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BUILDING A WIND POWER PROJECT DEVELOPMENT PORTFOLIO

A Case Study in Ghana

Technology and Communication 2020

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I wish to express my greatest gratitude to my supervisor, Professor Adebayo Agbejule, who guided me through the studies by providing the paths to find the motivation and the knowledge to achieve the ultimate objective.

Thank you, fellow students, for your support and encouragement when the time was not on our side.

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In Vaasa 31.7.2020

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TIIVISTELMÄ

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Tuoreimpien tutkimustietojen mukaan portfoliopäälliköt eivät saa portfoliotaan menestymään, vaikka yksittäiset projektit suoriutuvat tavoitteissaan. Työn tavoitteena oli tutkia projektiportfolion hallinnan teoriaa ja sen hyödyntämismahdollisuuksia käytännössä, tuulivoiman projektikehityksen projektiportfolion rakentamisessa ja lopulta kehittää toteuttamiskelpoinen projektiportfolio.

Ongelmaa tutkittiin laadullisen tapaustutkimuksen näkökulmasta, jossa käsiteltiin yhtä tapausta ’uutta löytävällä’ (exploratory) ja teoriaa testaavalla lähestymistavalla. Projekti- ja portfoliohallinnan taustat selvitettiin laajasti soveltuvan kirjallisuuskatsauksen avulla. Tapaustutkimuksen pohjatietona käytettiin paikkatietoaineistoa, jota käsiteltiin eri paikkatietoanalyysien avulla.

Tuloksena havaittiin yhteys teorian ja organisaation hallinnan ja strategian välillä sekä havaittiin portfolion hajautuksen tärkeys. Tuloksena esitettiin myös 12 projektin tuulivoiman projektikehitysportfolio, joka sijoittui ympäri kohdemaa Ghanaa.

Tutkimus rajoittuu raportointihetkellä saatavilla olleeseen aineistoon ja lähdemateriaaliin. Tapaustutkimusta ei käsitelty taloudellisesta näkökulmasta eikä varsinaista toteutettavuusselvitystä tehty. Tuloksena esitettiin kaupallisille toimijoille lähtökohdat kansallisen uusiutuvan energian tuotannon tiekartan toteuttamiseksi ja paikallisille viranomaisille mahdollisuudet markkinoida omien alueidensa tuulivoimapotentiaalia kansallisen strategian toteuttamiseksi. Kansallinen verkon haltija voi myös soveltaa tuloksia heikoimpien alueiden verkon vakauttamisessa.

Avainsanat portfolion hallinta, projektin hallinta, tuulivoima, projektin kehitys

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ABSTRACT

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Recent literature has demonstrated that portfolio managers seem to fail with their portfolios even though individual projects within the portfolios are well-performing. The objective of this thesis was to explore the theory behind the project portfolio management and to find the ways to implement the findings into the practical wind power project development portfolio creation and ultimately propose a feasible project portfolio.

The problem was approached from the case perspective as a qualitative single case study with characteristics of exploratory research and theory testing. The literature was reviewed thoroughly to get the applicable understanding of the context of project and portfolio management. In the case study, the spatial databases were gathered and analyzed with a set of geoprocessing tools.

As a result, the link between the theory and the organizational management and strategy was found and the importance of the portfolio diversification was discovered. The effect of the sensitivity analysis of the feasibility study was determined as the greatest single risk factor of the project portfolios. Moreover, the wind power project development portfolio of 12 projects all around the target country Ghana was presented.

The study was restricted to the data available and referenced at the moment of reporting. The financial aspects were not considered, and no feasibility analysis was made for the case study. The results presented a premise for commercial stakeholders to start fulfilling the roadmap for the demands of national renewable energy generation and for the local officials the possible areas for marketing their wind power potential to accomplish the national strategy. Moreover, the national grid operator can utilize the results in improving grid stability in the weak spots of the grid.

