generated ideas and by the complete implementation and market monitoring. (Botarelli 2008.) The application of this process lies on efficiency of push and pull factors: Push factor observes technological opportunities which firms create innovative products based on available technologies. Pull factors lies on markets' and customers' needs where innovative ideas start. Importantly, an integrated model is the couple of push and pulls factors. The model creates innovation through technological firm readiness and markets' and customers' needs. In addition, new innovative capabilities may emerge by the use of this. (Botarelli 2008.)

According to Oke (2007) innovation has influences in levels of growth in different sectors including transport, education, government, health care, social and personal services. Due to the levels of scarcity of resources and growing population, innovation has to be developed with high levels of sustainability, little needs in resources and less hazardous emission. Bessant (2011, 84) states that formal policy, institutions and governance have an enormous influence on the level and direction of innovation in a country. In fact, in order to influence the level and direction of innovation, regulation and control are needed. This approach entails formal policies used to manage innovation by implementing systems of regulation, targets, incentives and usually punishments for non-compliance, which involves policy-makers, consumers, firms, institutions and other stakeholders that may influence the direction of innovation. (Bessant 2011, 115.) However, the level of innovative activities and investments in R&D influence national economic growth and trade performance, and it, in fact, influences the size of the economy of a country, R&D expenditure on firms and the availability of venture capital and the involvement of small-medium size firms, but negatively, they are influence by the economic prosperity and foreign competition in home market. (Bessant 2011, 96.) It is clearly stated that innovations are driven by the policy markets, which are those that influence the level of innovation and the national economy. Furthermore, innovation has a strong connection with the level of sustainability. Green (2002) identifies few limitations in innovation which could potentially link the level of sustainability, thus, it is significant to highlight aspects for further research: An increase level of leadership in firms and managers as innovation is influenced by regulation, policy and social pressure. The scope on technologies should be wider and it must evolve. Lastly, the technology opportunities and market demands shall include social concerns, expectations and pressures.

Bessant (2011, 116) states that innovation must be one of the key solutions to a wide range of environmental issues such as offering cleaner products with low environmental impact over their life cycle, innovate efficient processes to minimize waste to reuse or recycle, innovate alternative technologies to reduce emissions. Additionally, innovating renewable energy, and new services to replace or reduce the consumption of other products. The figure below consists of a typology of different ways in which innovation could contribute to sustainability.

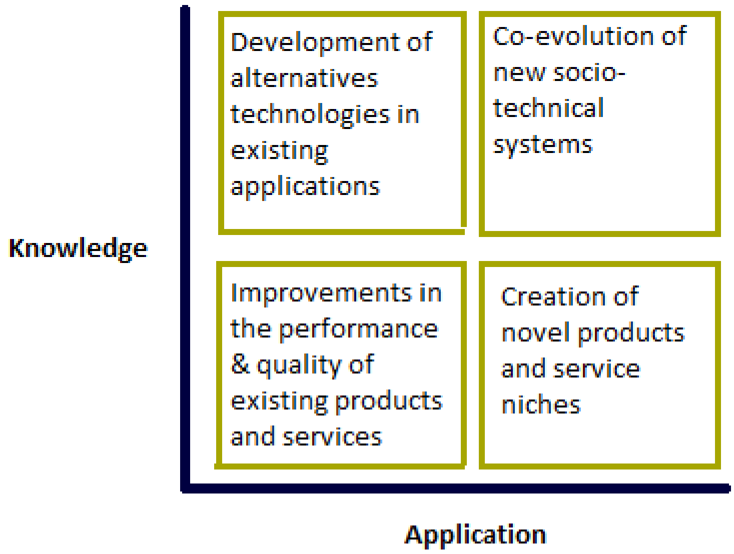

FIGURE 5. Typology of sustainable innovations (Adapted from Bessant 2011, 116)

Wagner (2012) considers that innovation enables a restructure process on the social and technical infrastructures that support everyday life. Moreover, innovation seems to decouple economic growth from environmental and social externalities. Hence the development of alternative technologies is considered significant contributor to sustainability. However, a larger amount of other externalities are involved in its progress (Bessant 2011, 117). Innovation forms part of this as it generates and use new products, services and ways of working supported by new ideas, improved processes, new products or new ventures (Bessant 2011, 172).

3 SUSTAINABILITY & SUSTAINABLE ENERGY

This section presents information of sustainable development, as well as sustainable energy in order to assist the reader with a better understanding of the topic. The chapter addresses background information of sustainable development and energy, including their origin, definition and common objective. Ultimately, contributory factors in sustainability as well as its pitfalls affecting in livelihood are presented. Subsequently, the latter sub-chapter focuses on wind turbines; functionality and opportunities and challenges.

3.1 Sustainable development and sustainable energy

During the mid-eighteenth century, governments in Britain, France and Germany recognized that primary material used for fuel was becoming unsustainable (Blewitt 2015, 6). In 1980, the IUCN published a strategy with a potential future practice of sustainable development (IUCN 1980). The term "Sustainable development" was dispersed in 1987 by the World Commission on Environment and Development in a report called "*Our Common Future"*, known as the Brundland report. The classic definition of sustainable development is a development which meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED 1987). Sustainable development has various definitions, but there is a clear connection between the present and future affecting the environment, economy and society for development and growth. Hence, the dominant definition of governments and businesses is that sustainable development is continued economic growth made more environmentally sensitive in order to raise living standards globally and break the link between poverty and environmental degradation (WCED 1987). Furthermore, Ratner (2004, 4-53) considers the term sustainable development as "sustained growth" and often entails social goals (including justice, participation, equality empowerment and cultural integrity), ecological goals (including biodiversity preservation, ecosystem resilience, resource conservation) and economic goals (growth, efficiency and material welfare).

Since The United Nations Conference on the Human Environment in 1972, authorities had been aware of the paramount significance of sustainable development. Progress was accomplished along the years with the creation of indicators to measure progress such as gross domestic product (GDP), a measure of a country's overall economic output, Human Development Index, and the gross national happiness indicator of Bhutan as well as other entities, in charge of protecting the environment and other sectors. In addition, even the private sector was also concerned about sustainable development, as it was refered as corporate social responsibility (CSR) (Drexhage 2010.) The realization of sustainable development requires:

- A political system that engages and secures citizen participation in decision making.
- An economic system capable to generate surpluses and technical knowledge on sustained basis.
- A social system that provides solutions for the tensions arising from disharmonious development.
- A production system that preserve the ecological base for development.
- A technological system that searches continuously for new solutions.
- An international system that encourages sustainable patterns of trade and finance.
- An administrative system that is flexible with the capacity for self-correction (WCED 1987.)

However, the progress towards implementing sustainability was being unsuccessful (Drexhage 2010). MacNeil (2007, 5) states that evaluating the symptoms were significant but evaluating the source of the problem was vital. Poverty eradication is the greatest challenge in sustainable development. More importantly, this forms part of the overarching objectives, which are poverty eradication, promotion of economic growth, sustainable management of natural resources and ecosystems to provide equal social development that supports social, economic and human development while conserve the ecosystem, regeneration and restoration in the face of new challenges. (UN 2012.)

The utilization of sustainable energy is considered a way to implement sustainable development from renewable sources, which are energy efficient, and therefore, a safe, environmentally sound and economically viable energy pathway enable human progress (WCED 1987). More importantly, sustainable energy refers to those technologies that do not significantly degrade the biosphere’s capabilities for supporting existing species. Furthermore, sustainable energy is in regard not only to energy and environmental technologies, but also to the economic, social and political factors that impact human lifestyle. (Tester 2012, 5-6.) Hence, United Nations Conference on Sustainable Development (2012) addresses the integration of three dimensions in order to strengthen the implementation of sustainable development. The three dimensions are economic, environmnental and social. The environmental dimension refers to physical capacity of available resources to fulfill future generations without harming the environment, whereas the economic dimensions refers to economic growth such as employment, and different forms of capital physical, human, social and natural. Social dimension entails human security and equality. (Warnecke 2015.) Moreover, the influence of people in decision-making is fundamental for sustainable development (UN 2012). The figure below illustrates the interconnection of the three dimensions.

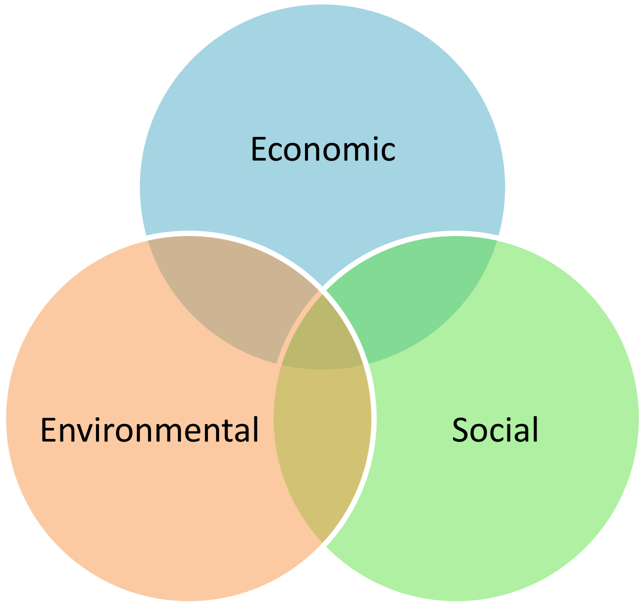

FIGURE 6. Dimensions of sustainable development

One of the main reasons of implementing sustainability is to avoid negative consequences primarily on food production and poverty (UN 2012). Primary energy sources are linked with growth and development as they provide positive as well as negative impacts due the combustion of fossil fuels, which accounts for about 85% of total energy source (Bradshaw 2014, 15). The mining, processing and burning of mainly coal, gas and oil have significant consequences on the environment, economy and social life. Thus, progress towards integrating the three dimensions of sustainable development has a great significance. However, such progress has been insufficient mainly due to financial, economic, food and energy crises (UN 2012). But in order to evaluate sustainable energy, sustainable development introduces a set of criteria by which energy systems are evaluated (Carvalho 2000):

- It should be aligned with sustainability concept. Energy systems must present relevance to sustainability indicators. This may imply a development of new technologies with knowledge system based.
- Energy systems must show physical indicators for their evaluation. Data shall be obtained in qualitative or quantitative form.

- Energy systems must meet sustainability on every phase of the life cycle. Energy systems work under different conditions in order to meet environmental change, social change. There will be different cycles for each of the mentioned time scale.
- Build a strategic view. Optimization of local resources including urban, industrial planning, transport optimization and use of renewable energy sources.
- Possibility to minimize energy costs, available material, government regulations, financial resources, protection of the environment with safety and reliability and maintenance of the system.

The United Nations (2012) considers energy as a contributor in poverty eradication, improving health, and helping provide basic human needs. Thus, encouragement towards implementing sustainable modern energy using appropriate energy mix including renewable energy sources and other low-carbon emission technologies, with a greater reliance and advanced energy technology, and cleaner fossil fuel technologies, and sustainable use of traditional energy resources. Additionally, improving energy efficiency, increase the share of renewable energy and cleaner energy efficient technologies are highly important for sustainable development, and as for climate change. (UN 2012.)

In order to support renewable energy and sustainable development, the Kyoto Protocol was adopted in 1997, and came into effect in February 2005. The focus of the Kyoto Protocol was to regulate and reduce emissions with the help of three mechanisms: International Emission Trading, Clean Development Mechanism (CDM) and Joint Implementation (JI). International Emission trading consists in allowing countries to sell emissions units to other countries that have exceeded their targets. CDM allows a country with an emission-reduction to implement an emission reduction project in developing countries. (UN 2014.) JI allows a country to share emission credits from emission-reduction or emission-removal projects in another country (Kopnina 2015, 32).

3.1.1 Environmental dimension

Sustainable development partly originated from the concern of environmental and natural resource degradation discussed for the first time globally at the United Nations Conference on the Human Environment in 1972. This concern was taken further to advance sustainable development for environmental conservation. (Drexhage 2010.) The environment consists of natural forest, fields, animals, rivers, atmosphere and wilderness. The fields and woodlands are work lands, therefore, the result of these are agricultural transformations. (Blewit 2015, 98.) About 30% of the earth's surface is land, while the remaining is covered by water. Humans work the land to fulfill their needs in production, economic growth and distribution system. (Tester 2012, 353.) Air quality is also a result of industrial production, technology, and investment flows and processes, but more importantly, the level of urbanization, construction of towns, cities and the quality of life is resulted from human behavior (Blewitt 2015, 99).The environmental footprint accounts for the entire energy chain lifecycle, which includes mining, processing, direct and indirect emissions, waste and recycling (Evans 2009). The use of exhaustible sources cause environmental footprint was recognized. In other words, the use of fossil fuels is the result of greenhouse gasses emitted. (Heal 2009.) The figure below, illustrates the global monthly mean of carbon dioxide (CO2):

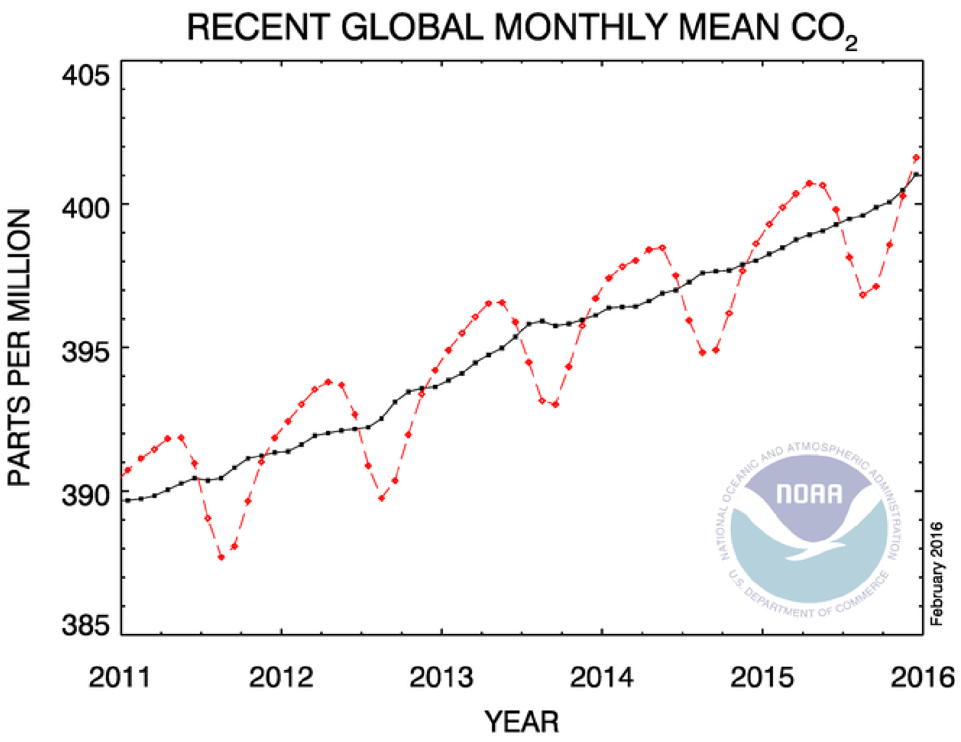

FIGURE 7. Global monthly mean CO2 (National Oceanic and Atmospheric Administration 2016)

In the above figure, the black line shows the increasing amount of carbon dioxide (CO2) over marine surface sites. From 1750 to 2012, CO2 increased in the atmosphere up to 392.52 parts per million (ppm) due to the excessive use of fossil fuels combustion (Yang 2015). CO2 can remain in the atmosphere for a long period of time, hence adding more of this creates long-term impacts to the atmosphere (Kopnina 2015, 31). About 61% of greenhouse gasses emissions and almost 75% of all CO2 come from energy-related activities, with the majority coming from fossil fuel combustion (Baumert 2005). Additionally, the use of fossil fuels destroys renewable resources like forest, and fisheries (Blewit 2015, 99). The combustion of fossil fuels is the results of increased emissions of GHGs, CO2, methane (CH4), nitrous oxide (N20), perfluorocarbons (PFCs) and sulfur hexafluoride (SF6) affects climate, which causes air pollution and environmental greenhouse emissions. Worldwide, the distribution of the CO2 is disproportional as some countries burn more energy than others countries do. Non-OECD (the less industrialized) economies today produce more greenhouse emissions of energy-related CO2. (IEA 2008.) Additionally, the use of fossil fuels and other carbon mix degrades the quality of life and contributes to climate change. (Delucchi 2013.) The IPCC (2007) refers to climate change as any change in climate over time due to variability or as a result of human activity. An increase of global temperature is noted from all the meteorological stations in the world (NASA 2015). The figure below shows the increase in temperature from 1880 to 2000. The increase over the 35 years has a mean of 1.4 degree Celsius.

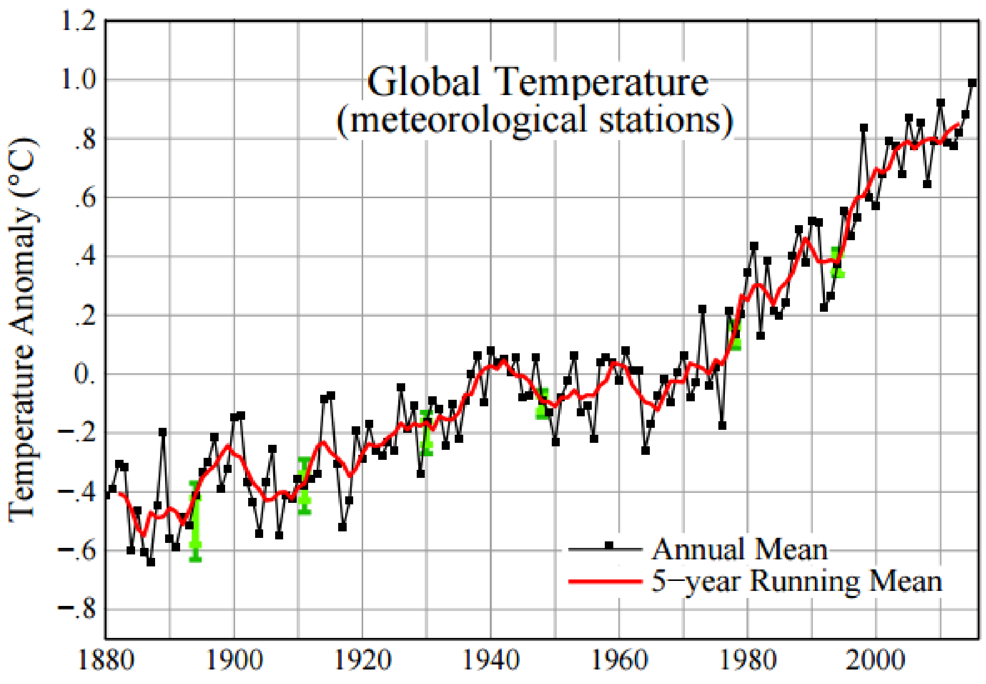

FIGURE 8. Global temperature (NASA Goddard Institute for Space Studies 2015)

Climate change is responsible for the pressure on agricultural land, forest and water resources by especially the least developed countries. Further, non-OECD countries suffer from the rapid depletion of natural resources that is undermining sustainable development. (Herrmann 2014.)

The use of chlorofluorocarbon (CFC), which is an organic compound of carbon, chlorine and fluorine derivative from gases, causes to deplete ozone layers forming holes on the earth allowing ultraviolet radiation from the sun to penetrate the earth. The result of this is harmful effects to humans, plant life, marine life and food (Rao 2012.) Among the aforementioned chemicals, there are others causing smog and acid rain (Kopnina 2015, 31.)

Another associated aspect is waste management and recycling issues. The sorting of recycle materials is determined by the level of labor cost for collection, sorting and processing, transport cost, electricity and water consumption for washing and processing the recovered materials (Karani 2006). The detection of toxic chemicals in nature, especially in water supply, vegetables and fruits jeopardize the environment and the production of goods (Rao 2012). The increase in industrial materials produce hazardous waste, which are chemicals, inflammable, explosive toxic to plants and animals. As for waste management, the issues with garbage and poor management takes place mostly in rural areas in Africa, Asia and Latin America (Karani 2006). The production of nuclear energy is also energy combusting as it produces ton of emissions due to the use of uranium, transport and construction. Additionally, the ecosystem also suffers from degradations caused by the oil production activities. Such activities are flaring of gas and oil spillage, which causes impact on the environment. (Kareem 2012.)

The percentage of urbanization and industrialization stresses the environment (Sarosky 2014). Human behavior has always influenced the environment (Kopnina 2015, 29). Population growth is a direct environmental impact as well as industrialization (Blewitt 2015, 98) The number of inhabitants in a country increase the number of production and economic activities as families need to produce to sustain themselves (Soubbotina 2004). Poverty highly impacts the environment as the poor are forced to overuse environmental resources to fulfill their needs. Also, poverty forces to cultivate marginal land, remove woodlands causing side effects in a long-term. (Kopnina 2015, 55.) It is noted that the overall environmental dimension has become dependent on social sustainability. The increase number of people in a social unsustainable development leads to social stress, and results in environmental degradation. (Cook 2004, 45).

3.1.2 Economic dimension

Economic growth is an essential mean to social progress (Bradshaw 2014, 7). Economics has a great influence in the development of sustainable development due to the application and extension of capital that beyond the spheres of economics, business and finance (Blewitt 2015, 29) and Foreign Direct Investment (FDI) enhances the existing capital towards promoting economic growth that can raise standards of living (UNCTAD 1997). In a long-term, significant impact of FDI inflow on GDP growth (Vu 2008). The level of foreign investement in different sectors ought to increase to add value and strengthen competitiveness along industries. However, the trade balance shall be somewhat equal between the levels of imports and exports. (Zaman 2012.) Foreign direct investment (FDI) has a significant role in a country depending on decisions made whether to invest in technology and in which industry. According to Witkowska (2011) the level of FDI is considered as a threat to the environment, especially in less developed countries. Manufacturing industries such as refined petroleum, chemical products, mining, metal, wood, rubber and plastic products are seen as pollution-intensive industries. In addition, services affecting the environment are hotels, restaurants and transport. The increase openness in foreign investment is unsustainable mainly in most developing countries due to the lack of laws governing natural resource exploitation. (Kareem 2012.)

Natural stock is an asset, which shall be given to future generations without reduction. This matter is also associated with social aspects as well as environment dealing with levels of urbanization and the ability to accommodate development without harming the environment (Counsell 199). Modernization is interconnected with the level of urbanization and industrialization, which increase living standards and in income. Urbanization provides growth in economic activities in a scale of production, but also entails a significant amount of side effects including the large amount of energy use in mobility, transportation, urban density, consumption of energy, as well as labor force (Sadorsky 2014).