Keywords Portfolio management, project management, wind power, project development

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ABBREVIATIONS

BoP	Balance of Plant
CFD	Computational Fluid Dynamics
ECOWAS	Economic Community of West African States
ECREEE	ECOWAS Observatory for Renewable Energy and Energy Efficiency
EIA	Environmental Impact Assessment
EPC	Engineer, Procure, Construct -agreement
EYA	Energy Yield Assessment
GIS	Geographical Information System
GPRS	Ghana Poverty Reduction Strategy
GWEC	Global Wind Energy Council
IEC	International Electrotechnical Commission
IRENA	International Renewable Energy Association
LiDAR	Light Detection and Ranging Device
MCP	Measure-Correlate-Predict
Measnet	International Network for Harmonised and Recognised Measurements in Wind Energy
PM	Project Management
PMBOK Guide	A Guide to the Project Management Body of Knowledge
PMI	Project Management Institute Inc.
PPM	Project Portfolio Management

PRINCE2	Projects in a Controlled Environment
SFS	Finnish Standards Association
SoDAR	Sonic Detection and Ranging Device
WAsP	Wind Atlas Analysis and Application Program
WFS	Web Feature Service
WMS	Web Map Service

1 INTRODUCTION

Where project management (PM) has been practiced from the early ages starting with the construction of Giza Pyramids and the Great Wall of China to name a couple and started to get recognized as a profession by the mid-20th century (PMI, 2017). Much younger field of study is the project portfolio management (PPM) concept. Within the last three decades the portfolio management has been expanding within the finance sector (Baker and Filbeck, 2013) and it has been standardized and utilized by the project driven organizations within the last two decades around the globe. However, despite the extensive variety of tools to implement the theory into practice, the organizations seem to fail to succeed on the portfolio level even if the single project execution is succeeding just fine. The problems such as resource sharing within the portfolio as well as repetitive changes in the portfolio's projects occur even if the managers are keen to follow the standardized frameworks (Martinsuo, 2012).

The recent literature indicates that the reason for the underperforming project portfolios lies in the managers' misunderstanding of the practice and context. The knowledge and resource sharing should be key elements for the project portfolio success creation, but the information is not passing throughout the organizations on what the managers actually do and how the conditions evolve during the project life cycles. At the same time, the project managers have their individual success goals to meet while optimizing the project resources. Concentrating on optimizing the individual projects may turn out as well-performing project portfolio but the capability and technology synergies that could be gained are not utilized. (Martinsuo, 2012)

But what is a successful project and how should one measure it? Different stakeholders may have different insights about the key successful indicators – some may prefer measuring the project objectives that are achieved or that are not. Traditionally the metrics of the project success are time, cost, scope and quality that are interconnected as presented in **Figure 1** below. (PMI, 2017)

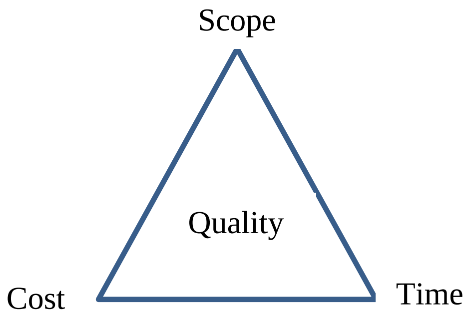

Figure 1. The Traditional Project Management Success Measures (own elaboration).

In this research, the project management success measures are studied on a portfolio level in the specific field of wind power project development. The ultimate goal is not only to understand the possibilities of the wind power project development portfolio as a business case but also to bring the understanding about the possibilities of the renewable energy projects in the developing countries.