Sustainable development seeks to increment economic growth through social development while lessening the impact on the environment. The increased number in population has demonstrated to an increment in labor force as humans must satisfy their needs with food, water, shelter, transportation, which results in economical growth. However, economic activity is the main driver of CO2 as the demand and supply for energy and energy intensive goods leads an increase of CO2 (Winkler 2008). The production of goods and services depends on the transformation of natural resources in order to attain a higher economic output (Herrmann 2014). The consumption of energy is synonym with the levels of economic activity. Simply, high demand on energy causes higher economic growth (Bradshaw 2014,9). Hence burning energy such as oil and electricity could demonstrate how developed a country is (Karani 2006). Energy is considered as one of the engines of growth in many countries, but more importantly, it is reflected in the level of gross domestic product (Winkler 2008). The level of economy is also reflected on the level of pollution as energy use also increases the level of pollution in the environment, which in a long-term is problematic (Zhang 2014).

The chart bellow shows the relationship between energy and economic development. The chart demonstrate that the oil consumption and energy promote economic growth, however, the world highly depends on energy as when the growth rate of energy is low, the growth rate of GDP decreases.

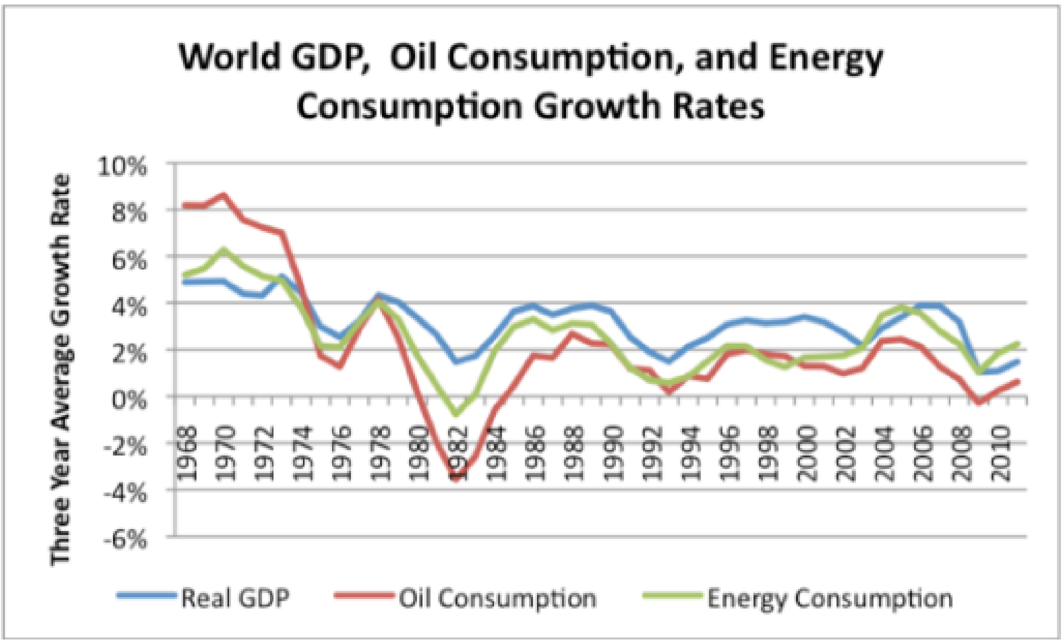

FIGURE 9. World GDP, oil consumption and energy consumption growth rates (Tverberg 2012)

3.1.3 Social dimension

Social dimension consists of human well-being, including income, quality of work, human security, health and education (Soubbotina 2004). According the social indicators, the population rate has increased during 2010 and 2015 (UN 2012). As the number of people living on earth has increased along the years, humans must satisfy their needs with food, shelter, transportation and commerce (Tester 2012, 352). The number of population growth occurs mostly in developing countries (Kopnina 2015, 58). However, the primary negative impact related to population is economic growth as not everybody has the same live, living under the same conditions. In order to have a broad sight of the quality of life in a country, it is important to analyze the distribution of income levels among the poor, average and reach households. Excessive inequality income distribution affects the quality of life, leading to poverty. This latter point limits to basic services such as in health and education. (Soubbotina 2004.) Low income limits the access to services, activities to work, purchase goods, and affecting livelihood in a long-term (Kopnina 2015, 55). According to the World Commission (1987), poverty is caused by unequal distribution of land, assets and other resources. Furthermore, high average of poverty provides a political instability. The figure below provides an understanding on how poverty and social conflicts can impact on economy.

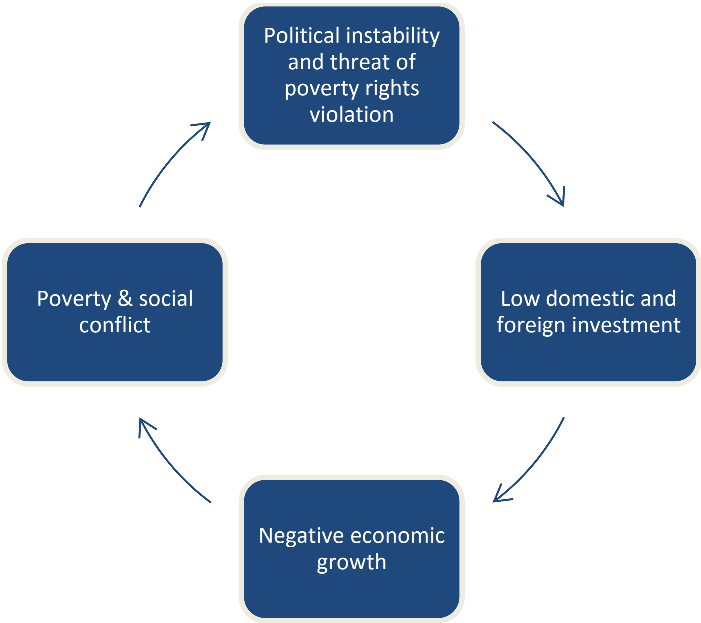

FIGURE 10. Circle of political instability (Adapted from World Bank 2004)

The average of poverty impacts negatively on economic growth as the production is low due to low investment and low income as well low consumption. This leads towards a negative image for investments preventing to economic development and reduce poverty. (Soubbotina 2004.) On the contrary, population growth and poverty are effected by the lack of political initiatives. Political initiatives enable to curve population growth by providing policies and access to information and services for a better support in communities (Kopnina 2015, 60).

The social dimension is highly dependent on ecological dimension as humans work the land and provide services (e.g. clean water and air as well as food and raw materials) (Cook 2004, 45). Furthermore, climate change presents negative impacts on water, food, and human health as the level of moisture increases and energy, together with changing weather patterns results in extreme water availability, along with sea level rise, coastal erosion and storm damages (Tester 2012, 349). This creates unstable place to live and in long-term it cause to shift regions to a more stable habitats.

Additionally, the ultra violet radiations causes health problems, and therefore, harms the animals as well as plants (Rao 2012). The consumption of water, fruits, vegetables and food intoxicated with chemicals or hazardous substances produces health risks (Rao 2012).

3.2 Wind energy

Wind energy is a byproduct of the sun. The sun heats the ground, causing motions in the air, which become bigger with heat and height. The ground transports heat from the surface and up (Energy Department 2015). Wind energy is converted in a machine called wind turbine or wind mill, which converts kinetic energy of wind into electricity (DEA 2009). Wind mills were used to produce electricity in 20th century, but in the late 1970s, firms in Denmark boosted the production of electricity by introducing new-designed tall wind turbines (European Commission 2015). Wind is the main source for electricity generation. However, extraction of energy from wind is also unstable as wind does not always blow at same speed. (DEA 2009.) Although wind speed is not steady, wind resource is plentiful, and therefore, it is a sustainable resource as the sun heat the planet (Energy Department 2015).

Wind resource is not fully accessible in all regions, unfortunately, only selected locations have sufficient wind-blowing for exploitation. Energy flux varies during the day causing variations in wind speed. It is said that the best wind are found near the coast and an overall decline in average quality in regions of large land masses. (Tester 2012, 726.) Moreover, wind resource is not accessible on earth’s surface, thus, wind turbines can have a total height up to 150 meters (DEA 2009). Further, the average wind speed increases with height as fluctuation is less in greater heights, treeless hills are advantageous to increase wind speed, but local condition also causes variations in the speed; temperature and pressures affects the quality of air, as well as height above sea levels as the density of air decreased causing a low average in wind velocity. Additionally water vapor may lower the speed in wind depending upon its level of temperature and total pressure. (Tester 2012, 726-733.)

Electricity is measured in watts, which are small units (EWEA 2016). Yet the electrical output of a wind turbine is measure in kilowatt (kW) or megawatt (MW), in which 1 MW is equivalent to 1000 kW or 1 million watts. As for production and consumption, electricity is measured in kilowatt-hour (kWh) or megawatt-hour (MWh). (DEA 2009.) Hence wind energy is measured in kilowatt-hour (kWh), by which a kilowatt-hour is equal to one kilowatt or 1000 watts of electricity produced or consumed for one hour. (EWEA 2016.)

3.2.1 Wind machinery

A wind turbine is a renewable source of energy capable of generating electricity through wind speed. Wind turbines fall in two basic groups; Horizontal-axis and vertical-axis. Horizontal-axis dominates the market as it produces a larger scale of electricity power. (EWEA 2015.) The horizontal-axis turbine consists mainly of a rotor, nacelle, which contains gearing, bearing and electric generator, and support tower and power conditioning equipment (Tester 2012, 736). Wind turbines size varies depending on the manufacturer and the capacity. An average size is a 2.5-3 MW with about 50 meters length, capable to power more than 1500 EU households (EWEA 2016). The figure below illustrates a sample of a 2MW turbine:

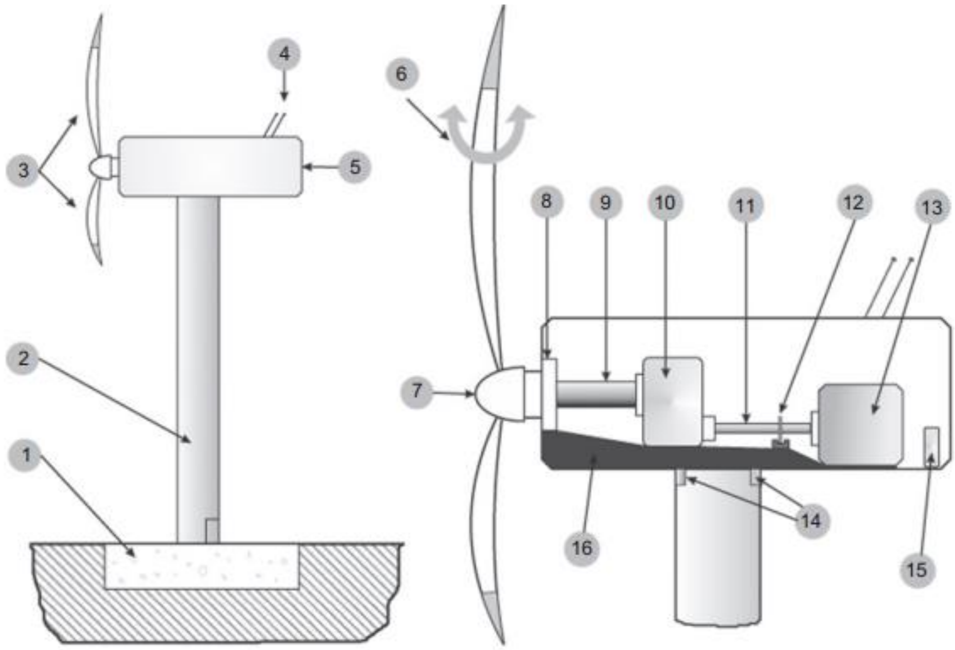

FIGURE 11. Components of a wind turbine (Perez 2013)

In the figure 10, foundation (1) helps prevent the turbine from falling over. The tower (2) holds the nacelle (5) and the rotor. (EWEA 2016.) The rotor is typically made of three blades (3) which contain a pitch system (6) in each blade that controls the power going to the wind turbine, and a hub (7), which holds the blades in a position as the blade turn. On top of the nacelle, a meteorological unit to provide weather conditions (4). The blades are the key to power extraction as they are exposed to wind speeds. Thus, progress towards improved version of the blades is carried out in order to optimize performance within an appropriate wind speed range. Some of the progress includes a substitution of lightweight composite materials for metal in blade design, the use of stall to protect the rotor, gears and generator against overstress, and avoid loss of performance due to accumulated junk. (Tester 2012, 739.) The main-bearing (8) is a supporter, which connects with the low-speed shaft (9) and this last one is connected with the gearbox (10). The gearbox connects with the high-speed shaft (11) and the latter is subsequently connected with the generator (13). Furthermore, a brake system (12) is located between the high-speed shaft and the generator. (Perez 2013.)

Additionally, the figure illustrates a converter (15) to maintain constant frequency, a yaw system (14) to rotate the nacelle mounted on a bedplace (16). The yaw system and the bedplate are used to align with the direction of the wind. The components vary in different types and sizes and costs. (Tester 2012, 740 & Perez 2013.) A wind turbine is made of different materials. The tower is made of steel or concrete, the blades and nacelle are made of fiberglass. The blades are reinforced with polyester or woo-epoxy (EWEA 20155).

A wind turbine reaches a great power output at 15 meters per second, but it starts operating at 4 meters per second (DEA 2009). Further, 25 meters per second is considered that the wind turbine is at high speed and thus, it needs to be shut down. It is said that a wind turbine produces electricity 70% to 85% of the time but in different outputs depending upon the wind speed. Yet, a wind turbine tends to generate 25% of the maximum output. (EWEA 2016.) Additionally, a wind turbine can take less than 1% of the land area (EWEA 2016).

It is recommended to place a turbine in a wide open place with few obstacles only. The turbine needs to be accessible for maintenance and repair work when needed. Noise level shall be calculated in order that the turbine is compatible with the level of sound required in national legislation (DEA 2009). Furthermore, wind condition and landscape of the location are determined for the type of the turbine (EWEA 2016).

3.2.2 Functionality of a wind turbine

The production of electricity of a wind turbine depends on the wind conditions. A turbine uses the wind’s pressure to produce electricity and a negative pressure on the blades that cause them to rotate. (DEA 2009.) The blades transmit kinetic energy via the low speed shaft through the gearbox to the high-sped shaft. The latter component is attached to the generator. The main bearing supports the low speed shaft, whereas the gearbox adjusts the speed. A converter is used to match the electricity with the grid connection. The yaw system is used to align with the wind direction. Additionally, a brake is used to stop the operation of the wind turbine. (Perez 2013.) The electrical energy travels with cables from the nacelle through the towel and into an underground cable. The cables connect with a substation. (FWEE 2016.) Lastly, it is said that not all the turbines contain converter, or a brake (Perez 2013).

A turbine is an energy mechanical carrier used to convert natural energy into electricity. In order to transmit energy from wind turbines, connection lines are contrstucted to interconnect turbines to energy storage or to grids. Turbines are connected with a high-voltage transmission (DC) and andanced sensors and communicators. The distance between the turbine and the grid determines the investment cost to interconnect and produce electricity. (Tester 2012, 758-778.)

3.3 Opportunities and threats

The European Union intends to decouple economic growth from the natural resources by improving eco-efficiently products and services (Ciegis 2011). Further, the emphasis on technologies based on scientific knowledge is being implemented. The European Comission categorizes sustainable energy as an energy system capable to produce clean energy from renewable sources such as hydro, solar (photovoltaic and thermal), wind, geothermal, tidal and biofuels (EU 2014). According to the BP (2015) renewable energy sources have an increase of 3 % of global energy consumption. More importantly, electricity generation showed a significant growth used in global power generation. Even though the importance of renewable energy has increased, its consumption yet presents a small fraction of the global energy consumption as the dominant sources are fossil fuels including oil, natural gas and coal. (Bp 2015.) The chart below shows the world primary energy consumption in 2014:

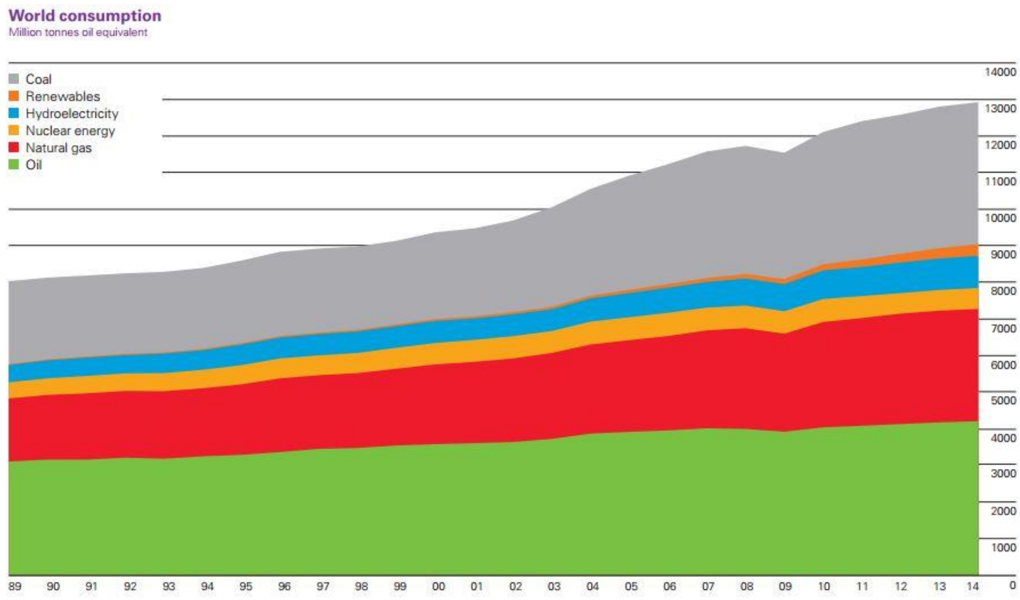

FIGURE 12. The world primary energy consumption (BP 2015)

The costs and risks of renewable energy sources are problematic, and the need for modern appliances with innovative development is crucial in order to supply the same amount of energy that the world consumes now (WCED 1987). Hence capital investment is required prior energy is generated but no fuel costs. In addition, these sources are dependent on the output levels and on the cost of the maintenance and operations. (Heal 2009.)

Although the investment in renewable energy sources may be high, the long-term deployment results in good investment. For instance, if a wind power is set up, it is likely that will provide energy for many years. (Heal 2009.) Large numbers of nations understand the significance of renewable energy, and therefore, the intention is to deploy them. Thus, the European Union (2014) set a target, which entails renewable erngy consumption to be 27% of final energy consumption by wich half of that would be generated by wind energy (EWEA 2014). In addition, the United States presents a target: 10% of electricity shall be generated by renewables by 2012 and 25% by 2025 (Heal 2009).

Currently, wind energy turns to be as competitive as gas and coal in some parts of the world. This is due to its availability of air and non-dependence of other components and the amount of wind farms capable to produce electricity. (Runyon 2015.) However, wind is not a 100% reliable source. It presents variations of productions which are related to the wind speed during the day and night and from season to season. Additionally, the lack of storage of energy on large scale, and the need to construct high-voltage transmission system to makes wind a less viable source. (Tester 2012, 727)

Wind turbines are considered to have a large capital investments as well as large cost in operation and maintenance. The installed cost is rated in euros/kWh and similarly with the maintenance cost. (EWEA 2009.) Tester (2012, 743) describes that the prices of wind turbines can be similar with nuclear power and more costly than natural-gas-fired combine turbine. Despite the large investment capital and operations needed for a wind turbine project, it is estimated that when the capacity of wind power doubles, the cost per kWh produced for new turbines is reduced between 9 and 17%. (EWEA 2009).

As for social impacts, wind power has major benefits as it is not associated with atmospheric emissions like CO2, SO2, Nox. However, the lifetime of wind turbines is analysed using a life cycle assessment, where the wind turbines's components and raw material, energy consumption for production, transport and operations cause negative impacts on the environment. Such impacts are very mininal compared to an average european electricity production. In addition, wind turbine's lifetime is normally about 20-25 years, and it can product 35 times more energy than the energy production involve in its manufacture. Yet there are few other negative aspects such as shadow, aesthetic impact, noise, land use, raptor kill, which are still considered as undesirable features. (DEA 2009.) On the other hand, turbines do not consume fuel which reduces the cost of operations. Additionally, further improvement in the operating and maintenance cost (Tester 2012, 744.)

With the rapid development of wind energy capacity, wind energy capacity doubles approximately every three to four years (EWEA 2009). The growth rates of wind turbines remain at a high level and therefore, if social, political and economical factors favor wind energy, the industry is to be established as a worldwide leader among renewable energy technologies. Furthermore, advances in the industry have demonstrated to provide efficiency at deploying energy from wind. (Tester 2012, 749.) Among the EU2020 targets, the plan is to help to financed wind farm projects to increase the potential of renewable energy (EU 2010). Hence,

4 RESEARCH & DATA GATHERGING

This chapter presents the process of empirical research of this thesis. The fist sub-chapter describes the purpose and the process of data collection through primary and secondary data while utilizing different methods.

4.1 Data collection process

The process of data collection consists of two main parts: desk study and interviews. The desk study is the start of the analysis for benchmarking, whereas the purpose for the interviews was to gather genuine data from stakeholders. The objective of this thesis is to improve the wind energy industry in Bolivia taking lessons learnt from Denmark. Thus, this process entails finding the data from public sources in regards to activities within wind energy to compare the situation in Denmark and Bolivia. The main focus is to evaluate the situation in Denmark in order for Corani to learn while taking into account somewhat aspects within the industry. Hence, factors that influence in the industry and which reflect the three dimensions of sustainable development, social, environmental and economic dimension are to be compared between Denmark and Bolivia.

This phase started in during November 2015 and lasted until March 2016. The data was gathered from the public domain such as private and public firms involved in the industry, and also electronic sources which reflect on the theory. The table below shows the process of collecting primary and secondary sources of this thesis:

TABLE 3. Data collection process

Task	Nov 2015	Dec 2015	Jan 2016	Feb 2016	March 2016	April 2016
Desk research	X	X	X			
Search interviewees			X	X		
Send email to invite for interview			X	X	X	
Conduct interviews				X	X	x
Data analysis & results					X	X

Once confirmed that Denmark is right benchmarkee, the author selects to conduct interviews as it is a valid method to confirm the findings for benchmarking the industry. Moreover, the information regarding the industry in Bolivia originates mostly from the case company. However, Bolivia lacks of secondary sources as secondary sources are not fully reliable. Thus, interviews are vital in data gathering.

Depending on the purpose of the research, the researcher decides among there three different types of interviews: structured interviews, semi-structured interviews and unstructured or in-depth interviews. Structured interviews use standardized questions for all the interviewees, semi-structured interviews covers a list of themes and the interviewer is able to omit or add more questions depending upon the case, whereas unstructured interviews are meant for general topics, where there is no set of questions list and the interviewee has the opportunity to talk freely. (Saunders et al, 2012, 320-321)

The author selects semi-structured interviews. Semi-structured interview type allows describing the situation and providing extensive answers (Saunders et. 2012, 337). Repeatability of the results is a proper way to confirm the reliability of the study. This is to guarantee that the information gathered is correct. This should be carried out whether the interviewer and interviewee are using other language than their native one, language barrier might hinder the process and lead to misunderstanding in questions. (Hirsjärvi 2009.) In this research, reliability is carried out by recording the interviews, writing memos, and sending the memos to the interviewees to confirm whether the information gathered is correct. The author selects interviewees from different companies, therefore, the interviews contain different framework. Although the interviews conduct questions related to wind energy industry, there are five interviews: a representative from the Danish Energy Agency, a representative from Lumituuli Oy, which owns a Danish turbine, and operates and sell its electricity in Finland. As for the rest of the interviews, three employees at Corani S.A are contacted. The representative from the Danish Energy Agency and Lumituuli Oy were contacted firstly by email with information regarding the research and its purpose. The interview with the representative from the Danish Energy Agency is conducted via skype, whereas the interview with the representative of Lumituuli Oy is carried out face-to-face. The questions are sent to interviewees prior the meeting time, in order to give them time to prepare. The interviews with employees at Corani are carried out face-to-face as the author of the thesis travel to Bolivia to gather information from the company.

4.1.1 Interviews

As explained earlier, the interview stage is to evaluate the credibility and reliability of the public domains from desk research. One of the interviews was conducted via skype, whereas the rest were carried out face-to-face. The author discussed in all interviews the opportunities of wind energy in the world, the answer from the interviewees was positive, even though the industry is rather new; its potential is increasingly growing.

The interviews with employees of Corani demonstrated willingness to learn from other countries, as the country is newly involved in the industry. The intention is to compare how the industry functions in other countries. However, the aim is not to become a big share in the industry of the world, but to acquire best knowledge and know-how skills within wind industry. Therefore, the aim is to learn by doing while getting acquainted with the industry, and hence its active deploying was a priority.

The interviews with the representatives of the Danish Energy Agency and Lumituuli Oy concentrate no understanding the situation in the market via their standpoints. In regards of this, topics included were governmental action plans, company background, wind energy market, maintenance and supply chain of wind energy and electric networks.

The semi-structured interviews were chosen to provide significant information in order to understand various aspects, which influence on the wind energy industry. The objective was to compare the results between countries on a national level.

5 EMPIRICAL RESEARCH ANALYSIS

This thesis intends to demonstrate the realization of benchmarking between two countries. The author unfolds the benchmarking process by describing each stage in this chapter. Hence, the study focuses on Bolivia and Denmark wind energy. Altogether five interviews were conducted. Among the interviewees were from public and private institutions. Therefore, empirical research analysis provides a comprehension of these two markets with various data collection methods. The empirical research is built as follows: benchmarking process, dividing the process country by country, and analyzing focus areas in each country.

5.1 Benchmarking process

The figure below describes the benchmarking process used in this thesis.

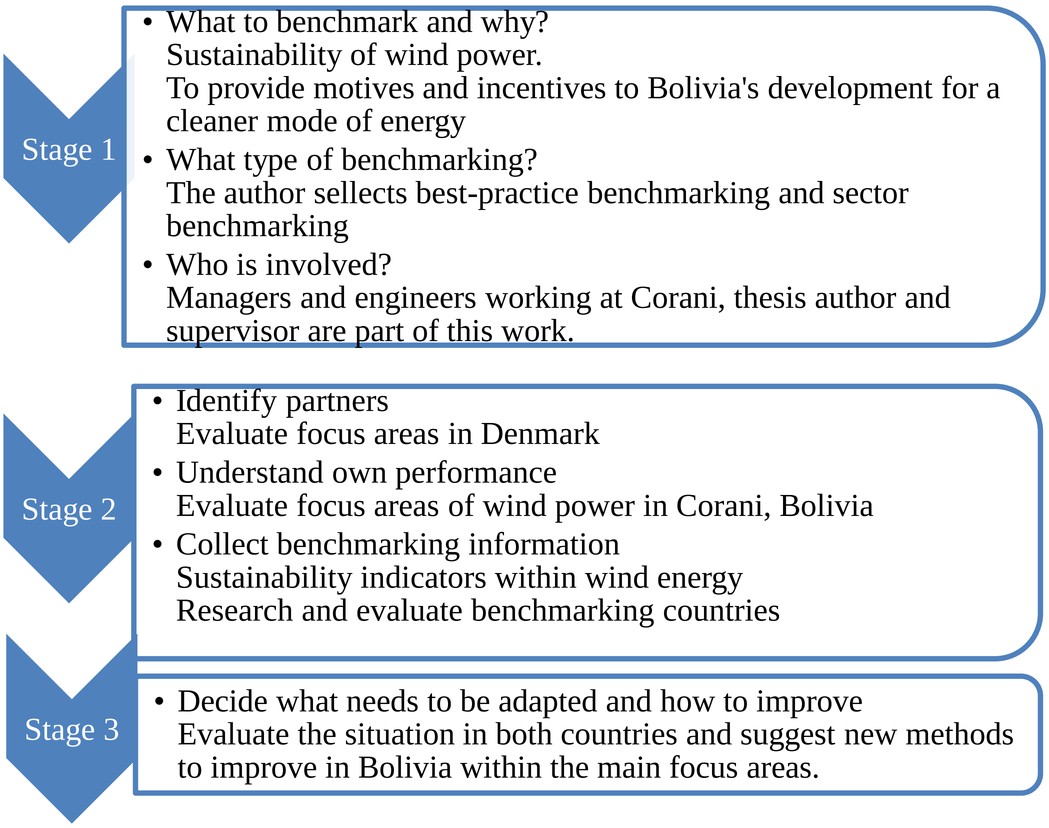

FIGURE 13. Benchmarking process

This thesis presents a combination of best-practice benchmarking and sector benchmarking in order to benchmark an industry. However, benchmarking an industry entails several sectors which impact the industry (Wober 2002). Thus, the areas for benchmarking within wind energy are selected: **Governmental decisions and investment in R&D** form part of the benchmarking. **Price of wind energy generation** is selected to study the price per unit of turbine in Denmark and to compare the prices of the turbines in Bolivia. **Reliability** of wind energy is selected to evaluate the **supply chain** as well as **maintenance procedures** and the integration of electrical power through **connection lines**. Reliability of wind turbines consist of the design and operation, distribution systems over the lifetime of a turbine. Turbines are expected to function at certain capacity within a certain period of time. (Hill 2008.) A variety of components are significant for a wind turbine to generate electricity (State of green 2015). Maintenance plays an important role on reliability to repair or refurbish a turbine whether a failure occurs (Hill 2008). Moreover, there are also externalities that affect a turbine, failures caused by weather conditions or wind speeds, which affect negatively the engineering dynamics, and subsequently affect the entire machinery. The results of these require replacing or repairing some components causing a downtime in a turbine. (G-cube 2016.) Therefore, this research is based on Hill's theory (2008) which describes the failure characteristics of the electrical component statistically divided in two:

- Failure rate: failures per year per component
- Downtime to repair or replace a component after it has failed in service (also expressed in hours per failure)

With the above mentioned, stage one will be introduced in sub-chapter 3.2 with sustainability indicators of wind power, as well as in Sub-chapter 5.2 to investigate basic grounds for the benchmarking, reasons for benchmarking, and people involved in the project. More importantly, the Sub-chapter explains the current situation of the industry in Bolivia. Stage two of the benchmarking process is carried out in chapter 5. Sub-chapter

5.3 is dedicated to evaluate Denmark and unfold the focus areas. Sub-chapter 5.2 consists on evaluating the current situation in Bolivia in regards to the focus areas. Stage three of the benchmarking process is located in chapter 6 as it is used to evaluate the industry and recommendations for wind power best practices in Bolivia.

5.2 Bolivia

The Plurinational State of Bolivia is located in central South America with a total area of 1.098.581square km. (CIA 2016). The country has a population of 11 million inhabitants with a density of 9 inhabitants per square km. (INE 2011). Urban population consists of 68% of the total population but it has a population growth rate of 1.5% and birth rate of 22.76/1000 population. Bolivia presents a gross domestic produc of 33.54 billion $, and a gross domestic product per capita of 6500$. However, the country has an unployment rate of 7.4%. Natural gas forms as essential component to export mainly to neighboring countries, whereas electricity is produced and consumed by locals only. (CIA 2016.)

History of renewable energy

Bolivia started the integration of renewable energies in 2009, when President Morales (2009) launched a decree to define and evaluate policies for the electricity sector. The plan included an engagement of different parties, from public to private sectors in order to form part of the production, transmission and distribution of electricity service. The objective of the plan was to promote policies for electrification, and provide an equal access to electricity in the country. More importantly, an integration of renewable energy sources including wind. (Morales 2009.)

Current energy scenario

Most of energy consists of natural gas and 71.5% constitute the consumption of hydrocarbons. The electricity sources form only 10% of the total energy production in Bolivia (Ministry of hydrocarbon and energy 2009). The picture below shows the current electricity sources in Bolivia:

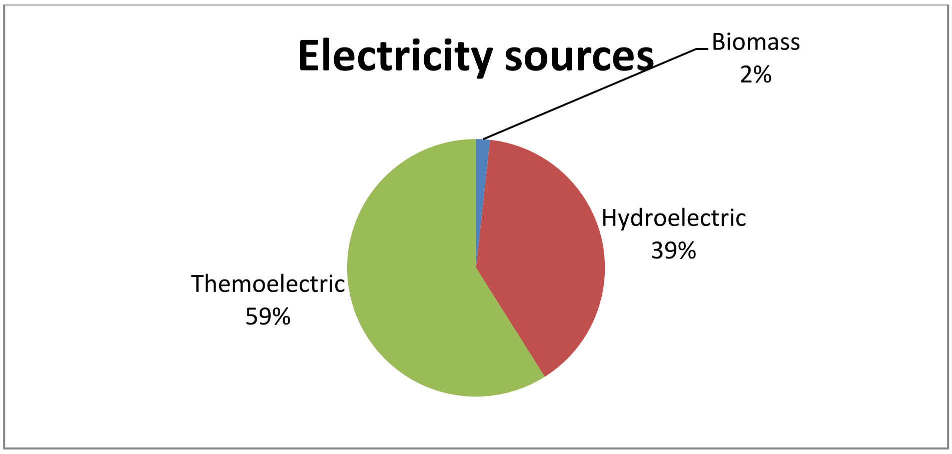

FIGURE 14. Electricity sources in Bolivia (Adapted from the Bolivian Ministry of hydrocarbon 2011)

Figure 14 shows that thermoelectric plants produce 59% of electricity, while hydroelectric produces 39% of electricity and lastly, biomass 2% of the electricity production. It is estimated that 417.790 households do not account with electricity access due to isolated location, and lack of electric network connection. (The Bolivian Ministry of Hydrocarbon 2011.) Bolivia is 76.2% electricitly connected. Hence the Bolivian government states that the electric sector is state-owned whithin the production, transmission and distribution chain of electricity. (Ministry of hydrocarbon and energy 2009.) The National Electricity Enterprise (ENDE) is in charge of controlling and distributing electricity over the country. ENDE controls directly or indirectly the generation of electricity. (ENDE 2015.) ENDE created the National Interconnected System (SIN), which provides electricity to main cities and some isolated places. Hence, ENDE controls the installations of generation and transmission and distribution electric consumption in main cities via the SIN. (Ministry of hydrocarbon and energy 2014.) Bolivia accounts with 3007.9 km of connection lines from the SIN, with a capacity to generate 1384.8 MW and 179.4 MW in isolated systems. (Ministry of hydrocarbon and energy 2014). Bolivia presents a regulated power system. The power system regulates the electricity capacity and ultimately, delivers electricity according to the consumption of electricity in different areas (Marcus 2016.) The transmission is delivered separately through different cable connections. The CNDC (National Comitee of Cargo Dispatch) is in charge of the operations of the SIN and coordinates integrated operations within the generation, and transmission in order to meet the demand (CNDC 2016). Bolivia presents three different connection lines:

- Rural cable is 24 kV
- Local cables within cities: the cable reaches 115 kV
- Interregional cables: connects from cities to another cities reaching to 115 KV (Marcus 2016.)

The figure below shows the interconnection system (SIN) in Bolivia.

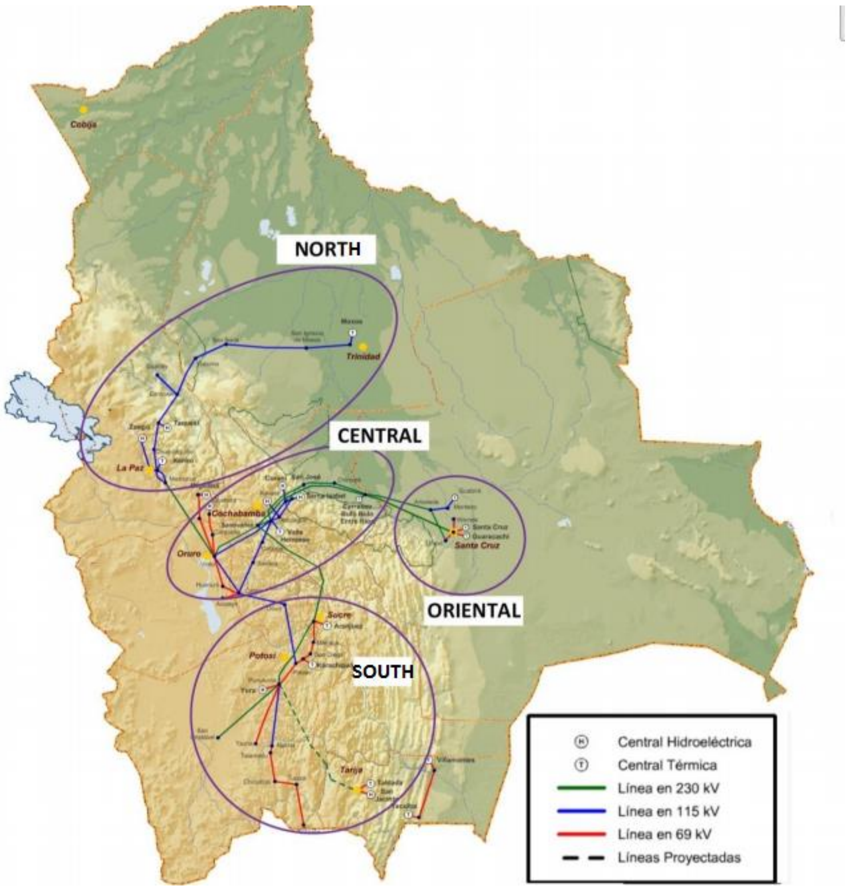

FIGURE 15. Interconnected system (SIN) (Ministry of hydrocarbon and energy 2012)

The CNDC assigns certain amount of electricity that shall be delivered to different regions. The connection lines are state-owned but are open to the public to realize activities related within the electric industry. (CNDC 2015.) A regulated system offers the possibility to control the electric system and therefore, it lowers the cost of operations and maintenance (Ponce 2016).

Isolated regions in Bolivia are planned to be connected to the SIN. Currently, such regions are supplied by private firms, which mostly generate electricity via thermoelectric plants. Furthermore, isolated regions concentrate high demand of energy as there are approximately two hundred thousand inhabitants in those areas.

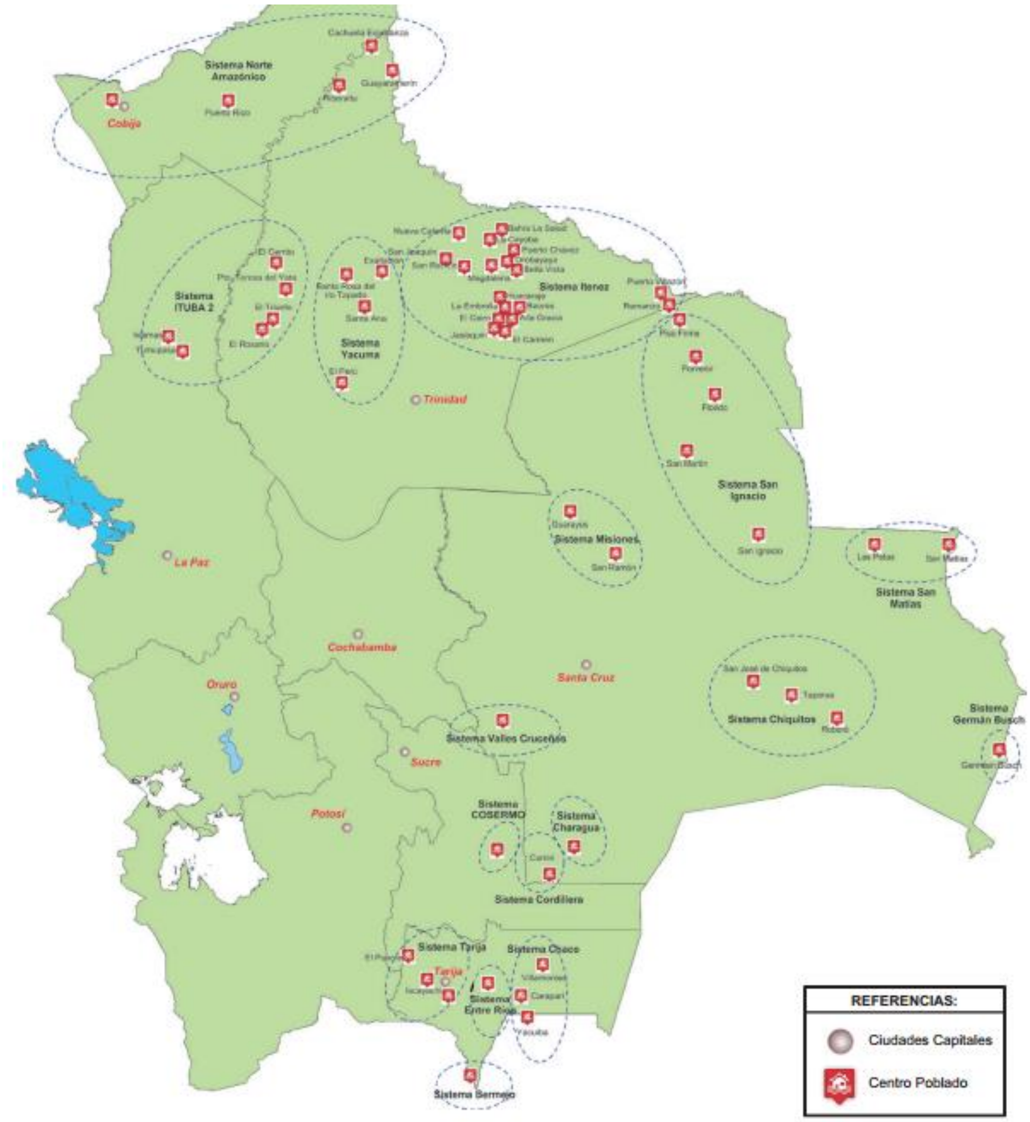

FIGURE 16. Isolated regions (Ministry of hydrocarbon and energy 2012)

The figure above illustrates the isolated regions in Bolivia which depend on the supply of electricity from private firms. In 2012, these regions consumed 35 million liters of gas oil. (Ministry of hydrocarbon and energy 2014.) As such, Bolivia presents several regions where the SIN is not available.

By the year 2015, the country reached 88% of electricity access over the country. Urban areas will account with electricity access rapidly, whereas in rural areas lack of connection which limits the access. In order to provide electricity access in rural areas, the government intends to build extension networks and incorporate the usage of renewable energies (solar, hydroelectricity, wind and biomass). (Ministry of hydrocarbon and energy 2015.)

Future Strategy

Bolivia established a National Development Plan which includes the hydrocarbon sector and the electricity sector. Among the strategy was the development of electricity infrastructure to generate, transmit and meet the local demand. Also, increase the network connection in rural and urban areas to equalize the electricity service in the country. More importantly, the plan considers the development of new energy from renewable sources such as hydroelectric, geothermal, wind and biomass. (Ministry of hydrocarbon and Energy 2009.) The strategy for the plan:

- Plan and develop a regulated system
- Guarantee the supply of basic electricity service
- Establish electricity efficient tariffs
- Achieve an equalized service

Ultimately, the plan includes the installation of new renewable energy plants during the year 2009-2019. Thus, the government long-term objective is to connect 97% of the country with electricity by 2027. This corresponds to approximately 2250 MW of electricity. (Ministry of hydrocarbon and energy 2009.) The table below depicts the action plan for the development of the long-term objective:

TABLE 4. National Development Plan (Adapted from the Ministry of hydrocarbon and energy 2009)

National Development Plan	
Reduction of the consumption of liquefied gas	Reduction of the consumption of liquefied gas and petroleum by-products in households and transportation sector.
Export liquefied gas and petroleum by-products	Substitute liquefied gas and petroleum by-products for natural gas.
Increase the usage of renewable energy and electricity generation	Increase the generation of electricity through hydroelectric and geothermic plants
Major usage of electricity	Increase hydroelectric generation in larger scale
Export electricity	Increase electricity generation through hydroelectric sources
Decrease levels of CO2, Sox emissions	Increase the usage of natural gas and hydroelectricity

The government included short and medium term plans in order to achieve the plans for year 2027. However, the plans did not include specifically the generation of wind power, as hydroelectric, natural gas and liquefied gas and biomass produce at high capacity. In the long-term plan, the electricity sector is to account 10% of the total energy production. (Ministry of hydrocarbon and energy 2009.) In order to achieve the long-term plan, the government launched three programs to provide incentives in tariffs: Firstly to offer a 25% discount to households that consume up to 70kWh monthly. Secondly, electricity shall reach most of the population even in rural areas by the year 2025. This program entails the implementation of different technology projects which produce electricity. Thirdly, to optimize the usage of electricity by providing light bulbs, which reduce 72MW from the total electricity demand. (Ministry of hydrocarbon and energy 2014.) Previously, another initiative was to decrease the amount of electricity consumption during rush hour. Moreover, the initiative was to inform the cause of usage of electric equipment in certain hour in environment and economy. (Morales 2008.)

The government restructured the electricity law in the country in order to preserve the environment and deploy clean energy (Ministry of hydrocarbon and energy 2014). Despite the great wind speed in some Bolivian regions, the energy prices are highly dependent on the prices of natural gas (Rehfeldt 2016). This is due to the high demand of natural gas and liquefied gas in regards of the cost, efficiency, and possibilities to export, which makes natural gas and liquefied gas competitive. Thus, these two sources were selected within the scenario of the long-term development plan (Ministry of hydrocarbon and energy 2009). This makes wind energy less competitive in the Bolivian market (Rehfeldt 2016).

As for the targets of the national development plan within the electric sector, it is crucial to develop new electric plants, with transmission networks and distribution in order to reach 97% of the population by 2027. Furthermore, there is a need to evaluate the potential of renewable energies in the country towards integrating them into the system. (Ministry of hydrocarbon 2009.)

The ultimate plan for the year 2025 entails the production of electricity and the future export of electricity to countries in South America. This plan includes projects related to the production of renewable energies including wind energy, which is a future projects aim at generating 50 MW of electricity in the department of Cochabamba and Santa Cruz. (Ministry of hydrocarbon and energy 2014.) Additionally, the aim is to export 10 thousand MW to the neighboring countries by the year 2025 (ABI 2016).