As a preview to the wind power industry, the total installed wind power capacity has been growing steadily for several years. The compound annual growth rate from 2014 to 2019 has been 12 % as presented in **Figure 2** below, thus there is an existing trend for the future growth of the capacity. (Irena, 2020)

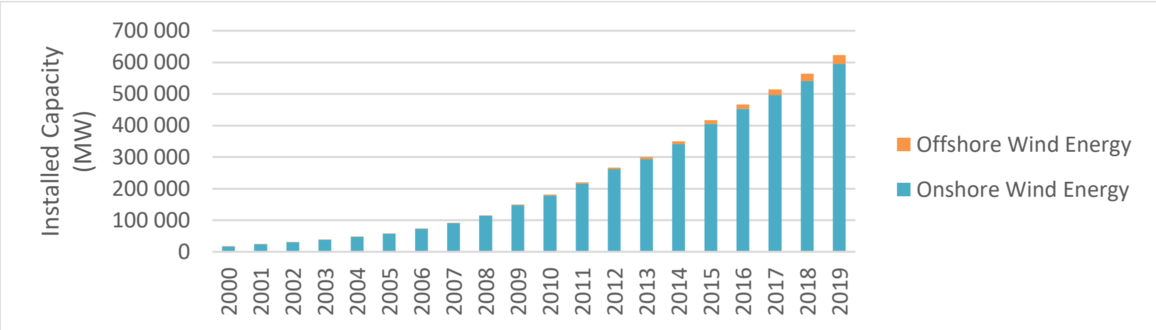

Figure 2. Cumulative Globally Installed Wind Energy Capacity (Irena, 2020).

The case study presents the country Ghana, one of the Africa's most stable economy, with its challenges of providing affordable electricity throughout the country (CIA, 2020). The current electricity generation and consumptions are described as a background to the demand for new implementation of the power plants and the electricity grid as well. The country analysis of the wind power project development possibilities is made based on the most recent literature and the databases. The result presents the idea of a feasible project portfolio in the case study country.

2 PURPOSE OF THE RESEARCH

This research aims to find the main strengths and weaknesses in the project portfolio management when creating a new wind power project development portfolio in the studied market area. The study is founded on the recent literature about the PPM context and specifically the wind power studies made about the studied market area.

The goal is to answer the following research questions:

> RQ1. In what way the project portfolio management theory shall be implemented to the wind power project development portfolio?
>
> RQ2. How does the wind power project development portfolio look like in the case study market area?

The main source for the literature is the recent articles published in the International Journal of Project Management and the latest standards within the area of project management (PMI, 2017; SFS, 2012). Additionally, latest articles from other journals are studied as well.

For the case study section, there are previously made case studies as the reference for the project portfolio creation. Otherwise the data is collected from the literature together with the open data sources related e.g. geographical information systems.

The study includes literature review with the conceptual qualitative case study research. The focus is on the successful theory implementation to the real-life case study. **Figure 3** shows the theoretical framework of the study.

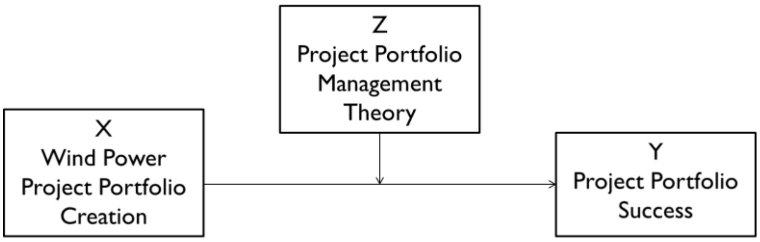

Figure 3. Theoretical Framework of the Research (own elaboration).

This research is not proposing the optimal wind power project portfolio to the studied market area but aiming to find the risks and opportunities that impacts on the project portfolio creation.

2.1 Wind Power Market Review

The future estimates presented in this chapter are done before the COVID-19 pandemic was realized thus the extent of the effects are still to be quantified.

In the year 2019 the wind power industry's new installations surpassed 60 GW for the second time in the history corresponding the annual growth of 19 %. The world's largest onshore wind markets were China and USA with together more than 60 % of new installed capacity. The leading onshore wind region in the new installations was Asia Pacific with 27.3 GW followed by Europe even though the German market shrank by 55 % from the year before. In **Figure 4**, the latest market insights are presented. (GWEC, 2020)