An extension plan for the period 2023-2030 remarks the deployment of renewables sources. This plan is vital to meet the future energy demand as they were identified to be economically viable compared to geothermic electricity generation. Hence the wind power will form part of the extension plan as the annual demand is to increase by 6.4%. This plan is fully financed by the government, and thus, it is estimated an investment of 1070 US$/kW with a capacity of deploy 33.84 MW and an annual cost of operation of 53 US$/MW. (Ministry of hydrocarbon and energy 2012.)

The plan is to switch the electricity generation from thermoelectric power to hydroelectric power and other renewable sources including wind power (Ministry of Hydrocarbon and Energy 2014). The reason for this plan is to provide growth in Bolivia in order to guarantee electricity access and promote economic and social development (Sosa 2014).

Corani

Corani S.A. is a public organization controlled by ENDE. Corani generates electricity through the wind turbines and other electric sources. The focus is to include the electricity generation into the national system and meet the local demand. Bolivia intends to increase the development of renewables and to connect hydroelectric system and wind turbines. (Corani 2015.) Corani has the mission to produce clean electricity by the deployment of wind power connected to the centralized system. (Ponce 2016).

Corani built a station in 2009 to measure the wind speed at a height of 38.5, 48.5 and 58.5 meters. This led to the realization of potential wind speed in the zone (Ministry of hydrocarbons and energy 2013). In order to begin with the planning of the industry, the Bolivian government spent nearly a year to measure the wind speed in different regions of the country. Thereby, land was purchased and acquired by Corani to install wind turbines. (Corani internal 2016.) It is a requirement to have an environmental license in which consist of environmental impact assessment (EIA) to evaluate positives and negatives impacts in the environment. (Environmental Law 2003). Bolivia accounts for high wind-speed level in different regions, which reach 12km/h. (Ministry of hydrocarbon and energy 2009).

In 2013, Corani S.A. singed a contract with HydroChina ZhongNan Engineering Corporation to install and implement wind turbine project with a capacity of 3 MW. Hence, in 2014, two Goldwind turbines were installed located at Qollpana Wind Park, located 126 km from the city of Cochabamba. Hydrochina leads the operations and maintenance for two years, whilst educating the local personnel from Corani. The installed turbines have a total capacity of 1.5 MW each, with the aim of supplying electricity in the area while being connected to the SIN. (Ministry of hydrocarbon and energy 2014 & The Wind Power 2015.)

During 2014, the government signed an agreement with Enercon, for an extension of the Qollpana Wind Park. The agreement is to install Enercon turbines with a total capacity of 24MW, and it is meant to begin the production during May 2016. (Corani internal 2016.) Additionally, ENDE is to inform about nine wind stations in order to evaluate the region to install new wind parks (ELFEC 2014).

5.2.1 Electricity price

Currently, Bolivia accounts with two wind turbines in the department of Cochabamba. The latest acquisition was eight new Enercom wind turbines with a capacity of 24 MW, which will be installed during July/Augutst 2016 (Ponce 2016.) However, the capacity varies among the new and older turbines. Thus, the cost per unit is evaluated to find the cost of electricity generated (IOWA 2016). In order to evaluate this cost, the total annual cost is needed and divided by the annual energy production.

$$Cost\ of\ energy = \frac{AC}{\mathrm{AEP}}$$

Where:

AC = Annual Cost

AEP = Annual Energy Production

The author has taken turbines from Corani in order to evaluate and find the cost per kWh. In Bolivia, the cost of the turbine represents roughly 75% of the total investment cost. Hence, the investment cost per unit per turbine is varies among Goldwind and Enercom. (Corani internal 2016) The maintenance cost is a set price in regards to the agreement signed with the manufacturer. The lifetime of a turbine is estimated to be 20 years. The annual electricity production is taken from the annual production of the current installed turines, and an estimation of the Enercon turbines (Corani internal 2016.) The figure below depicts the cost per kWh of two turbines.

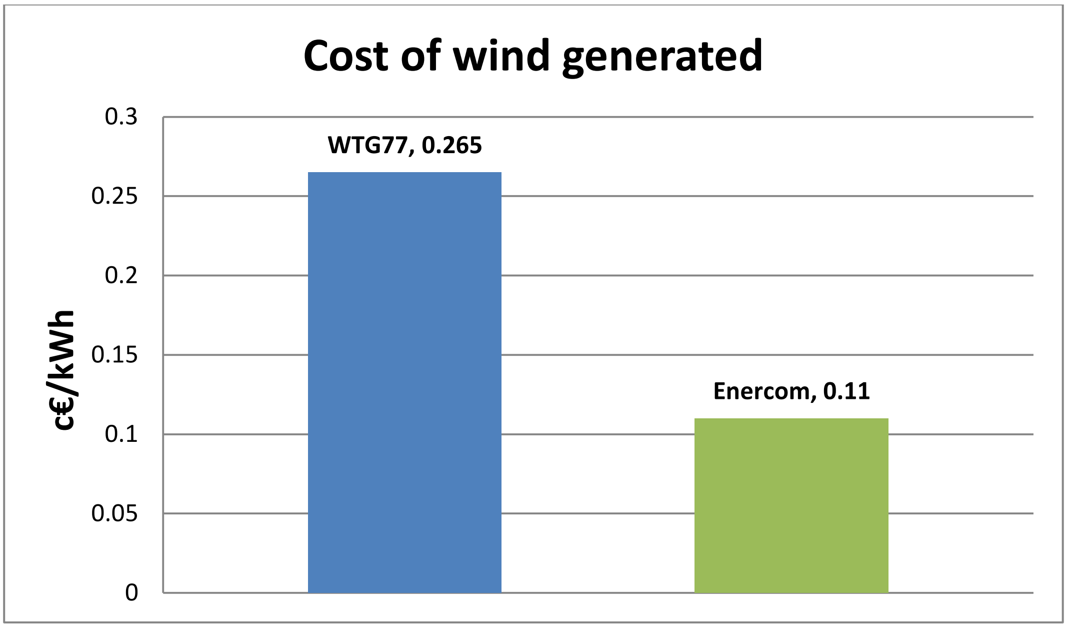

FIGURE 17. Calculated cost of wind-generated power

The figure above compares the cost per kWh of two different turbines with different output capacity. The manufacturers are Goldwind, with a capacity of 1.5 MW, and Enercom with a capacity of 3MW. The author has taken these two types of turbines as there will be eight Enercom turbines, each with a capacity of 3MW, and currently, two Goldwind turbines, each with a capacity of 1.5MW. The Goldwind model WTG77 has a cost of 0.265 c€/kWh, whereas Enercom has a cost of 0.11 c€/kWh.

The turbines are located in Qollpana Wind Park. The park is located in the department of Cochabamba (Corani 2015). The cost is highly influenced by the year of the turbine, its location and capacity. Moreover, the amount of wind speed in the area also determines the production figure. As the turbines are located in the same area, the production is based on the capacity of each turbine.

5.2.2 Reliability

The integration of wind energy in the system requires tools to control the planning of the power grid, interconnection, through a wind forecast (Vinther 2015). Hence, benchmarking connection system is vital for the deployment of wind energy. Reliability is divided in two: Connection lines and Operation maintenance and supply chain.

Connection lines

The Gold Wind turbines started the production of electricity in 2014. The turbines are connected to a voltage level of 24.9 kV, which connect to a converter, and subsequently, connected to a rural cable that provides electricity. During the first year of operation, the turbines were connected to a rural connection line in order to provide electricity to the nearby village located in Cochabamba. However, the connection did not match the tension of the turbine, which resulted in a reduction of electricity production. (Corani internal 2016.) Furthermore, the connection also caused failures and outages due to poor power connection (Marcus 2016). The lower production of electricity led to a development of connecting the turbines to a connection line of 115 KV. According to the production of the year 2016, the turbines have produced a great amount of electricity which resulted in maximum output. (Corani internal 2016). Hence the plan is to connect the future Enercon turbines to 115 kV connection line. The connection line has a total distance of 120 Km (Marcus 2016). The current plan consists on connecting the turbines without curtailing, but it could stop functioning in case of outage or maintenance (Corani internal 2016).

Operation maintenance & supply chain

The installed turbines are located at an altitude of 2800 meters above the sea level. Although the two turbines are exposed to weather conditions, such as temperature and altitude, the turbines have not experienced major mechanical failures. (Corani internal 2016.) While the current turbines have two years of operation, the turbines have experienced only electrical failures. During the first year of operation, the turbines could not produce electricity at high capacity due to the low connection line. Also, excessive wind speed has caused failure damage in some components of the turbine as wind speed exceeded 25 m/s. (Corani internal 2016.) The longest downtime was due to an electric failure which lasted roughly a week. More importantly, the altitude causes the turbine to lower the production of electricity as the wind is dense, which causes the lower rotation of the blades. Overall, the turbines are fairly new; the two years of function have not seen severe damages. (Ponce 2016.)

Bolivia entered the wind energy industry with the installation of high technology turbines (Rehfeldt 2016). In order to mitigate mechanical failures, the turbines are taken through a variety of inspection every six months, annually, every three years and five years. The six month maintenance consists of a general maintenance, which among important components entails corrosion, inspection in the noise, inpection of the connection line, control the adjustment of the sensor of the temperature, the yaw system should be well lubricated, verify that the cable ground is connected, the bearings should be well lubricated and should remain clean. Also to inspect the nacelle to be in proper order illuminated, without corrosion and inspection of the blades to revise if there is corrosion, scratch and to see whether the blades are connected correctly and to check if the rotor is damaged. (Corani internal 2016.) The annual maintenance entails with the comparison when the turbines was new and to revise if there is a need to replace certain components among mechanical failures of connection lines related to temperature, corrosion and level of dryness in some components. The maintenance for the third year consist of checking the oil and changing the oil of the yaw and the yaw reducer. Lastly, the fifth year of maintenance consist of inspecting the converter to analyse whether there is a weeping, the converter should be replaced. (Corani internal 2016.)

Bolivia has currently two wind turbines manufacturers, which are able to deliver new components in case of new replacement. Hydrochina Corporation has a warehouse located in Chile. The warehouse is able to deliver new components for the turbines, which could last maximum 30 days. The 30 days begins from order delivery till the components reach the Qollpana Wind Park. The plan with Enercon is to contruct a warehouse in Qollpana Wind Park. The contract agreement with Enercon entails the supply and delivery of wind turbine's components in the event replacement is needed. (Corani internal 2016.)

There are several limitations in in the supply of new components and maintenance. Bolivia entered the wind energy industry with the opening of two pilot turbines manufactured by Hydrochina. The plan was to enter the industry, and test the turbines in order to learn its functionality, design, operation, and more importantly, to understand the industry. The better understanding would lead to enhance the industry as well as the new planning of wind parks in the country. (Marcus 2016.) Hydrochina, is currently, the only supplier in case of the need for new component and know-how. Enercon becomes the second supplier in the second phase of the extension of the Qollpana Wind Park. (Ponce 2016.) Furthermore, the lack of R&D limits the deployment of the industry. The high dependency on Hydrochina limits the operation and capabilities to develop the industry. Additionally, the lack knowledge in know-how has also limited the abilities to provide development in the industry. (Marcus 2016.) Corani has signed an agreement with Hydrochina Engineering Corporation. The agreement entails to provide two years of training to local technicians at Corani, in order for them to learn about the industry. Similarly with Enercon, local technicians will be provided with training for five years. (Corani internal

2016.) Thereafter, local technicians should confront the industry by themselves with the support of the government (Ponce 2016).

5.3 Denmark

Denmark is located in northern Europe in the borders of the Baltic Sea including also several islands with a total area of 43 thousands square kilometres. The country has a population of 5.5 million inhabitants with a growth rate of 0.22% and a birth rate of 10.27 birthds/1000 inhabitants. Urban population consists of 87.7%. Denmark presents a gross domestic product of 291 billion $ and a gross domestic product per capita of 45800$. The country has an unemployment rate of 4.7%. Therefore, Denmark exports a great amount of crude oil but as well as a great exports of electricity. (CIA 2016.)

Hisory of wind turbines

Denmark began the construction of wind turbines in the late 1970s, which had an output of 22 kW. The country gradually scaled up to 55, 75 and 95 kW by the 1980s. The government funded a development programme by electricity companies to test larger pilot wind turbines. Since 1980s, the wind turbine industry has grown into a larger-scale. (DEA 2009.) By 1985, the Ministry of Energy had agreed with power stations to expand their production capacity reaching 100 MW of wind turbines. By the year 1990, an action plan was published called Energy 2000. The objective was to cut CO2 emissions by 20% between the periods of 1988 to 2005. (State of Green 2005.) Wind power share of domestic electricity supply had reached 1.9% in 1990. More importantly, during the mid-1990s, Danish wind power were upscaled as the majority of wind turbines that had an output of 225 kW were replaced by few and larger wind turbines with an output of 500 kW. (DEA 2009.)

The figure below illustrates the development of wind turbines throughout the years:

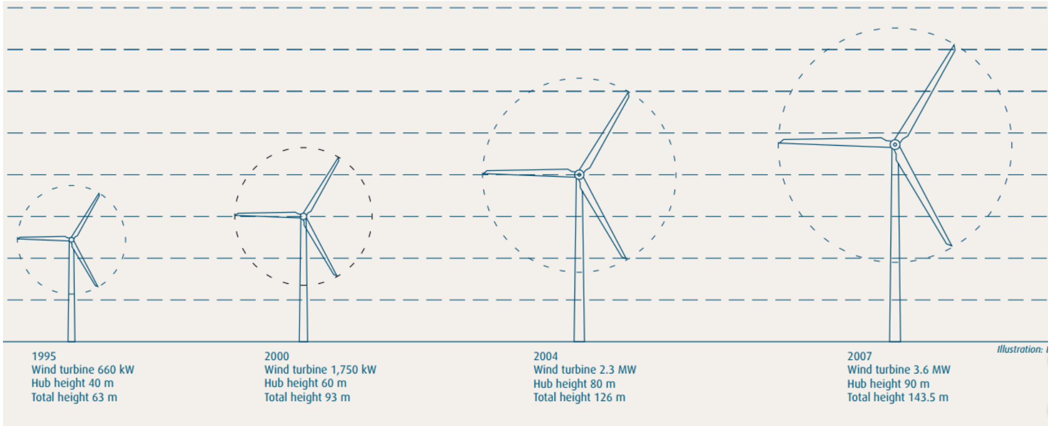

FIGURE 18. Wind turbine history (Danish Energy Agency 2009)

During the 1990s, investments in wind energy took place leading to a more decentralised production and increase in units (DEA 2012). In 1998, Denmark decided to connect large wind farms to the transmission grid of 100 (Kv), as transporting large volumes of power in small voltage grid is not feasible (DEA 2015).

Current energy scenario

In 2008, the Danish government settled an energy policy agreement with the aim of lowering the dependency on fossil fuels. The agreement includes a renewable energy consumption which should have increased to 20% by 2011. Hence, municipalities are responsible for the planning of wind turbines, subsidies for renewable energy plants, a compensation scheme, a guarantee fund and a model for local joint ownership. (Energy policy agreement 2008.)

Among other plans of the Energy Policy Agreement settlement in 2008, was that gross energy consumption should fall by 4% by 2020. Unlike consumption, energy efficiency must have annual savings of 1.5% of the final energy consumption. Also, new buildings must have a reduction in energy of at least 25% in 2010, another 25% in 2015 and 25% by 2020. More importantly, the agreement demands a doubling of funds for energy research and development. The intention is to reserve funds from the globalization reserve in order to reach 750 million DKK in 2009. (DEA 2008.) Additionally, municipalities will offer citizens (especially those living within 4.5km) the opportunity to buy a share in local turbine projects. The shares must imply a 20% of the value (cost) of the turbine. The shareholders share the cost, revenues and risks. (DEA 2015.)

Municipalities are responsible for the planning and establishment of onshore wind turbines. The Danish Energy Agency provides project and turbine certification given by the executive board that controls a standard installation of turbines in Denmark. (Bizet 2016.) The nature agency manages the legislation regarding the planning activities and environmental impact assessment (EIA). Energinet.dk is charged with connecting wind turbines and other sources of electricity to electricity grids, paying subsidies for environmental friendly electricity production and acting as secretariat for the four schemes (DEA 2015). Energy taxes are included in the Energy Policy Agreement (2008), which consist of CO2 taxes estimated at 22.91 $/ton effective from 2008 and nitric oxide (NO) and nitrogen dioxide (NO2) tax of 0.76 $/kg, which comes to effect in January 2010.

Denmark launched another energy agreement in 2012. The agreement covers a set of targets which need to be completed by the year 2020. According to the Danish Energy Agreement (2012), half o f the electricity consumption has to be produced from wind power reaching 35% of renewable energies in gross energy consumption by 2020. (IEA 2013.) Additionally, a 7,6 % reduction in energy consumption compared to 2010, leading to 34% reduction in greenhouse gas emissions compared to the year 1990. This means that Denmark will become less dependent on fossil fuels. (Danish Energy Agreement 2012.)

In 2014, the number of onshore wind turbines was 4768 with a total capacity of 3616 MW (DEA 2014).

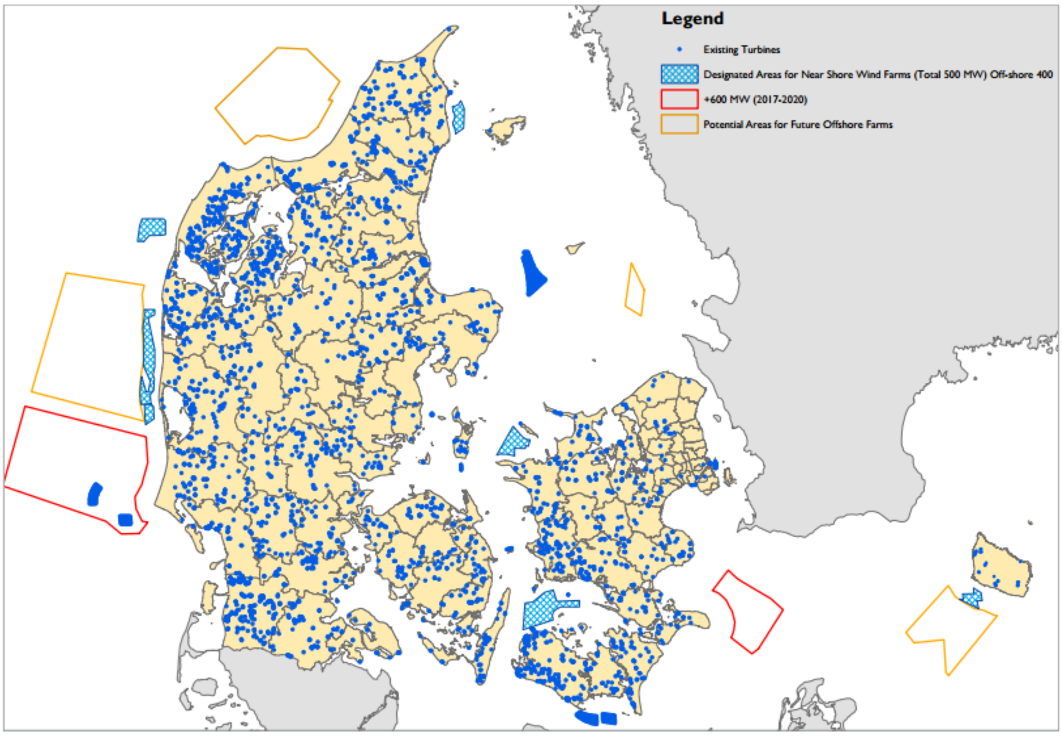

FIGURE 19. Wind turbines in Denmark (DEA 2015)

Figure 9 despicts with blue dots the number of onshore as well as offshore wind turbines in Denmark. The figure shows notably a larger amount of wind turbines in north-west Denmark.

The Danish government assigned the power system responsibility to the transmission system operator (TSO), Eltra in west Denmark and Elkraft in east, which later on merged and became Energinet.dk, managing the entire Danish power system (Energinet.dk 2015) Thus, Denmark divides its electricity grid in different voltage levels:

- Electricity transmission grid 400 kilovot (KV), which is used to connect large-scale power stations in Denmark and abroad to the electricity grid at lower voltage leve.
- Regional electricity transmission grid 132 kV east of the Great Belt and 150 kV west of the Great Belt. This grid connects the transmission grid

to the distribution grid. Normally, large-scale wind farms are connected to this voltage level.

- The distribution grid in charge to transport power to households and companies.

Energinet owns these electricity grids, whereas local grid companies are in charge to transport the last phase of the power to households and companies. Energinet account for 185 substations with 4900 km of overhead lines and 1900 km cables each of them with double cable systems. Energinet controls the Danish electricity consumption, and therefore, it is responsible for maintaining a constant frequency and voltage in the Danish part of the European power system. (Energinet.dk 2014.)

The transmission grids are connected to the neighbouring countries with Norway, Sweden and Germany. From eastern Denmark (Zealand) to Sweden, two high-voltage alternate current (HVAC) 400 kV cable connection and two 132 kV cable connection. Additionally Zealand has an export capacity of 1700MW to Sweden and an import capacity of 1300MW. This connection is also linked to the Nordic grid. As for the interconnection with East Denmark and Germany, Kontek has a 400 kV high-voltage Direct Current (HVDC) with a capacity to transmit 600 MW. The connection from western Denmark consists of an interconnection with Sweden, Konti-Skan, which entails two 285 kV (HVDC) with a transmission capacity to export 740 MW and import 680 MW, whereas the interconnection with Norway, Skagerrak, entails three direct current connection capable to transmit 1000 MW. In 1976-1977 were stablished the first two connections of 250 kV and 250 MW and the latest interconnections 350 kV and 500MW was established in 1992. Lastly, four HVAC connects with Germany, two 400 kV that starts from Kasso, and two 220 kV connection which begins from Kasso and Ensted Power Station. There is an additional 150 kV cable which starts from Ensted Power Stations to the city of Flensburg. Normally, the transmission capacity is 1780 MW exports and 1500 MW imports.

The island of Bornholm is interconnected with a 60 kV sea cable HVAC with a thermal capacity of 60 MW. The island of Jutland-Funen is connected with Zealand through the Great Belt Power Link, a 400 kV HVDC connection with a transmission capacity of 600 MW. (Energinet.dk 2014.) The map below shows the interconnection with the neighbouring countries:

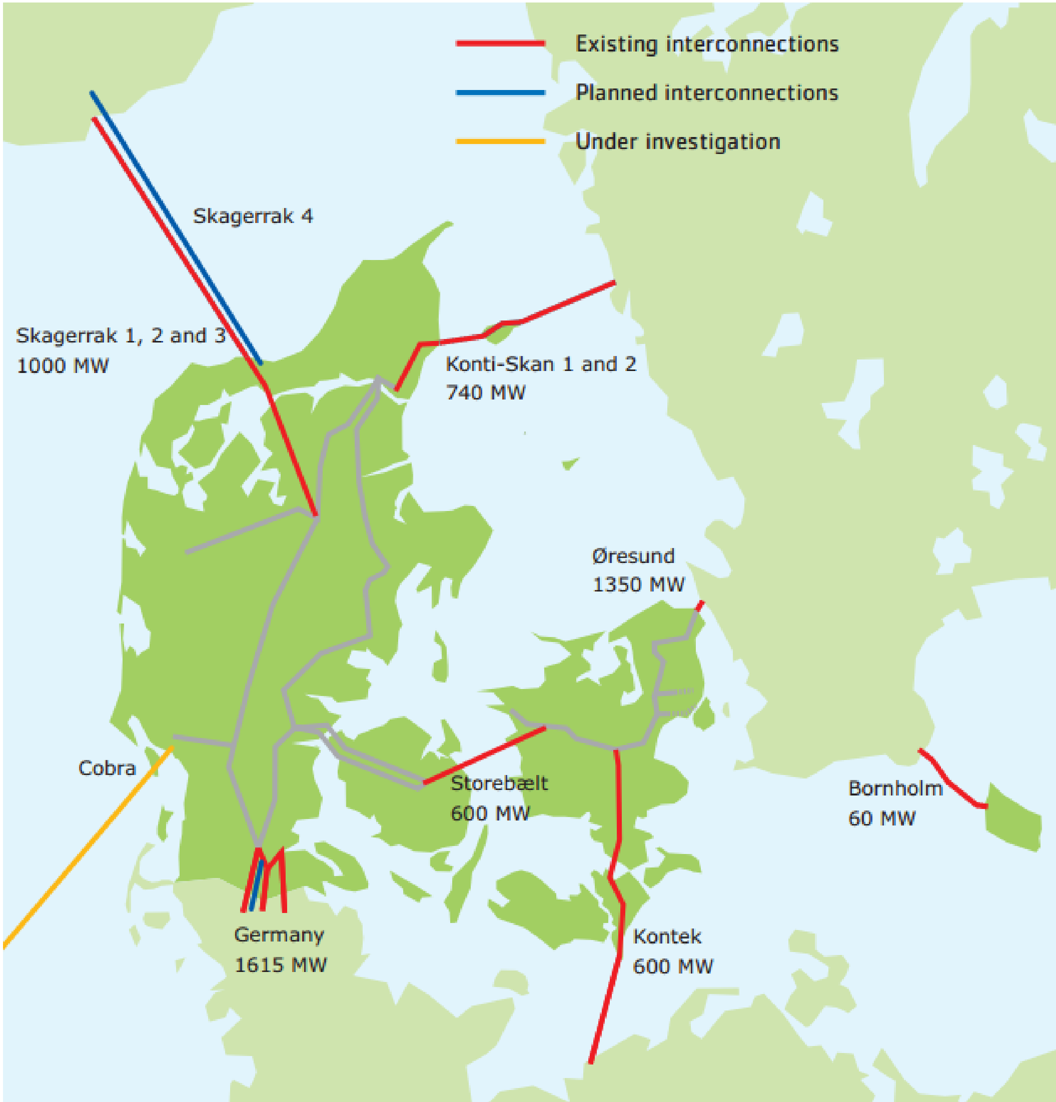

FIGURE 20. Electricity innterconnection (Energinet.dk 2015)

Future Strategy

The Danish government (2011) set a number of targets as a working plan, which is a strategy for 2050:

- Denmark is to be a green and sustainable society
- Denmark will be among the top three countries worldwide in terms of increasing its renewable energy share by 2020
- Denmark will be among the three most energy-efficient countries in the OECD by 2020.

The reason of the aforementioned work plan is to receive policy support to achieve the goal of accomplishing complete independence from fossil fuels. Hence, the ultimate vision of Denmark is to be 100% independent of fossil fuels by the year 2050 (Danish Ministry of Energy 2015). Therefore, energy and climate policy initiatives are present as part of the energy strategy. (Danish Government 2011.)

In 2012, wind power accounted for 29,8% of domestic renewable energy consumption (DME 2015). In order to accomplish the mentioned targets, the Danish government set a number of targets:

- Launch electricity supply legislation and regulation in order to align the transition from fossil fuel dependence, supported by incentives and rules.
- Continue to support municipal planning areas in the development of new onshore wind turbines, focusing particularly on the planning tool. An increased capacity of 1800 MW in combination with other external conditions.
- Allocate DKK 20 million for strategic energy planning partnerships between municipalities, local companies and energy companies. This fund has been introduced to promote the development of energy demand and supply. (The Danish Government 2011.)

- Analyze opportunities for reducing the distance requirements for wind turbines placed along roads, with a view to a better use of location in such areas.
- Investment in retrofitting buildings: energy companies shall increase energy savings by 2.6% of final energy consumption excluding transportation. Energy savings should rise by 2.9% annually from 2015-2020, even though the EU’s Energy Efficiency Directive suggests an annual reduction of 1.5% compared to the level of energy consumption (excluding transportation) in 2010. Additionally, energy companies are obliged to achieve energy savings in enterprises and households by offering subsidies or consultancy. (Danish Ministry of Climate, Energy and Building 2012.)
- Include a mobile wind task force to assist municipalities with wind turbine planning.
- Commission a strategic environmental assessment with view to calling for tenders or nine state-owned land plots for the erection of onshore wind turbines. (The Danish Government 2011.)
- A strategy to develop smart grids: the installation of intelligent and remotely readable hourly electricity meters. Also, develop an analysis of grid functionality, to comprehend the increased share of wind power. The analysis will be carried out to regulate the electricity supply sector and ensure incentives for green conversion, costs effectiveness and consumer protection. (Danish Energy Agreement 2012.)

In order to finance the aforementioned points, the Ministry of Climate, Energy and Building (2012) illustrates the ways in which the cost will be covered in the figure below:

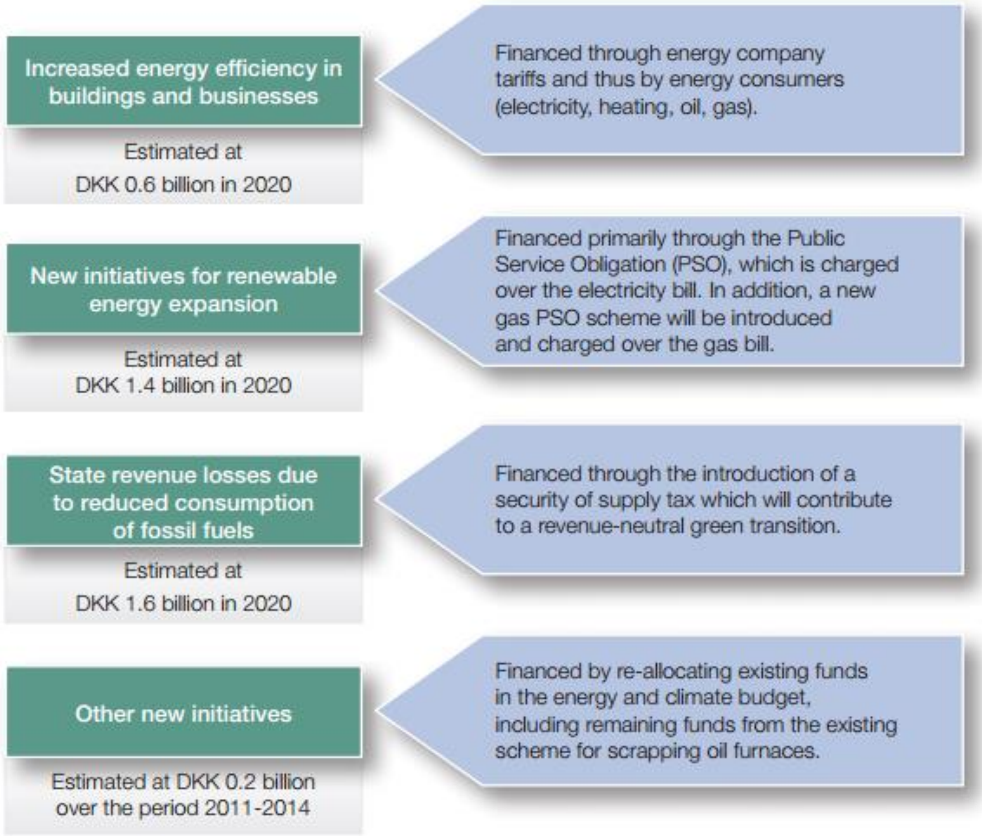

FIGURE 21. Financing the government's proposal (Danish Ministry of Climate and Energy 2011)

The government's energy and climate initiatives are fully financed up to the year 2020 (The Danish Government 2011). As a final result, by 2020 savings in the final energy consumption is estimated to cost 8 million $ (DEA 2012). The costs cover improved energy efficiency, expansion of supply from renewable energy and lost in revenues due to the reduced use of fossil fuels. On the other hand, 1 million $ is saved in energy consumption as the cost will be less than 0.25% of GDP in 2020. (Danish Government 2011). By the end of 2013, the total amount of onshore wind turbines was 3506 generating a capacity of 4.777 MW. (Danish Ministry of Energy 2015.) Part of the government initiatives is to expand onshore wind turbines. Such initiatives are financed by PSO scheme (Public Service Obligation), which is an addition to the electricity price. Also, a small proportion of the PSO costs will be covered by gas consumers. (Danish Government 2011.) In the future, wind turbines will increasingly be placed offshore as suitable locations for onshore wind turbines are limited (Danish Ministry of Climate Energy 2011).

The energy policy is a start for green growth, but the government's ambition is to achieve much lower energy consumption through energy efficiency efforts and more renewable energy. More importantly, this policy applies for all Denmark as everyone is to finance the investment, which aims at a fruitful result (Danish Government 2011.)

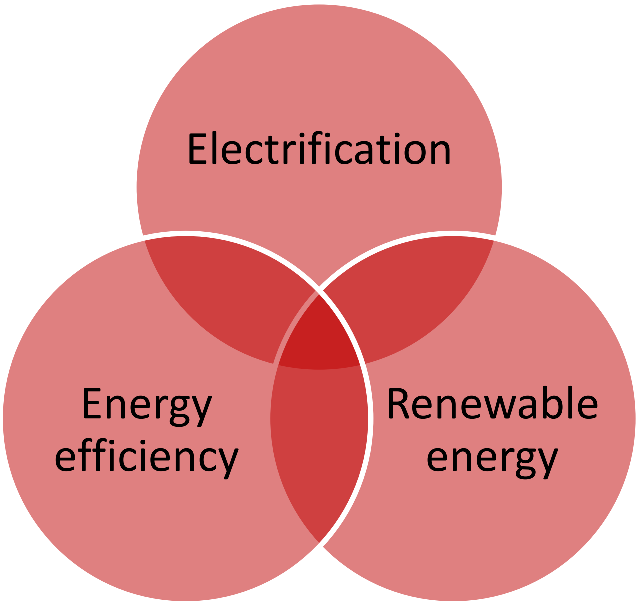

FIGURE 22. Energy system (Adapted from the Danish government 2011)

The figure 10 illustrates the energy system that Denmark is able to implement with the help of research development and demonstration, in order to expand the supply for renewables and eliminate fossil fuels. (Danish Government 2011).

5.3.1 Electricity price

Figure 10 illustrates the capacity and share of domestic electricity supply of wind turbines.

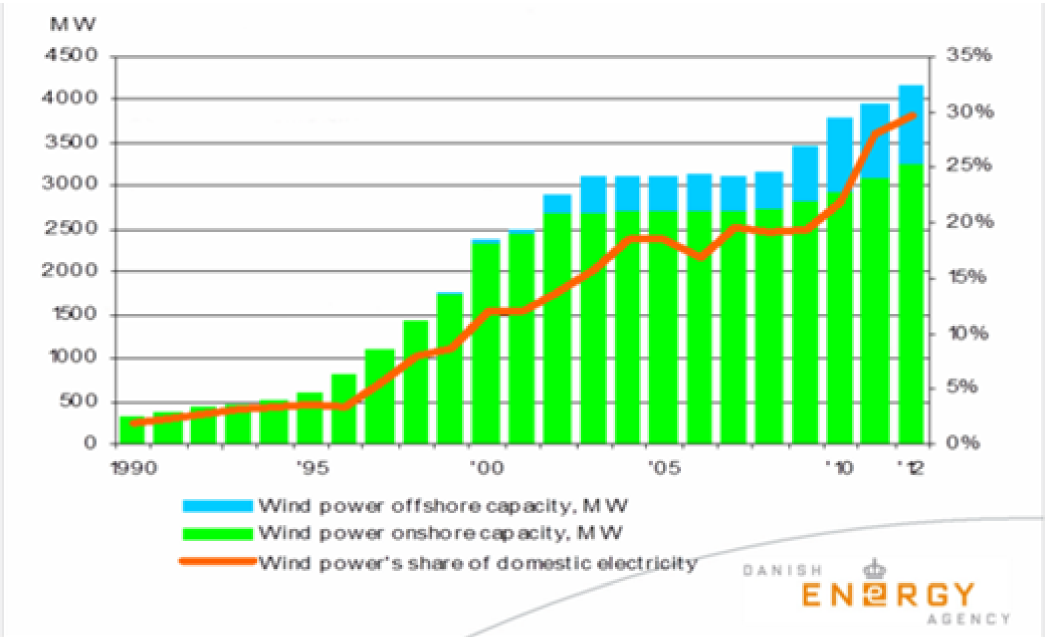

FIGURE 23. Wind power capacity and wind power's share of domestic electricity supply (DEA 2013)

The figure shows that onshore turbines account for most of the domestic electricity produced (DEA 2013). However, the capacity of each turbine varies as each turbine has a different energy output (DEA 2014). In order to evaluate a turbines' energy output, a calculation on the price of electricity based on the cost per unit per kilowatt hour (kWh) is carried out. The key elements for onshore wind turbines are: annual cost including turbine, foundation, grid connection, land rent, operation and maintenance cost, electricity production/wind farm capacity factor (Morthorst 2014 & IOWA 2016).

$$Cost\ of\ energy = \frac{AC}{\mathrm{AEP}}$$

Where:

AC = Annual Cost
AEP = Annual Energy Production

The author of the thesis has taken medium and high capacity turbines in order to demonstrate the cost of wind turbines. For this purpose, the calculation is based on generic assumption as generating electricity through turbines depends highly on the turbine's location and wind condition (Morthorst 2014). The investment cost of wind energy projects are dominated by the cost of the turbines, which could reach up to 75-80% of the total cost (EWEA 2009). In Denmark, the investment cost of onshore turbines is typically 1350 €/kW. Operation and maintenance (O&M) entails various components: insurance, planned maintenance, repairs, spare part and administration. O&M represent a share of the total annual cost of a wind turbine. On an annual basis, O&M cost might start at 10-15% of the total levelized cost per kWh for a new wind turbine, whereas an old wind turbine might average 20-35% of the total levelized cost per kWh. (Morthorst 2014.) For this purpose, the author takes a percent out of last year's wind turbine's statistic; amount of kWh produced and input the mean of the O&M according to the year of the turbine. The lifetime of a turbine normally is 20 years (EWEA 2009). The annual electricity production is taken from the statistics of the Danish Energy Agency as it shows the annual electricity produced from the past years.

The figure below shows the cost per kWh of different turbines:

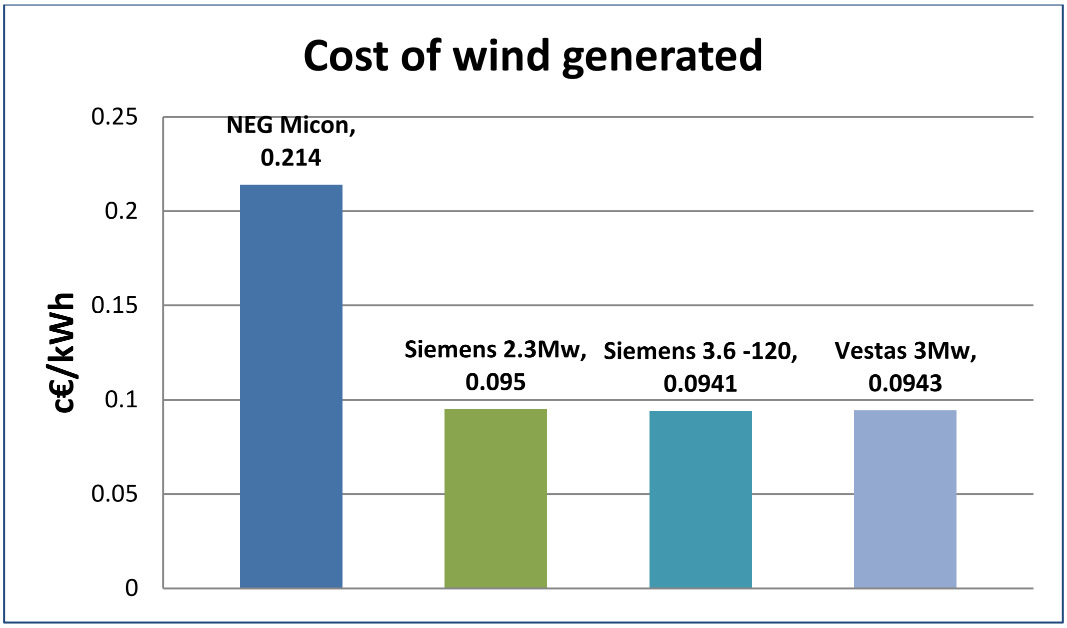

FIGURE 24. Calculated cost of wind-generated power

The figure compares the cost of four different turbines with different output capacity. The turbine manufacturers are MEG Micon, two Siemens and Vestas. In the figure, NM 2000, provided by MEG Micon, has a cost of 0.214 c€/kWh, whereas Siememens 2.3 has had a cost of 0.095 c€/kWh. Siemens SWT 3.6 has the highest cost of 0.094 c€/kWh, Similarly, Vestas with cost of 0.0943c€/kWh.

The turbines are located in different locations, and thus, the cost varies. Moreover, the cost is highly influenced by the year of turbine as the operation and maintenance may increase over the turbine's lifetime. Additionally, the amount of wind blowing in the area also determines the amount of electricity produced by the turbine. Although the year of the turbine determines the capacity factor, the calculation shows that yet an older turbine has capability to generate a fairly good amount of energy at low price. More importantly, newer and larger turbines contain a larger-scale of production, with a slight lower price than older turbines.

5.3.2 Reliability

Wind power requires various tools to control and integrate into the system. Tools include planning of the power grid, interconnections through accurate wind forecast as well as reserve capacity for calm periods. (Vinther 2015.) Integrating wind power into electrical grid is an important aspect for wind energy deployment.

Connection lines

During the 1990s, investments in wind energy took place, leading to a more decentralised production and increase in units. Furthermore, the integration of wind power was successful due to the combined heat and power plants (CHP), which was more efficient to deploy energy. (DEA 2012.) The combination of CHP plants facilitates the integration of wind, as when wind speed is low, and the demand for electricity is high, the combined heat and power plants can generate electricity (DEA). In 1998, Denmark decided to connect large wind farms to the transmission grid of 100 (Kv), as transporting large volumes of power in small voltage grid is not feasible (DEA 2015). Thus, small scale wind turbines need a converter to match the 32 kV grid, whereas newer turbines are capable to deliver 32 kV (Bizet 2016).

Energinet.dk owns these electricity grids, whereas local grid companies are in charge to transport the last phase of the power to households and companies. (Energinet.dk 2014.) Denmark presents a decentralized power system, which means that all the turbines and other energy sources deliver electricity directly to the national grid without the need of an electricity station (Bizet 2016). Denmark demonstrates an efficient and resilient power system with high security to supply a decentralised production. However, grid investments in time are very important to secure the grid operator incentives and finance the needed grid connections, reinforcement and support. (DEA 2012.) Figure 14 illustrates the de-centralised power system in Denmark.

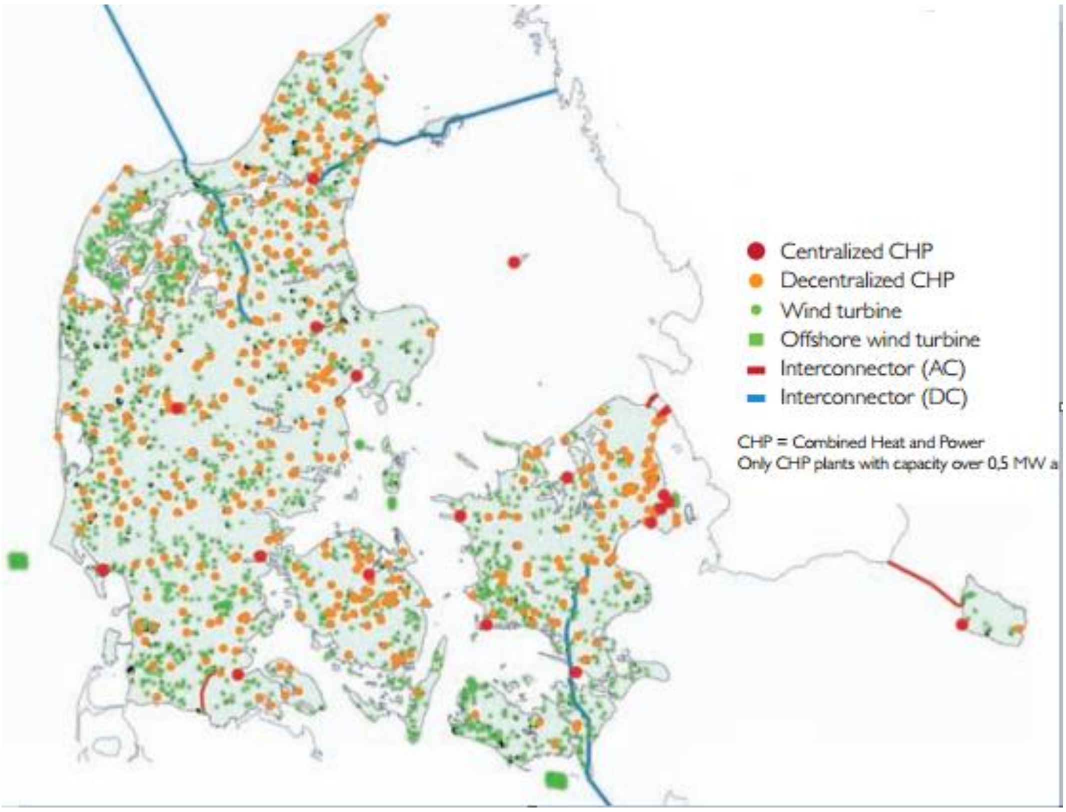

FIGURE 25. Ifraestructure of electric power in Denmark (DEA 2012)

Energinet.dk controls the Danish electricity consumption, and therefore, it is responsible for maintaining a constant frequency and voltage in the Danish part of the European power system. However, a challenge is to predict whether wind blows at the exact speed as predicted. Control center must follow the wind power production carefully. (Energinet.dk 2015.) Denmark does not prioritize wind energy production as all energy sources deliver electricity to the national grid. (Bizet 2016). Although priority access to the grid is provided in order to sell and transmit electricity at all times in accordance with connection rules (DEA 2012)

As the output of wind power varies from 0 up to 3100 MW in only few hours, Denmark reserves an amount of power of other types of power generation. Hence, when wind is not strong enough, Denmark is able to import electricity from Norwegian hydropower. Fortunately, Denmark is situated between hydropower-base Nordic system and thermal power base system in the south. (Energinet.dk 2015.) Additionally, Denmark is capable to export wind power to the neighbouring countries when there is an excessive amoung of electricity. Interconnectors with other countries facilitate the integration of wind power (DEA 2012). A challenge for the realization of wind energy projects is be to connect isolated turbines to the existing grid. Some projects are far away from the grid, which results in high cost due to the price of the grid extension. The grid though, provides opportunities to develop projects at any place in Denmark. (Bizet 2016.) Thus, in order to encourage the erection of wind turbines, Energinet.dk approves and provides guaranteed tariffs according to Renewable Energy Act (2008) to make it more attractive for the erection of onshore wind turbines.