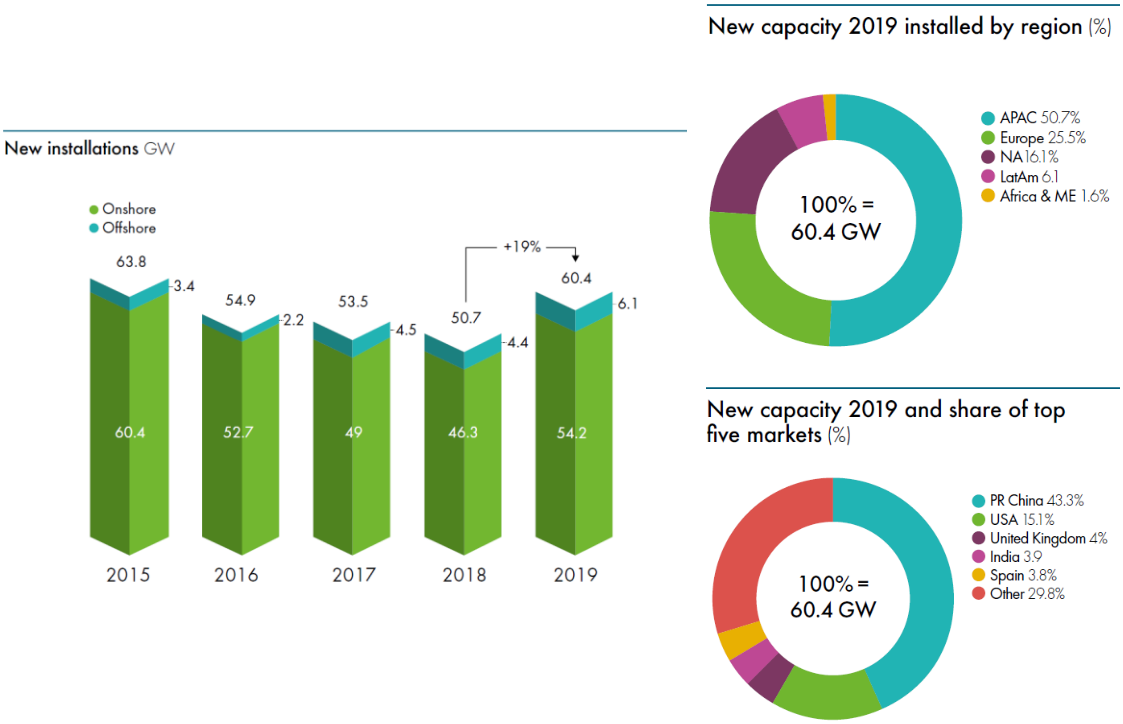

Figure 4. Wind Power Market Status of the Year 2019 (GWEC, 2020).

The Chinese auction, introduced in 2018 and their national roadmap toward subsidy-free onshore wind from 2019 can already be seen from the new installations but the auction quota capacity is likely to be seen in 2020 as well due to the fact that Feed-in-Tariff will be granted if the plant is connected to the grid before the end of 2020 (GWEC, 2020).

The global wind energy market is estimated to be growing with a 4.0 % compound annual growth rate for next five years summing up over 355 GW of new capacity by the end of 2024 (**Figure 5**). The growth will be mainly driven by the governmental support mechanisms such as the feed-in-tariffs, auction systems and renewable roadmaps. Moreover, the feed-in-tariff policies have been increasingly replaced by auctions in the last decade with more than 100 countries having held at least one auction. However, the global bid levels get lower and the auction systems may award the applicant with an additional risk to carry. The sample of the latest lowest winning bids are presented in **Figure 6**. (GWEC, 2020)