The electricity produced from wind turbines is transmited to the electricity supply grid, and subsequently, sold under market conditions. Hence, 0,4$ supplement is paid for electricity produced. Such price is applied for the first 22000 full-load hours. Additionally, 0.04 $/kWh is paid to cover balancing cost during the turbines' lifetime. (DEA 2009). Onshore wind turbines must establish the connection on cost sharing basis as the government obligues the utilities to connect according to detailed specification of sharing cost. The wind turbine owner pays the connection from the wind turbine above 1.5 MW to a certain connection point in whereas the distribution system operator must reinforce the grid if necessary. Additionally, the distribution system operator pays the reinforcement and wind turbines are free from charges of the use of the transmission system. (DEA 2012.)

Most turbines are connected at a medioum voltage level (60kV) and grid code also applies to that level. Due to the grid code of 1999, wind turbines always remain connected in order to deliver power to the grid. New turbines can be controlled remotely. TSO has managed to maintain the turbines operating without curtailing but rarely TSO stops the turbines due to outage. (DEA 2012.)

The utilazation of smart grid is to regulate the electricity, control when wind produces plenty of energy. Ultimately, the goal is to store that energy and use it when the production is low. (Bizet 2016.) The long-term planning and stable policy framework is the key to successful large scale integration and distribution of wind power (DEA 2012).

Operation maintenance & supply chain

Perez (2013) states that blades, gearboxes and generators tend to have high failure rates. Small components also cause failures (Hario 2016).

Danish turbines present high failures rates in electrical systems, followed by blades and converter (Perez 2013). Older turbines that produce 10 kV need a converter to match the 32 kV grid's tension (Bizet 2016). Gearboxes cause the longest downtime due to failure. Even though larger wind turbines presents a simple nacelle with few components (Hario 2016), the higher the turbine, the higher the failure rates, longer downtimes and higher costs are found in larger turbines (Perez 2013). Fortunately, the failure frequency in Danish turbines is lower than in other countries, this is due to the greater, age and smaller size of Danish turbines. However, there are certain components in turbines that need to be evaluated at the time of designing and maintaining such as the rotor subassembly, which is exposed to high wind pressure, as well as the electrical system and converter are considered less reliable. (Spinato 2003.) Among all the components, the capacitor, the generator side converter, and the grid side converter are ranked among the most common failures in wind turbines (LR 2016). But turbines with a direct drive generator would not need a gearbox, which increases reliability and avoid downtime. (Larsen 2014.) Although maintenance is very important for the lifetime of a turbine, new turbines tend to have very low cost in maintenance and operation (Hario 206). Yet inspection is carried out to guarantee the supply of a purchase. As Denmark presents a large number of turbines, the author selected few components in which the turbines have experienced failures.

Gearboxes present vibration problems; therefore, it is hard to measure on monitoring systems. Also, oil transports different particles which may spread out from one component to another. The viscosity at cold starts is an important aspect to optimize. Additionally, damaged components may affect the other components as gearboxes are included in a closed system. There is a variety of possibilities to prevent gearbox failures: optimize the lubricating system and cold starts, monitor temperature, vibration, wind rotational speed, and inspect the service control in regards to the alignment, contamination and deterioration. Components at maintenance shall be replaced by sophisticated coponents. (Bertling 2012)

Fatigue in turbines is caused by low-speed shaft, high-speed shaft, rotor and gearbox. However, fatigue is hard to predict, but the effect of corrosion could be a starting point of fatigue damage. Fatigue can lead to failures in a very short time, thus, it is advisable to acquire a proper design with sufficient fatigue failure is very important. (Bertling 2012)

In order to mitigate failures, a wind turbine stethoscope is utilized to measure acoustic emissions to help technicians during daily work to detect failures on wind turbines. The stethoscope measures mechanical vibration analysis. Additionally, a major part of the stethoscope is to develop a user-friendly notification system, which consist of transmit the data of the turbines to a mobile device. Lastly, diagnosis of external environment factors such as wind speed, temperature as well as the failures in wind turbines. SCADA produces algorithm provides condition status of the major components in turbines. (Bertling 2012.)

Danish suppliers have formed part of an important collaboration partners and problem solvers in the evolution of the Danish wind energy. The designing and production phase of turbines normally was carried out in collaboration with suppliers, research institutions and turbine manufacturers. The leading role of Danish suppliers results in technological advances in the industry. More importantly, the suppliers were charged to supply the turbine components to the manufacturer. (Andersen 2012.) The modern turbines require a strong value chain of suppliers with good collaboration in order to ensure the delivery (State of green 2015). Furthermore, in order to be in the forefront of the industry, Danish suppliers demonstrate willingness to collaborate with foreign control companies as the knowledge of the industry is expanding globally (Andersen 2012). The Danish wind industry association has now more than 260 member companies with expertise needed throughout the value chain for producing wind turbines (State of green 2015).

Manufacturers are pressured to streamline the product and production processes. Denmark has reached a level of efficiency by being innovative and flexible. Moreover, it is noted that suppliers are knowledge providers for manufacturers. Hence, many suppliers have shared knowledge with manufactueres. However, Danish suppliers do not strongly rely in collaborations with large Danish manufacturers to play a role in the Danish wind industry. Fortunately, more than half of the suppliers share knowledge with Vestas and Siemens in product delivery, technical view and best solution (Andersen 2012). Yet manufacturers demand a higher degree of integrated solutions or system solutions. Additionally, due to the high demand, it is easily accessible to find compaies involve in all levels of supply chain, consulting, transport, logistics, electronic management. (DWIA 2012.) Currently, key suppliers take on high responsibility in supplying parts and components, which becomes supplier of sub-systems, design and assembly to provide more value and build long-lasting relationship with the manufacturers. The Danish sub-suppliers intent to cooperate across the value chain by developing a strong R&D (research and development), Hence, sub-suppliers include their customer in the R&D work in order that together with the manufacturers, the industry becomes industrialized. (Megavind 2013).The figure below shows the plan of the future supply chain in Denmark by adding specialised supplier to control the supply chain management.

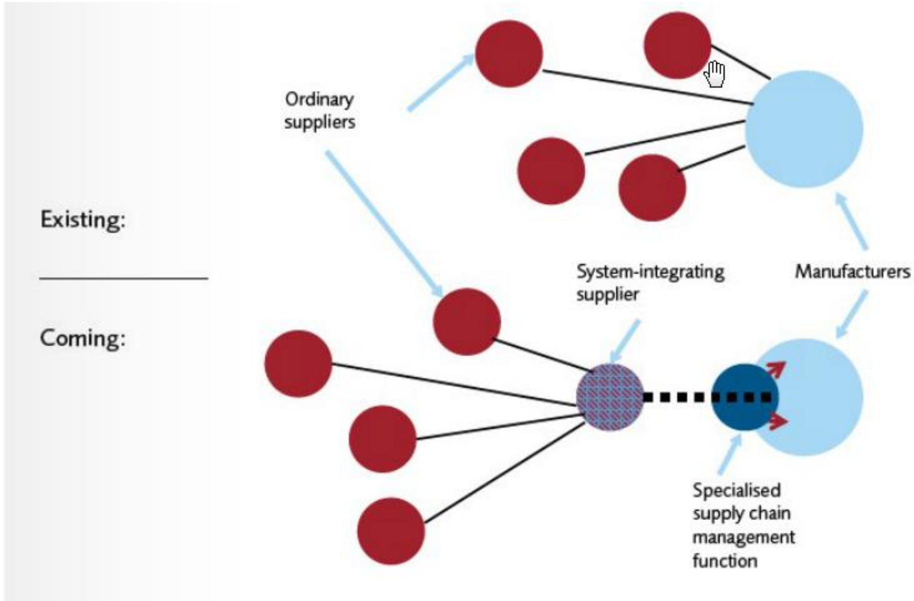

FIGURE 26. Future plan for supply chain (DWIA 2012)

Currently, twelve suppliers in Denmark have formed a supplier network to find new ways of cooperation, provide innovative solutions with product development processes and maintain attractive working places (DWIA 2015). In order to meet demand, optimize the process of value chain and documentation of manufacturing quality, the Danish industry has implemented a variety of methods such as Six Sigma. Six Sigma method has been used in other industries, and it is said to meet customer's demand by reducing errors. However, implementing such methods requires a high level of trust between the parties involved as the supplier must undergo through extended performance evaluation and the manufacturers verify the requirements that the supplier should meet (Andersen 2012.) The high expertise of suppliers and manufacturers in wind industry is also attributed to the joint projects with educational institutions, foreign companies as well as local manufacturers and local suppliers and sub-suppliers. Thus, some manufacturers have (R&D) in their assembly facilities for testing and verification. Also, sub-suppliers have strong competence in R&D with facilities at their service (Megavind 2013). More importantly, the employee know-how has increased along the years in the wind energy industry. The increase in expertise is due to the years of employee training in wind power companies (Andersen 2012.) Upgrading the qualification of existing employees increases the opportunities to enhance skill labor force (DWIA 2015). However, Andersen (2012) states that some suppliers had already built a certain portfolio with manufacturers, and in fact, were involved in the logistical processes, having formalised collaboration in developing activities.

Denmark prioritises investments in R&D, production, education and innovation in order that the Danish hub can maintain a leading position for wind energy. (Megavind 2013). As for manufacturers, they provide a reliable supply of new components for turbines. Vestas is based in Denmark. It provides the possibility of a rapid supply and maintenance. In order to mitigate turbines' failures, Vestas provides an integrated Supervisory Control and Data Acquisition (SCADA), a system that controls the performance and monitor the production level (Vestas 2016)

Wind energy accounts for a large market share over the energy market. Companies continue to establish operation in R&D in Denmark. Therefore, the market is expected to grow due to the national targets from the European renewable energy directive (Megavind 2013). Networking collaboration, durable partnership with municipalities, companies and education institutions are vital to strengthen the development of wind (DWIA 2015). The creation of new technology is the result of decrease of cost in wind energy. Thus, manufacturers should be able to offer turbines with the highest return on investment (Megavind 2014). Additionally, the market for wind is secured with an ambitious energy act until 2020 (Megavind 2013).

6 BENCHMARKS OF WIND INDUSTRY

As the thesis introduces focus areas to benchmark wind energy in chapter 5, chapter 6 evaluates the focus areas in both countries. The focus areas in this study are governmental decisions and R&D, cost of wind-generated and reliability, which divides into connection lines and operation maintenance and supply chain.

6.1 Governmental decisions

Policies are presented with detailed information in both countries. Decision making has demonstrated to be the key to deploy a source of energy. Therefore, policies strongly influence the country and the people living in it.

Denmark presents ambitious targets for the deployment of wind energy. Along the years, the country has reached a high production of electricity with investment and stakeholders' engagement. The Danish have responded positively with new wind turbine projects in different regions. The government has set out several opportunities in order to foster its development and engage more stakeholders in the industry. The government has provided several incentives for stakeholders to begin the production of wind energy. Ultimately, stakeholders benefit with the selling price of the wind energy to the local grid companies.

In comparison with Denmark, Bolivia accounts with a large area and therefore, unpopulated. Yet Bolivia remains in a developing phase where the country's first plan is to connect the entire country to the SIN. Bolivia should revise its strategy for the electricity sector. Policies do not deeply include the production of wind energy. This makes wind energy a less viable source of energy. Wind energy should become part of the future electricity plan, which shall include specific law to erect wind turbines and supply the domestic use. Set strategic targets to generate wind energy as well as to evaluate specific locations to install new wind parks. Also, engage private stakeholders, as well as public stakeholders into the industry to take part in the development will enhance the vision of the industry. Incentives for the public shall be provided, as well as educating the public in regards of the opportunities of the industry. Bolivia should promote the education towards wind energy in order to enhance the level of local know-how and increase the number of local technicians, which in a long-term will reduce the cost of future maintenance and operations. Bolivia should install more wind turbines in different regions as if the capacity factor of wind energy increases due to the number of wind parks and output production, the capacity factor of other electricity sources will be reduced.

6.2 Electricity price

The price of wind-generated in Bolivia and Denmark differs in several aspects. The prices are highly dependent on the year of the turbine, the cost of operation and maintenance (O&M), as well as the annual energy production. The figure below illustrates the cost per kWh of turbines in Bolivia and Denmark:

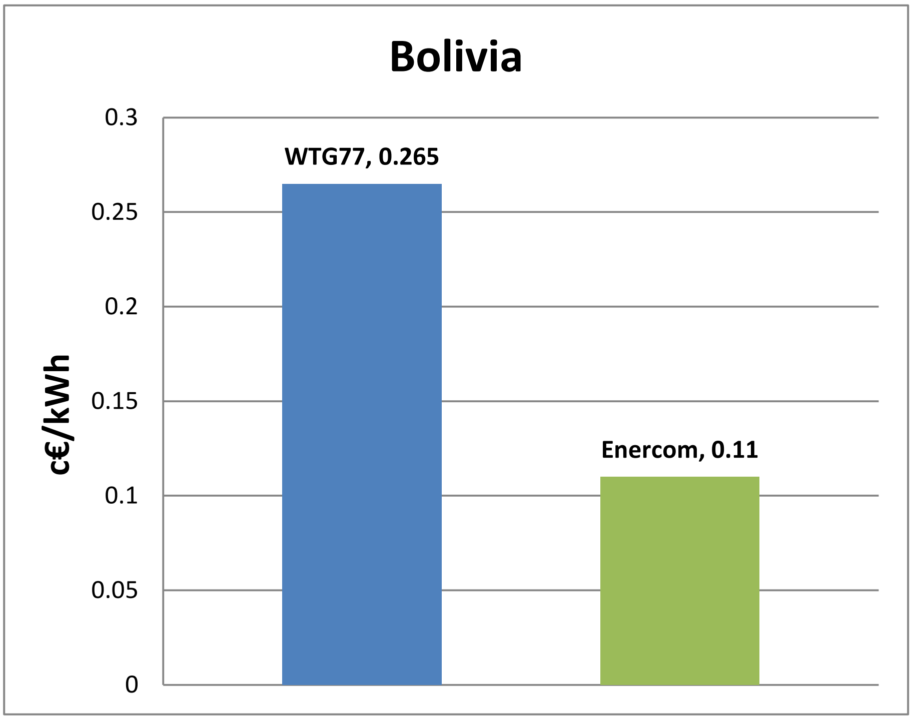

FIGURE 27. Cost of wind-generated power in Bolivia

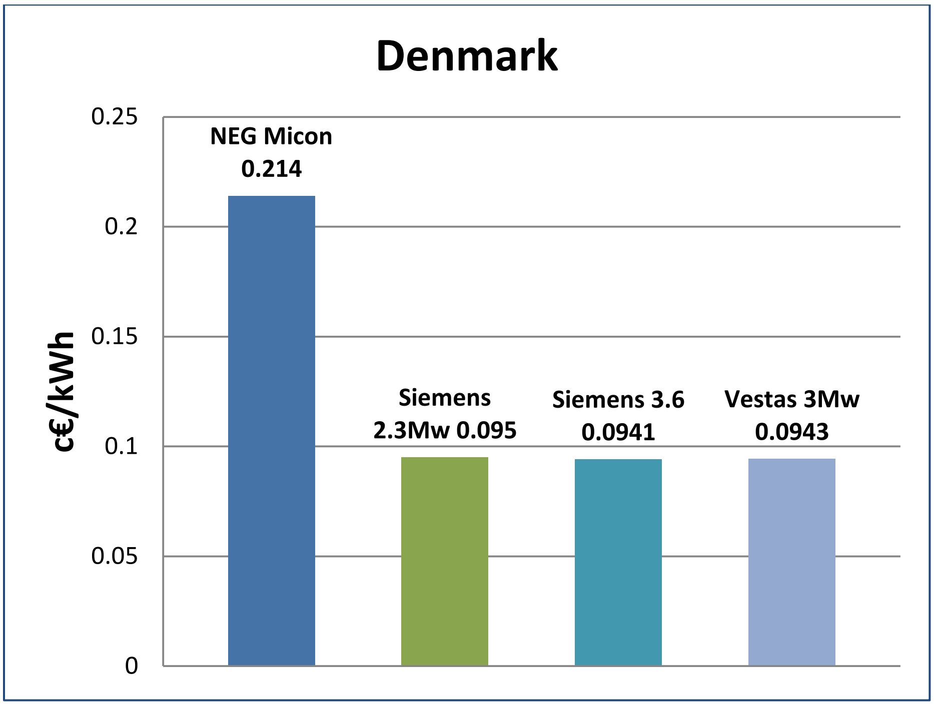

FIGURE 28. Cost of wind-generated power in Denmark

The figure shows that in Bolivia, the price of the Goldwind and Enercon turbines are elevated due to the high investment and low production of Goldwind's turbines during the year 2015. The cost for O&M is 15% of the cost of the turbines. The cost of O&M demonstrates to increase the investments capital and turning wind a less viable energy source. In the near future, when Bolivia presents a standard level of expertise in the industry, the investment capital and O&M should decrease. In comparison with the experiences from Denmark, wind turbines show a low cost in O&M as when the wind turbines start operations, they present a very low cost. Hence, it is advisable to support education and involve local technicians to reduce the cost of foreign labor force. By the reduce dependency of foreign labor, the turbines should present a lower cost in O&M and will provide opportunities for local technicians to be employed in the industry.

With the information shown from the Danish turbines, the investment capital presents a standard price per unit of turbine. Furthermore, the large production demonstrates to reduce the cost of wind generated per turbine unit. Additionally, the cost of O&M varies in regards to the year of the turbine, and therefore, older turbine presents a higher cost in O&M, whereas new turbines present a low cost in O&M.

6.3 Reliability

Connection lines

Denmark presents a reliable network connection. The usage of CHP plants provides a high level of reliability to generate wind energy. The connection lines present a high voltage level with the possibility to transmit high capacity of electricity, which enahance the production of electricity. The de-centralised system offers the possibility to generate electricity and connect to the system rapidly regardless of the location of the turbine.

Denmark accounts with the opportunitiy to export electricity whether the production is high. Hence, country is connected to the neighboring countries with Norway, Sweden and Germany. More importantly, in case low production from wind, Denmark can be supplied by other electric sources from the neighboring countries. Similarly, Denmark is able to supply these countries when the production of wind energy is high. The electricity consumption is controlled by Energinet.dk but its main challenge is to predict the wind speed to produce electricity. Denmark does not prioritize the production of wind energy but it provides access to connect wind turbines to the grid in order to transmit and sell the electricity. Additionally, Energinet.dk provides guarantee tariffs to encourage the public to install wind turbines.

Bolivia is limited to transmit energy to the entire country as it presents areas that remain isolated. Such areas account with other forms of electricity generation, which is mainly fossil fuel combusted. Moreover, rural areas are connected through a low connection line. Bolivia should accelerate the planning of the connection lines in order to deliver energy through the SIN for the entire country. Reinforcements in the connection lines shall as well be provided as the population will grow on rural areas and the rural areas will not be provided with sufficient electricity. Also, wind turbines demonstrate a higher production capacity to generate electricity, thus, reinforcement are essential to support the tension of the connection lines in case of good production of wind. The regulated system should be able to demand energy from wind turbines in order to supply other regions of the country. More importantly, wind energy presents few limitation to generate electricity, the need to connect wind turbines to other electricity source is significant as when the turbines presents a low production, other electricity source is able to support and supply electricity to the system. Similarly, the need to connect Bolivia with neighboring countries is vital for the supply of other electricity generation source and to export future energy.

Operation maintenance and supply chain

Danish turbines present failures in electrical system, blades and convertes while gearbox causes downtime in the machine. Strong collaboration among suppliers, research institutions and manufacturers drive the industry to continuous improvements, which results in investments in further research and development of wind energy.

The industry requires a robust supply chain in order to streamline the production and suplly of new components. Due to the remarkable growth, the large number of suppliers in Denmark offers the possibility to rely on several suppliers that are able to deliver new components for wind turbines. Also, the know-how skills have driven the industry further to reach high productivity of clean electricity. Several firms account with warehouses in Denmark to supply wind turbines owners with knowledge and components of wind turbines.

During the first year of operation, the Bolivian wind turbines presented failures in electrical systems. The turbines did not produce at high capacity due to a low power connection line, which was connected to a rural cable of 24 kV. Also excesive wind speed caused failure damange in some components. Bolivia should stop the machine when the wind speed is high in order to avoid mechanical damanges. A machine inspection shall be provided in order to measure the wind speed and the functionality of the turbine. Bolivia should acquire a maintenance and inspection plan in order to mitigate electrical failures and mechanical failures. This will avoid downtime and increase the production of wind energy without curtailing.

Bolivia should increase its network with international suppliers in order to increment the possibilities to receive support in the industry. Moreover, engage private firms and other institutions experienced in the field will enhance the know-how skills and increase the amount expertise in the industry. Joint project with research insitutions and universities is also a possibility to receive support in the industry. Hence Bolivia should increase the number of local technicians and increase know-how skills.

7 CONCLUSION & SUGGESTIONS

This final chapter summarizes the findings and results throughout this thesis, and answer the research questions. It also discusses recommendations for further research.

7.1 Answers to the research questions

“How can Corani provide a better wind energy services in the future?”

Currently Bolivia experiments the possibility to deploy electricity from wind. Positively, the country deploys wind energy to provide growth. Hence, the deployment has resulted in an introduction of entering wind energy industry to meet the local demand. Bolivia presents a large area where it could explode the development of wind by installing more turbines in different regions and therefore, connecting them with the nearby stations, thermoelectric, hydroelectric in order to provide support in case of low wind speed and high demand.

I. What is the current situation of wind energy in Bolivia? And what is the reason for its deployment?

The production of wind energy began with two wind turbines, with a total capacity of 3 MW. Therefore, Bolivia started the process to utilize natural resources and to supply the local demand in order to provide a clean energy source. It is important to note that the population is continuously growing, and the current electricity will not be sufficient to supply the domestic demand. With the experiences from the current wind turbines, the country is about to move towards an improvement of a better service and understanding in the industry. Ultimately, future plans are carried out to buil wind farms in the future.

II. What is the current situation of wind energy in Denmark? How does the government cooperate to develop wind energy?

Denmark has the capacity to provide a large amount of electricity from wind. The government has engaged the public to produce electricity from wind by providing subsidies and compensations and proposing very attractive alternatives to erect wind turbines. Moreover, the government supports the development of onshore wind turbines by supporting in the standard installations of wind turbines. Additionally, the government reserves areas to install onshore wind turbines and gives priority access to the grid system in order to sell and transmit electricity.

III. What is the potential and pitfalls of generating electricity through wind?

The production of wind energy has proven its capabilities to supply domestic demand of energy. Currently, Denmark is able to supply nearly 40% of its domestic consumption with nearly 5000 wind turbines. However, the initial cost of the project makes it less attractive to start the process of generating wind energy, but it is proven that the cost will be lower during the lifetime of the tubines.

More importantly, wind is unpredictable as sometimes there can be a good wind speed but this can change and turn in low wind speed. Also, excessive wind speed can damage wind turbines machinery. This can results in downtime of the turbine.

IV. How can Corani learn from Denmark?

Bolivia could engage more parties into the development of wind energy. The public presents a source to strengthen the development of the industry. Cooperating with the public for distribution land, as well as other priorities in regards to connection lines could lead towards industry growth.

Increasing the network is a possibility that Bolivia could enhance to increase the number of suppliers and expertise in the industry. Network groth is an opportunity for Corani to increase its options of different suppliers and build a relationship with international suppliers. Additionally, the result of the networks could lead to increasing expertise level.

7.2 Reliability and validity

The data gathering: desk study and interviews fulfilled the findings for the empirical research of this thesis. From the five interviewees, three are representatives of Corani, while the rest are stakeholders that affect the Danish wind energy. The results of the data gathering proved the findings to be logical and consistent. Hence, the author believes that if a second study is carried out in the near future, the result's aim at being similar.

Similarly, this thesis answers the research questions and sub-questions. The theoretical part is structured based on several academic sources such as books, school journals, as well as trusted public domains. Most of the sources present a review from the past. However, some theories are retrieved from sources dated many years ago. Such sources were used in this study as they have proven to be effective. In order to strengthen this, the author has selected up-to-date articles and other books related to the topic. In addition, the information used in the Bolivian wind energy originates from trustworthy internal source of the case company. To conclude, this thesis is greatly reliable and validated.

7.3 Suggestions for further research

This thesis focuses on benchmarking government decisions, cost of electricity and reliability of wind energy. Such aspects are only few sustainability aspects within wind energy. Hence this thesis only focuses on providing suggestions learnt from a foreign market within the aforementioned sustainability aspects. A further study on developing an actual plan for developing sustainability aspects of the Bolivian wind energy is highly recommended. Therefore, it is recommended to study the Bolivian electric sector thoroughly in order to focus on energy prices to make wind energy a viable source of energy in Bolivia. Additionally, to understand other Bolivian electric sources such as thermoelectric source and hydroelectric source in order to increment the production of wind energy.

8 SUMMARY

Bolivia entered the wind energy industry with the instalment of two pilot turbines. Corani leads the operation of the two wind turbines, which the latter provided knowledge and incentives to erect more turbines in the country as it demonstrated great opportunities for the local market. Hence, the goal of this thesis is to find benchmarks from lessons learnt from Denmark, and utilize those lessons to suggest future improvements in the Bolivian wind energy.

This thesis uses deductive approach to test, describe and implement a theory. Moreover, the primary and secondary data originates from qualitative data collection methods. Primary data is collected through observations and interviews. The secondary data is derived from books, academic journals, trustworthy public domain as well as trustworthy internal sources from the case company. In regards to the thesis scope and limitations, desk study is utilized and proved to be useful for research purposes.

The main idea of this thesis is to utilize a benchmarking theory to find best practice of the industry. Ultimately, to create suggestions from experienced Danish wind industry for better practice in Bolivia. Moreover, innovation management theory provides emphasis on the benchmarking theory to innovate and explore business. Lastly, sustainable development theory is also described as the wind energy entails sustainability aspects in production, economic growth and deploying a clean source of energy.

As Denmark was selected as benchmarkee, the author selected focus areas to study within benchmarking. The selected focus areas are governmental decisions, cost of wind energy and reliability. Hence, information of the history in regards to the industry, together with the current energy scenario and future strategy was described in both countries. Also, the cost of wind-generated of several turbines was studied. Additionally, the author studied the connection lines and maintenance operations and supply chain to evaluate how reliable the wind industry could be.

In conclusion, the study reached its objective to study appropriately the wind energy market in both countries while answering the main research questions and subsequentely, the sub-questions. The findings have demonstrated that the wind energy could become a viable source with ambitious long-term strategies as well as engagement of stakeholders and local personnel to increase know-how skills in the industry. Also, incrementing the Bolivian network with international suppliers will provide more options for business opportunities.

More importantly, the study demonstrated that the wind energy has become a viable source as the wind speed is strong to generate electricity. Bolivia started the deployment of wind energy with a fairly great amount of production capacity, which will lead to further investments and higher production.

REFERENCES

Published references

Bessant, J. Tidd, J. 2011. Innovation and entrepreneurship. Second edition. John Wiley & Sons Ltd.

Blewitt, J. 2015. Understanding sustainable development. Second edition

Bradshaw, M. 2014. Global Energy Dilemmas. Energy security, globalization and climate change.

Camp, R. 1995. Business Process Benchmarking Finding and implementing best practice. 2nd edition. Milwauke. ASQ quality press publication.

Camp, R. 1989. Benchmarking: The search for industry best practice that lead to superior performance. Milwauke Wisconsin: ASQ quality press.

Carrol, A. Bushholtz, A. 2015. Business & Society. Ethics, sustainability and stakeholder management. Cengage learning 9th edition.

Cook, D. 2004. The natural step: a framework for sustainability. Schumacher Briefings.

Kopnina, H. Blewitt, J. 2015. Sustainable Business: Key issues in environmental and sustainability. Routledge.

Johnson, G. Scholes, K. 2001. Exploring public sector strategy. 1st edition. Essex: Pearson education limited.

MacNeill, J. 2007. Our Common Future: Advance or Retreat? Sustainable Development: A New Urgency. Geneva: EcoLomics International.

Ratner, B.D. 2004. Sustainability as a dialogue of values: challenges to the sociology of development. Sociological inquiry.

Saunders, M., Lewis, P. & Thornhill, A. 2009. Research Methods for Business Students. 5th edition. Essex: Pearson Education Limited.

Tester, Jefferson W. Drake, Elisabeth M. Driscoll, Michael J. Gollay, Michael W. Peters, William A. 2012. Sustainable Energy. Choosing among options. 2nd edition.

Electronic sources

Agencia Boliviana de Informacion (ABI). 2016. Bolivia-Energia. Sanchez dice que la meta hasta 2025 es de exportar 10000MW de electricidad y generar mas que la renta petrolera. (Referenced 1 May 2016). Available: http://www.abi.bo/abi/?i=349341

Allio, R. 2005. Strategy and leadership: An interview with Henry Chesbrough: Innovating innovation. Strategy & Leadership. Vol. 33, Iss 1, pp 212-231. (Referenced 10 January 2016). Available: http://www.emeraldinsight.com.aineistot.lamk.fi/doi/pdfplus/10.1108/10878570510572617

Amaral, P. Sousa, R. 2009. Barriers to internal benchmarking initiatives: An empirical investigation. Benchmarking: An international journal. Vol. 16. No. 4, pp 523-542. (Referenced 13 December 2015). Available: http://search.proquest.com.aineistot.lamk.fi/docview/217397091/fulltextPDF/E85FB1EFA62B4C60PQ/1?accountid=16407

Anand, G. Kodali, R. 2008. Benchmarking the benchmarking models. Benchmarking: An international Journal. Vol. 15. No.3. (Referenced 18 December 2015). Available: http://web.b.ebscohost.com.aineistot.lamk.fi/ehost/command/detail?sid=4a3fa936-4e82-4e56-a880-0672f1f6eb4b%40sessionmgr113&vid=5&hid=115

Andersen, P. I. 2012. Denmark-the wind power hub. Transforming the supply chain. Danish wind industry association. (Reference 24th March 2016). Available: http://ipaper.ipapercms.dk/Windpower/Denmark_the_Wind_Power_Hub_Transforming_the_Supply_Chain/

Baumert, K. Herzog, T. Pershing, J. 2005. Navigating the numbers: Greenhouse gas data and international climate policy. Washington DC. World Resources Institute. (Referenced 8 November 2015). Available: http://www.wri.org/publication/navigating-numbers

Bertling, L. Wennerhag, P. 2012. Wind turbine operation and maintenance. Survey of the development and research needs. Elforsk report. (Referenced 5 May 2016). Available: file:///C:/Users/DiegoPC/Downloads/12_41_rapport_screen.pdf

Blakeman, J. 2002. Benchmarking: Definitions and overview. Center of urban transportation studies. University of Winsconsin-Milwaukee. (Referenced 10 December 2015). Available: https://www4.uwm.edu/cuts/bench/bm-desc.htm

Botarelli, M. Titicchi, P. Cagnazzo, L. 2008. A literature review on innovation management tools. UFSM, Santa Maria. Vol. 1. No. 3. p, 316-330. (Referenced 20 January 2016). Available: http://cascavel.ufsm.br/revistas/ojs-2.2.2/index.php/reaufsm/article/viewFile/620/463

BP. 2015. BP Statistical Review of World Energy June 2015. 64th edition. (Referenced 1 November 2015). Available: http://www.bp.com/content/dam/bp/pdf/energy-economics/statistical-review-2015/bp-statistical-review-of-world-energy-2015-renewables-section.pdf

Carvalho, M. Afgan, N. Hovanov, N. 2000. Energy system assessment with sustainability indicators. Energy Policy.Vol. 28, Iss. 9, p. 603-612. (Referenced 15 January 2016). Available: http://ac.els-cdn.com.aineistot.lamk.fi/S0301421500000458/1-s2.0-S0301421500000458-main.pdf?_tid=0b2ab510-c9c7-11e5-bf57-00000aacb361&acdnat=1454429422_36171a5c7fb32c9800443cf385d1c3ac

Central Intelligence Agency. 2012. Electricity -from other renwable sources. The world factbook. (Referenced 22 December 2015). Available: https://www.cia.gov/library/publications/the-world-factbook/rankorder/2240rank.html#da

Central Intelligence Agency. 2016. Europe: Denmark. The world factbook. (Referenced 9 May 2016). Available: https://www.cia.gov/library/publications/the-world-factbook/geos/da.html

Central Intelligence Agency. 2016. South America: Bolivia. The world factbook. (Referenced 1 May 2016). Available: https://www.cia.gov/library/publications/the-world-factbook/geos/bl.html

Ciegis, R. Kliucininkas, L. Ramanauskiene, J. 2011. Assessment of state and tendencies of sustainable development in Lithuania. Management of Environmental Quality: An international journal. (Referenced 6 January 2016). Available: http://search.proquest.com/docview/916316165/fulltextPDF/D71AB82D672540F9PQ/4?accountid=16407

Comite nacional de despacho de carga (CNDC). 1994. Ley de electricidad No. 1604. Ministerio de hidrocarburos y energia. (Referenced 18 April 2016). Available: http://www.cndc.bo/normativa/ley_electricidad.php

Counsell, D. 1999. Sustainable development and structure plans in England and Wales. Operationalizing the themes principles. Journal of Environmental Planning and Management. (Referenced 6 January 2016). Available: http://search.proquest.com/docview/214401832/fulltextPDF/C22A5837D12F4DE2PQ/1?accountid=16407

Corani S.A. Electric enterprise. 2015. Mission of Corani. (Referenced 26 April 2016). Available: http://www.corani.com/index.php/features/mision

Corani S.A. Electric enterprise. 2015. Qollpana wind park. (Referenced 12 April 2016). Available: http://www.corani.com/index.php/pages/parque-eolico-qollpana

Dahlander, L. Piezunka, H. 2015 Distant search, narrow attention: how crowding alters organization's filtering of suggestion in crowdsourcing. Academy of management Journal. Vol. 58 No 3. (Referenced 8 December 2016). Available: http://web.b.ebscohost.com.aineistot.lamk.fi/ehost/pdfviewer/pdfviewer?sid=96ba0852-be86-43fa-8b82-388c0795b385%40sessionmgr111&vid=1&hid=102

Danish energy agreement. 2008. Agreement on Danish Energy Policity for the years 2008-2011. (Referenced 9 February 2016) Available at: http://www.ens.dk/sites/ens.dk/files/policy/danish-climate-energy-policy/agreements-danish-energy-policy/february-2008-agreement-danish/Energy%20Policy%20Agreement%2021%20Feb%2008_final.pdf

Danish energy agency. 2012. Denmark a leading player in combined heat and power. (Referenced 3 April 2016). Available: http://www.ens.dk/sites/ens.dk/files/politik/Kina-samarbejdet/Materialer/Faktaark/chp.pdf

Danish energy agency. 2015. Energy in Denmark 2014. Data, tables,statistics and maps. (Referenced 25 February 2016). Available: http://www.ens.dk/sites/ens.dk/files/info/tal-kort/statistik-noegletal/aarlig-energistatistik/energyindenmark2014.pdf

Danish energy agency. 2012. Energy policy toolkit on system integration of win power. Experiences from Denmark. (Referenced 1 April 2016). Available: https://stateofgreen.com/en/files/System-Integration-of-Wind-Power

Danish energy agency. 2014. Facts and numbers. (Referended 23 February 2016). Available: http://www.ens.dk/en/supply/renewable-energy/wind-power/facts-about-wind-power/facts-numbers

Danish energy agency. 2016. Master data register of wind turbines. Data on operating and decommissioned wind turbines. (Referenced 16 March

2016) Available: http://www.ens.dk/en/info/facts-figures/energy-statistics-indicators-energy-efficiency/overview-energy-sector/register

Danish energy agency. 2015. Onshore Wind Power. (Referenced 9 February 2016) Available at: http://www.ens.dk/en/supply/renewable-energy/wind-power/onshore-wind-power

Danish energy agency. 2015. Physical planning on wind turbine. Experiences from Denmark. Energy policy toolkit. (Referenced 15 January 2016). Available: http://www.ens.dk/sites/ens.dk/files/policy/Global-Assistance/Materials/tool_physical_planning_wp_web.pdf

Danish energy agency. 2009. Wind turbines in Denmark. (Referenced 12 January 2016). Available: http://www.ens.dk/sites/ens.dk/files/dokumenter/publikationer/downloads/wind_turbines_in_denmark.pdf

Danish government. 2011. Our future energy. The Danish Ministry of Climate, Energy and Building. (Referenced 6 April 2016). Available: http://www.ens.dk/sites/ens.dk/files/policy/danish-climate-energy-policy/our_future_energy.pdf

Danish minister for climate, energy and building. 2012. Accelerating green energy for 2020. The Danish Energy Agreement of 2012. (Referenced 7 February 2016). Available: http://www.ens.dk/sites/ens.dk/files/dokumenter/publikationer/downloads/accelerating_green_energy_towards_2020.pdf

Danish ministry of energy, Utilities and Climate. 2015. Wind. (Referenced 1 January 2016). Available: http://www.efkm.dk/en/climate-energy-and-building-policy/denmark/energy-supply-and-efficiency/renewable-energy/wind

Danish wind industry association. 2015. Danish Market. Statistics on the development of wind power in Denmark 2005-2014. (Referenced 3 January 2016). Available: http://www.windpower.org/en/knowledge/statistics/the_danish_market.html

Danish wind industry association. 2012. Denmark – Wind power hub. Profile of the Danish wind industry. (Referenced 1 April 2016). Available: http://power-cluster.net/Portals/6/Denmark%20-%20Wind%20Power%20Hub_%20InvestinDK_DWIA_Jan2011.pdf

Danish wind industry association. 2015. Midtvind. A supplier network. (Referenced 1 March 2016). Available: http://ipaper.ipapercms.dk/Windpower/Midtvindasuppliernetwork/

Davila, T. Epstein, M. 2014. The innovation paradox: Why good businesses kill breakthroughs and how they can change. Berrett-koehler publishers. (Referenced 23 January 2016). Available: http://site.ebrary.com.aineistot.lamk.fi/lib/lamk/reader.action?docID=10879089

Delucchi, M. Jacobson, M. 2013. Meeting the world's energy needs entirely with wind, water and solar energy. Bulleting from Atomic Scientist. (Referenced 1 November 2016). Available: http://web.a.ebscohost.com/ehost/pdfviewer/pdfviewer?sid=5db3c270-0c50-47bc-8fc0-1f8d96978a48%40sessionmgr4002&vid=1&hid=4101

Department of Energy. 2008. 20% of Wind energy by 2030. Increasing wind's energy's contribution to the U.S. Electricity supply. Available: http://www.nrel.gov/docs/fy08osti/41869.pdf

Drexhage, J. Murphy, D. 2010. Sustainable Development: From Brundtland to Rio 2012. Background paper. United Nations Headquarters, New York. (Referenced 5 February 2016). Available: http://www.un.org/wcm/webdav/site/climatechange/shared/gsp/docs/GSP1-6_Background%20on%20Sustainable%20Devt.pdf

ELFEC. 2014. Wind energy and renewable energies: Bolivia extent wind park with Chinese turbines. (Referenced 21 April 2016). Available: http://www.elfec.com/noticias/eolica-y-energias-renovables-bolivia-amplia-parque-eolico-con-aerogeneradores-chinos

Ende corporacion (ENDE). 2015. Proyecto eolico Qollpana fase II. (Referenced 20 April 2016). Available: http://www.ende.bo/NewProyectos/resena/proyecto-eolico-de-energia-renovable-qollpana-fase-ii

Energinet.dk. 2014. Electricity facility. Structure of the electricity grid. (Referenced 22 March 2016). Available: http://www.energinet.dk/EN/ANLAEG-OG-PROJEKTER/Generelt-om-elanlaeg/Sider/default.aspx

Energinet.dk. 2014. Electricity interconnections. (Referenced 22 March 2016). Available: http://www.energinet.dk/EN/ANLAEG-OG-PROJEKTER/Generelt-om-elanlaeg/Sider/Elforbindelser-til-udlandet.aspx

Energinet.dk. Wind power. To combat climate change. How to integrate wind energy into the power system. (Referenced 22 March 2016). Available: http://energinet.dk/SiteCollectionDocuments/Engelske%20dokumenter/Klimaogmiljo/Wind%20power%20magazine.pdf

Energy department. 2015. Wind energy basics. Office of energy efficiency and renewable energy. (Referenced 20 March 2016). Available: http://energy.gov/eere/wind/wind-energy-basics

European comission. 2014. Renewable energy. (Referenced 8 December 2015). Available: http://ec.europa.eu/energy/en/topics/renewable-energy

Environmental law policy. 2003. Environmental control and prevention. Bolivian Law Legislation. (Referenced 10 April 2016). Available: http://biblioteca.unmsm.edu.pe/redlieds/Recursos/archivos/Legislacion/Bolivia/reglamento_prevencion.pdf

European comission. 2015. Europe 2020 targets. (Referenced 28 November 2015). Available: http://ec.europa.eu/europe2020/europe-2020-in-a-nutshell/targets/index_en.htm

EU. 2010. 2020 Climate and energy package. European commission. (Referenced 10 March 2016). Available: http://ec.europa.eu/clima/policies/strategies/2020/index_en.htm

European commission. 2015. Research and innovation energy. Wind energy. (Referenced 15 March 2016). Available: http://ec.europa.eu/research/energy/eu/index_en.cfm?pg=research-wind

European wind Energy association (EWEA). 2015. How a wind turbine works. (Referenced 6 March 2016). Available: http://www.ewea.org/wind-energy-basics/how-a-wind-turbine-works/

European wind energy association (EWEA). 2015. Wind energy facts and wind energy FAQs. (Referenced 15 February 2016). Available: http://www.ewea.org/uploads/pics/EWEA_Wind_energy_factsheet.png

http://www.ewea.org/wind-energy-basics/faq/

European wind energy association. 2009. The economics of wind energy. A report by the European Wind Energy Association (EWEA). (Referenced 24 February 2016). Available: http://www.ewea.org/fileadmin/files/library/publications/reports/Economics_of_Wind_Energy.pdf

European Wind Energy Association (EWEA). 2015. Wind in power: 2014 European Statistics. (Referenced 9 February 2016). Available: http://www.ewea.org/fileadmin/files/library/publications/statistics/EWEA-Annual-Statistics-2014.pdf

Foundation for water and energy education. 2015. How wind turbines generate electricity. (Referenced 12 November 2015). Available: http://fwee.org/nw-hydro-tours/how-wind-turbines-generate-electricity/

G-Cube. 2016. Top 10 causes for wind turbine failure. (Referenced 29 March 2016). (Referenced 5 April 2016). Available: http://www.gcube-insurance.com/en/uncategorized/top-10-causes-for-turbine-failure/

Heal, G. 2009. The economics of renewable energy. National Bureau of Economic Research. NBER Working Papers Series No. 15081. (Referenced 19 December 2015). Available: http://www.nber.org/papers/w15081

Herrmann, M. 2014. The challenge of sustainable development and imperative of green and inclusive economic growth. Modern Economy. Scientific research. Avaialable: http://search.proquest.com/docview/1504176487/fulltextPDF/97D5121187C64173PQ/7?accountid=16407

Hill, R. Stinebaugh, J. Briand, D. Benjamin, A. Linsday, J. Ares Corporation. 2008. Wind turbines reliability: A database an analysis approach. Sandia National Laboratories. (Referenced 29th March 2016). Available: http://windpower.sandia.gov/other/080983.pdf

Instituto nacional de estadistica. 2012. Bolivia caracteristicas de poblacion y vivienda. Censo nacional de población y vivienda 2012. (Referenced 7 May 2016). Available: http://www.ine.gob.bo:8081/censo2012/PDF/resultadosCPV2012.pdf

Intergovermental panel on climate change (IPCC). Climate Change 2007. Synthesis Report. (Referenced 5 December 2015). Available: https://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm

International energy agency. 2013. Danish Energy Agreement for 2012-2020. (Referenced 8 February 2016). Available: http://www.iea.org/policiesandmeasures/pams/denmark/name-42441-en.php

International energy agency. 2008. World energy outlook. (Referemced December 7 2015). Available: https://www.iea.org/media/weowebsite/2008-1994/WEO2008.pdf

International union for conservation of nature and natural resources (IUCN). 1980. World conservation Strategy. Living resource conservation for sustainable development. (Referenced 15 March 2016) Available: https://portals.iucn.org/library/efiles/edocs/WCS-004.pdf

Iowa Energy Center. 2016. Calculating the cost per kWh. (Referenced 1 March 2016). Available: http://www.iowaenergycenter.org/wind-energy-manual/wind-energy-economics/calculating-the-cost-per-kwh/

Karani, P. Jewasikiewitz, M. Stan. 2006. Waste management and sustainable development in South Africa. Environment, development and sustainability. 2006. (Referenced 11 December 2015). Available: http://search.proquest.com/docview/219572101/F67C10FA41D54B42PQ/1?accountid=16407

Kareem, S. Kari, F. Alam. Chukwu, M . David, O. Oke, O. 2012. Foreign Direct Investment and environmental degradation of oil exploitation: The experience of Niger Delta. The International Journal of Applied Economics and Finance. Vol. 4, pp. 117-126. (Referenced 18 December 2016). Available: http://search.proquest.com.aineistot.lamk.fi/docview/1399694764/fulltextPDF/FA29DB58D30A46BDPQ/5?accountid=16407

Larsen, H. Petersen, L. 2014. Wind energy-drivers for highger shares in the global power generation mix. DTU International energy report 2014. DTU National laboratory for sustainable energy. (Referenced 1 February 2016) Available: file:///C:/Users/DiegoPC/Downloads/DTU-INTL-ENERGY-REP-2014-WIND%20(2).pdf

Lloyd's register energy. 2016. Introducing the top 30 chart from LR, ranking wind turbine failures by probability and consequence. (Reference 1 April 2016) Available: http://info.lr.org/top-30-wind-turbine-failures

Megavind. 2013. The Danish wind power hub. Strategy for research, development and demonstration. (Referenced 1 April 2016). Available: http://www.ens.dk/sites/ens.dk/files/ny-teknologi/1.pdf

Ministry of hydrocarbon and Energy. 2014.Opening of the first wind park in Bolivia. Plurinational State of Bolivia. (Referenced 12 April 2016).

Available:
http://www2.hidrocarburos.gob.bo/index.php/prensa/noticias/745-se-inaugura-el-primer-parque-eolico-en-bolivia.html

Ministry of hydrocarbon and energy. 2013. Implementation of electricity generation diversify the electric grid. Plurinational State of Bolivia. (Referenced 12 April 2016). Available:
http://www2.hidrocarburos.gob.bo/index.php/prensa/noticias/451-la-implementaci%C3%B3n-de-generaci%C3%B3n-el%C3%A9ctrica-e%C3%B3lica-diversifica-la-matriz-energ%C3%A9tica-y-cumple-con-el-plan-nacional-de-desarrollo.html

Ministry of hydrocarbon and energy. 2009. Development plan of Energy. Plurinational State of Bolivia. (Referenced 10 April 2016). Available:
http://www2.hidrocarburos.gob.bo/phocadownload/PLAN%20DE%20DESARROLLO%20ENERG%C3%89TICO.pdf

Ministry of hydrocarbon and energy. 2014. Electric plan for the Plurinational State of Bolivia 2025. Plurinational State of Bolivia. Viceminister of electricity and alternative energies. (Referenced 14 April 2016). Available:
file:///C:/Users/DiegoPC/Downloads/PLAN%20ELECTRICO%20DE%20BOLIVIA%20%202025%20(1).pdf

Ministry of hydrocarbon and energy. 2012. Plan to optimize the internconnected system 2012-2022. Plurinational State of Bolivia. (Referenced 16 April 2016). Available:
http://www2.hidrocarburos.gob.bo/phocadownload/Plan%20de%20Expansi%C3%B3n%20del%20SIN%202012-2022.pdf

Morales, E. 2009. Decreto Supremo No 29894. Estructura organizativa del Poder Ejecutivo del Estado Plurinacional. Mnisterio de hidrocarburos y energía. (Referenced 12 April 2016) Available:
http://www2.hidrocarburos.gob.bo/index.php/viceministerios/electricidad-y-energias-alternativas.html

Morales, E. 2008. National program of energy efficiency. Supreme decree No. 29466. (Referenced 19 April 2016). Available: http://www.ae.gob.bo/userfiles/file/pdf/ml/29466.pdf

Moriarty, J. 2011. A theory of Benchmarking. Benchmarking: An international journal. Vol. 18. No 4. (Referenced 4 January 2016). Available: http://web.a.ebscohost.com.aineistot.lamk.fi/ehost/command/detail?sid=b132b206-830d-462d-9854-9d4ed48930c0%40sessionmgr4001&vid=6&hid=4104

Morthorst, P. Gonzales, J. Schröder, S. 2014. Wind Energy – drivers and barriers for higher shares of wind in the global power generation mix. International Energy Report 2014. Technical University of Denmark. (Referenced 10 March 2016). Available: http://orbit.dtu.dk/files/102458426/DTU_INTL_ENERGY_REP_2014_WIND_79_85.pdf

National Aeronautics and Space Administration (NASA), Goddard Institute for Space Studies. 2016. Global Temperature, meteorological stations. (Referenced 7 March 2016). Available: http://data.giss.nasa.gov/gistemp/graphs_v3/Fig.A.pdf

National Electricity Enterprise (ENDE). 2015. Presentation. (Referenced 10th April 2016). Available: http://www.ende.bo/bienvenida

National oceanic and atmospheric administration. 2016. Global monthly mean CO2. U.S. Department of Commerce/NOAA Research. (Referenced 7 March 2016) Available: http://www.esrl.noaa.gov/gmd/ccgg/trends/global.html

Nelson, J. 2008. Guru interview: Robert Camp. Emeral group publishing limited. (Referenced 15 January 2016). Available: http://www.emeraldgrouppublishing.com/learning/management_thinking/interviews/pdf/camp.pdf

Oke, A. 2007. Innovation types and innovation management practices in service companies. International journal of operation and production management. Vol. 27. No. 6. (Referenced 14 January 2016). Available: http://www.emeraldinsight.com.aineistot.lamk.fi/doi/pdfplus/10.1108/01443570710750268

Perez, J. Marquez Garcia, P. Tobias, A. Papaelias, M. 2013. Wind turbine reliability analysis. Renewable and sustainable energy reviews. Vol 23. (Referenced 27 March 2016). Available: http://ac.els-cdn.com/S1364032113001779/1-s2.0-S1364032113001779-main.pdf?_tid=bf70adcc-ef65-11e5-853b-00000aacb360&acdnat=1458565778_34fff58c3c24054437fe73f7af03ee9e

Plurinational State of Bolivia. 2011. Politica de energias alternativas para el sector electrico en el estado Plurinacional de Bolivia. (Referenced 15 December 2015). Available: http://www2.hidrocarburos.gob.bo/phocadownload/politicas_energias_alternativas_2011.pdf

Runyon, J. 2015. Digging deeper why renewables are beating coal and gas in some parts of the world. Renewable energy world. (Referenced 2 December 2015). Available: http://www.renewableenergyworld.com/articles/2015/10/digging-deeper-why-renewables-are-beating-coal-and-gas-in-some-parts-of-the-world.html

Sadorsky, P. 2014. The effect of urbanization and industrialization on energy use in emerging economies. Implications for sustainable development. American Journal of economics and sociology. Vol 73 issues 2. (Referenced 28 December 2015). Available: http://web.b.ebscohost.com/ehost/pdfviewer/pdfviewer?sid=fddac1ff-92d9-4385-a963-e2ce843ffaff%40sessionmgr113&vid=4&hid=105

Sathaye, J. Lecocq, F. Masanet, E. Najam, A. Schaeffer, R. Swart, R. Winkler, H. 2008. Opportunities to change development pathways toward lower greenhouse gas emissions through energy efficiency. Energy Efficiency. 2009. Vol 2. (Referenced 28 November 2015). Available:

http://search.proquest.com/docview/220392556/49E836B863DF42EEPQ/1?accountid=16407

Scott, R. 2011. Benchmarking: A literature review. Academic excellence, Center for learning and development. Edith Cowan University. (Referenced 15 January 2016). Available: https://intranet.ecu.edu.au/__data/assets/pdf_file/0010/357193/Benchmarking-Literature-Review.pdf

Sekhar, S. 2010. Benchmarking. African Journal of business management. Vol. 4. (Referenced 20 January 2016). Available: http://search.proquest.com.aineistot.lamk.fi/docview/1663912331/fulltextPDF?accountid=16407

Soubbotina, T. 2004. Beyond economic growth: an introduction to sustainable development. The World Bank. 2nd edition. (Referenced 1 march 2016) Available at: http://www.worldbank.org/depweb/english/beyond/beyondco/beg_all.pdf

Spinato, T. Van Bussel, G. Koutoulakos, E. (2003). Reliability of wind turbine concepts with relevance to offshore application. Wind energy research group. (Referenced 25 March 2016). Available: http://www.wind-power-program.com/Library/Reliability%20papers/Offshore%20reliability%20paper%20by%20Tavner%20et%20al.pdf

State of Green. 2015. The political framework. State of Green. Join the future. Think Denmark. (Referenced 1 February 2016). Available: https://stateofgreen.com/en/profiles/state-of-green/solutions/state-of-green-the-political-framework

State of Green. 2016. The largest onshore windfarm in Denmark. State of Green. Join the future. Think Denmark. (Referenced 23rd February 2016). Available: https://stateofgreen.com/en/profiles/energy2020/solutions/the-largest-onshore-windfarm-in-denmark

State of Green. 2016. Wind turbines. Denmark has all the components needed throughout the entire wind power value chain. (Referenced 1 April 2016). Available: https://stateofgreen.com/en/sectors/wind-energy/wind-turbines?gclid=Cj0KEQjw2_23BRDb_qbvzK3X8M8BEiQAg87AFx5ksL02AlH4cCbNw8pIkcxf70nLLSgCa8BI-S5MkkcaAvKn8P8HAQ

Suryanarayana, R. Srinivasa B. 2012. Corporate social responsibility and sustainable environmental development. International journal of applied financial management perspectives. Vol. 1. (Referenced 25 January 2016). Available: http://search.proquest.com/docview/1648648471/F67C10FA41D54B42PQ/2?accountid=16407

The Danish Government. 2011. Energy Strategy 2050. From coal, oil and gas to green energy. (Referenced 16 February 2016). Available: http://www.efkm.dk/sites/kebmin.dk/files/news/from-coal-oil-and-gas-to-green-energy/Energy%20Strategy%202050%20web.pdf

The Danish Parliament. 2008. Promotion of renewable energy act. (Referenced 15 December 2015). Available: http://www.ens.dk/sites/ens.dk/files/supply/renewable-energy/wind-power/onshore-wind-power/Promotion%20of%20Renewable%20Energy%20Act%20-%20extract.pdf

The wind power. 2016. Wind park Qollpana (Bolivia). (Referenced 21 April 2016). Available: http://www.thewindpower.net/windfarm_es_21057_qollpana.php

Tverberg, G. 2012. An alternative theory for the world's limited oil supply. Economy watch. (Referenced 1st June 2016). Available: http://www.economywatch.com/economy-business-and-finance-news/an-alternative-theory-for-the-worlds-limited-oil-supply.29-10.html

The World Bank. 2014. Bolivia – Access and renewable energy project (English). Report NO. PAD856. (Referenced 25 November 2016). Available: http://www.worldbank.org/projects/P127837?lang=en

UNCTAD. 1997. World investment report: Transnational Corporations, market structure and competition policy. United Nations, New York and Geneva. (Referenced 10 March 2016). Available: http://unctad.org/en/Docs/wir1997_en.pdf

United Nations. 2012. Social indicators. Population growth and distribution. (Referenced 19 March 2016). Available: http://unstats.un.org/unsd/demographic/products/socind/

United Nations. 2014. Framework convention on climate change. UN. (Referenced 18 March 2016). Available: http://unfccc.int/kyoto_protocol/items/2830.php

United Nations. 2012. The Future We Want. RIO+20 United Nation Conference on Sustainable Development. (Referenced 1 March 2016). Available: https://sustainabledevelopment.un.org/content/documents/733FutureWeWant.pdf

U.S. Department of Energy. 2014. Plug-in Hybrid and Zero Emission Light-Duty Vehicle Rebate. USA gov. (Referenced 25 November 2015). Available: http://www.afdc.energy.gov/laws/8161

U.S. energy Information administration. 2015. Gasoline use constributes to air pollution. (Referenced 20 November 2015). Available: http://www.eia.gov/Energyexplained/?page=gasoline_environment#tab1

Vestas wind systems A/S. 2016. Turbines V112-3.45 MW. (Referenced 23 February 2016). Available: https://www.vestas.com/en/products_and_services/turbines/v112-3_3_mw#!at-a-glance

Vestas wind systems. 2MW Platform. (Referenced 24 March 2016). Available: http://nozebra.ipapercms.dk/Vestas/Communication/Productbrochure/2MWbrochure/2MWProductBrochure/

Vrontis, D. Papasolomou, I. 2007. Brand & Product Building: The case of Cyprus wine industry. Journal of prduct and brand management. Vol. 16. (Referenced 2 January 2016). Available: http://web.b.ebscohost.com.aineistot.lamk.fi/ehost/command/detail?sid=2db9b8c4-4eee-41ea-8ece-f92bb9acb81f%40sessionmgr115&vid=5&hid=115

Vu, T. B., Foreign direct investment and endogenous growth in Vietnam. Applied Economy. (Referenced 29 December 2015). Available: http://www.tandfonline.com/doi/abs/10.1080/00036840600749433

Wagner, M. 2012. Entrepreneurship, innovation and sustainability. Greenleaf publishing. (Referenced 1 February 2016). Available: http://site.ebrary.com.aineistot.lamk.fi/lib/lamk/reader.action?docID=10650065

Warnecke, T. 2015. Greening gender equity: Microfinance and the sustainable development agenda. Journal of economic issues. Vol. XLIX. No2. (Referenced 26 December 2015). Available: http://web.b.ebscohost.com/ehost/pdfviewer/pdfviewer?sid=4f70c2c6-fdc6-45d9-a1d7-2b81d190ec01%40sessionmgr111&vid=1&hid=128

Witkowska, J. 2011. Foreign direct investment and sustainable investment in the new EU member states: Environmental aspects. Comparative economic research. (Referenced 15 December 2015). Available: http://search.proquest.com.aineistot.lamk.fi/docview/1321426978/3F300BEB9EF04F18PQ/4?accountid=16407

Wober, K. 2002. Benchmarking in tourism and hospitality industries. CABI Publishing. (Referenced 25 January 2016). Available:

http://site.ebrary.com.aineistot.lamk.fi/lib/lamk/reader.action?docID=10060467

World Commission on Environment and Development. 1987. Our Common Future. Oxford: Oxfortd University Press. (Referenced 10 December 2015). Available: http://www.un-documents.net/our-common-future.pdf

Yang, Z. Dong, W. Xiu, J. Dai, R. Chou, J. 2015. Structural path analysis for CO2 emissions: A case study for China. Plos One. (Referenced 20 November 2015). Available: http://web.a.ebscohost.com.aineistot.lamk.fi/ehost/pdfviewer/pdfviewer?sid=15e40733-802f-4ffb-9bcc-821dae115c64%40sessionmgr4001&vid=1&hid=4204

Zaman, G. 2012. Ways of improving foreign direct investment (FDI) contribution to sustainable development. Annales Universitatis Apulensis Series Oeconomica. (Referenced 20 December 2015). Available: http://search.proquest.com/docview/1314736379/fulltextPDF/595C0359755948F5PQ/3?accountid=16407

Oral references

Bizet, B. 2016. Special Advisor. Danish Energy Agency. Interview 10 March 2016.

Hario, S. 2016. Director. Lumituuli Oy. Interview 22 March 2016.

Ponce, J. 2016. Operation Manager. Corani S.A. Interview 12 April 2016.

Markus, R. 2016. Maintenance Manager. Corani S.A. Interview 13 April 2016.

Rehfeldt. D. 2016. Ingineer. Corani S.A. Interview 15 April 2016.

APPENDICES

APPENDIX 1. Danish energy policy Agreement 2009

Energy Policy Agreement 2008
Renewable energy law: - A renewable energy law is gathered, which entails national target for overall municipal planning, subsidies for renwable energy plan, compensation scheme, guarantee fund, and a model of local joint ownership. **Planning wind turbines:** - Municipalities should reserve areas for wind turbines with an output of 150MW and a height up to 150 meters for the years 2010 and 2011. This includes a green fund and a guarantee fund of 1,5 million $ for financing local wind turbines, which is financed by PSO (Public Service Obligation). In addition, the owners of the wind turbines are compensated for their contribution to the green fund by an increased subsidy per kWh.
Compensation scheme: - Compensate neighbors of new wind turbines for loss of property due to the installation. This loss is paid by the wind turbines owner, although the compensation may not proceed if the sum is less than 1% of property value. - The compensation responsibility is a principle of the right to compensation with a concrete evaluation of the loss of property value. - Such compensation should be calculated by an authority.
Subsidies: - The subsidy of a new wind turbine should be raised to 0.4 c$/kWh for 22000 peak load hours, plus 0.04 c$/kWh for cost balancing and 0.1

c$/kWh to the green fund.

- Turbines unders scrapping scheme are given an extra 0.12c$/kWh for the first 22000 peak load hours.
- Green scheme: this subsidy is granted to municipalities in order to support the landscape and recreational areas in terms of cultural and information activities. The scheme includes about DKK 200,000 per turbine depending upon its size. (DEA 2015).
- Guarantee fund: this scheme is granted as a guarantee for loans by local groups. Such guarantee acts as a security for groups of citizens to support in areas of decision making, whether to erect a wind turbine and investigate the area. The guarantee is paid whether the project is not implemented or the loan cannot be repaid. (DEA 2015)

Appendix 2. Interview - Danish Energy Agency

- Does the Danish Energy Agency have any responsibilities on onshore wind turbines?
- How does Denmark give priority to wind energy while producing at the same time, electricity from other sources? Any type of priority depending upon the price of electricity?
- What are the challenges and opportunities of connecting the turbines with the electricity grid?
- Would you consider the levelized Cost of Energy (LCoE) a good method to evaluate the production cost per kWh?
- What are the economic pitfalls of generating electricity from wind turbines?
- In comparison with private firms, how does Denmark support wind energy activities?
- Denmark follows an evaluation of wind turbines through Environmental Impact Assessment (EIA) has there been any difficulties during the planning, construction, operation of decommissioned of the project? If so, could you please share what the problem was and how the government faced the problem?
- How does Denmark handle human-being interaction with wind farms? How does it reduce the problems regarding land, noise and CO2?
- Is there any other entity or country by which Denmark receives support from?
- Are the Danish citizens satisfied with the services that wind turbines have provided? Any negative aspects that influenced the public?
- How do you see the future of wind energy in Denmark? Any critical points to focus?
- What is the future for onshore wind turbines?

APPENDIX 3. Calculation of the costs per kWh in Denmark

$$Annual\ cost = \frac{I}{\mathrm{T}} + O\&M$$

$$Cost\ of\ energy = \frac{AC}{\mathrm{AEP}}$$

Where:

I = Investment cost

T = Expected life time of the turbine

O&M = Annual Operation & Maintenance

AC = Annual Cost

AEP = Annual Energy Production

Specification of turbines:

Turbine manufacturer: NEG Micon

Turbine model: NM 2000

Capacity: 2000

Date of connection to grid: 12.08.1999

Total production of energy in 2014: 3216 kWh

Total production of energy in 2015: 3320 kWh

$$Annual\ Cost = \frac{1350}{20} + 643 = 710{,}5$$

$Cost\ per\ kWh = \frac{710{,}5}{3320} = \ 0{,}214$ c€/kWh

Turbine Manufacturer: Siemens

Turbine model: SWT 2,3-93

Capacity: 2300 kWh

Date of connection to grid: 31.10.2011

Total production of energy in 2014: 6032 kWh

Total production of energy in 2015: 7041kWh

$$Annual\ Cost = \frac{1350}{20} + 603 = 670{,}5$$

$Cost\ per\ KWh = \frac{670{,}5}{7041} = 0{,}095$ c€/kWh

Turbine Manufacturer: Siemens

Turbine model: SWT 3.6-120

Capacity: 3600 kWh

Date of connection to grid: 10.03.2011

Total production of energy in 2014: 12393 kWh

Total production of energy in 2015: 13877 kWh

$$Annual\ Cost = \frac{1350}{20} + 1239 = 1306{,}5$$

$$Cost\ per\ kWh = \frac{1306{,}5}{13877} = \ 0{,}0941\ c€/kWh$$

Turbine manufacturer: Vestas

Turbine model: V112-3.0MW

Capacity: 3075 kWh

Date of connection to grid: 28.06.2013

Total production of energy in 2014: 10045

Total production of energy in 2015: 11357

$$Annual\ Cost = \frac{1350}{20} + 1004{,}5 = 1072$$

$Cost\ per\ kWh = \frac{1072}{11357}$ = 0,0943 c€/kWh

APPENDIX 4. Lumituuli Oy – Interview

1. What were early failures that your turbines faced?
2. What component has faced most failures?
3. What component causes most of the downtime?
4. What is downtime rate of your turbine when diagnosing the failure, gathering repair equipment, and repairing and restarting the wind turbine?
5. Does larger and newer turbine cause more failures comparing shorter turbines? What were these failures?
6. How often a failure occurs?
7. How is maintenance being carried out?
8. How does the supply of new components work? In case some components need to be replaced
9. How do you consider the failure rates of your turbine related to weather conditions, temperature and humidity?
10. Considering that wind does not always blow, is wind power a reliable source of electricity generation on demand?

APPENDIX 5. Calculation of the cost per kWh in Bolivia

$$Annual\ cost = \frac{I}{\mathrm{T}} + O\&M$$

$$Cost\ of\ energy = \frac{AC}{\mathrm{AEP}}$$

Where:

I = Investment cost

T = Turbine lifetime

O&M = Operation & Maintenance cost

AC = Annual cost

AEP = Annual Electricity Production

Specification of the turbines:

Turbine manufacturer:

Turbine model: Enercom

Capacity: 3MW

Date of connection to grid: 02.01.2016

Total production of energy in 2016: 6570

$$Annual\ cost = \frac{1580}{20} + 644 = 723$$

$Cost\ of\ energy = \frac{723}{6570}$ = 0.11 c€/kWh

Turbine manufacturer: Hydrochina Corporation

Turbine model: Gold Wind WTG77

Capacity: 1.5 MW

Date of connection to grid: 02.01.2014

Total production of energy in 2015: 2840

$$Annual\ cost = \frac{2192}{20} + 644 = 753.6$$

$Cost\ of\ energy = \frac{753.6}{2840} = 0.265$ c€/kWh

APPENDIX 6. Interview - Corani S.A.

What is the mission of corani S.A.?

What are the positives aspects of a regulated system?

How do you consider the functionality of wind turbines?

Who can supply new components in case of replacement of new components of wind turbines?

When will Enercom turbines be concluded to begin with the production of electricity?

Who becomes the second supplier for the Qollpana Wind Park? And for how long can they supply new components?

What happens after the two years training provided by Hydrochina Corporation, and five years training by Enercom to local techniquians?

APPENDIX 7. Interview – Corani S.A.

In terms of electricity, how is Bolivia connected?

What are the connection lines that exist currently in Bolivia?

Which connection line has caused failure? And what happened?

What is the distance of the connection lines from the turbines to the regulated system?

What was the main reason why Bolivia entered the wind energy industry?

What is missing in Bolivia? How can the industry grow?

Appendix 8. Interview – Corani S.A.

What is the main disadvantage of generating wind energy in Bolivia? What could be the possible solution for this?

What is your opinion regarding the current situation of the wind energy industry in Bolivia compared to other markets?

Do you consider as an option to implement a connection plan with foreign markets?

What is the advantage that Bolivia has in the maintenance and operations of the turbines?