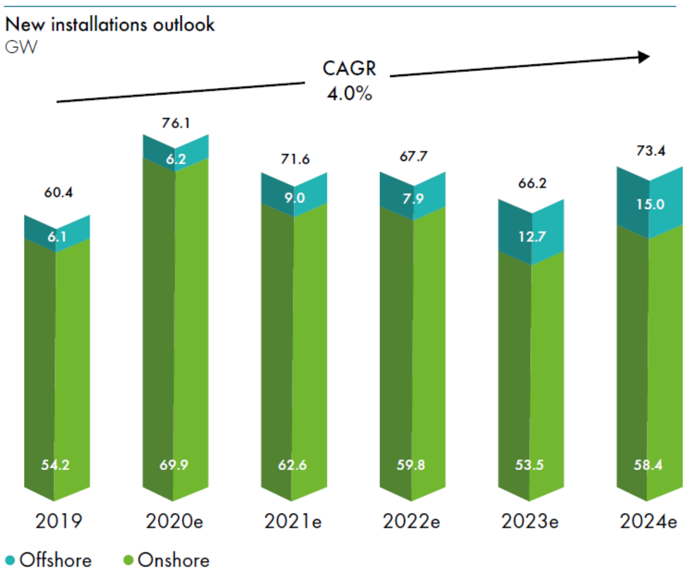

Figure 5. Global Outlook – Total Estimated New Wind Power Installations (GWEC, 2020).

Figure 6. A Sample of the Global Bid Levels (GWEC, 2020).

When it comes to African market, the current capacity of the industrial wind power is concentrated to South Africa, Egypt and Kenya with the 31 %, 22 % and 5 % shares of the total capacity respectively as presented in **Table 2-1** below.

Table 2-1. Installed Wind Power Capacity in Africa (GWEC, 2020).

MW, onshore	New installations 2018	Total installations 2018	New installations 2019	Total installations 2019
Egypt	380	1,190	262	1,452
Kenya	312	338	0	338
South Africa	0	2,085	0	2,085
Other Africa	278	2,115	682	2,798

The outlook estimates a stable increase for the African / Middle East region, but as before the new installations will be concentrated to some few countries with strong economy (**Figure 7**).

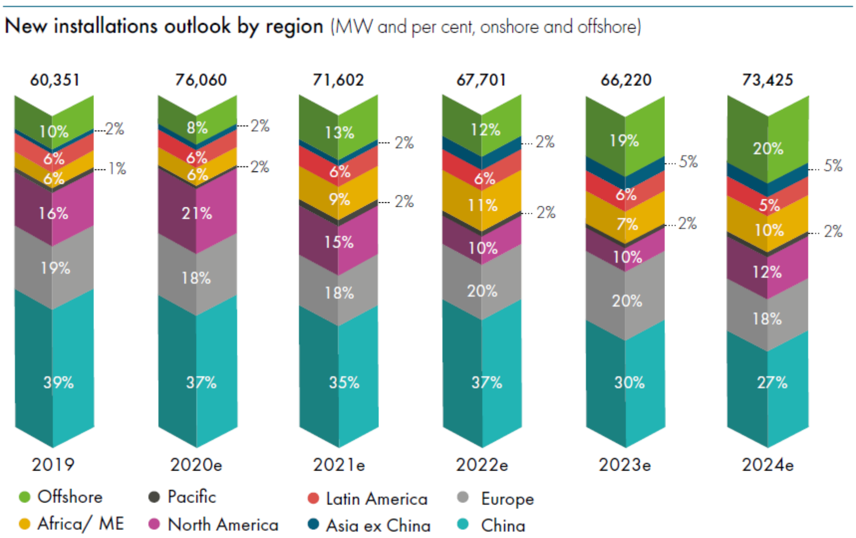

Figure 7. Global Outlook – Total Estimated New Wind Power Installations by Region (GWEC, 2020).

In the technical perspective, the wind turbines have been growing in rotor and tower sizes as well as in the generator capacity sizes, especially when considering the offshore technology. In the beginning of the decade an example turbine was 3.0 MW in capacity, 126 m in the rotor diameter and 137 m in the tower height (Vestas). According to the latest news releases from the wind turbine manufacturers, the orders are for up to 5.6 MW and 14.0 MW turbine capacity for onshore project and offshore project respectively as presented in **Table 2-2** below.

Table 2-2. Latest Orders According to the News Releases (Nordex, 2020; Siemens Gamesa 2020; Vestas, 2020)

Manufacturer	Total Capacity of the Project	Turbine Model	Turbine Capacity	Rotor Diameter	Project, Commission Year
Siemens-Gamesa[1]	1 400 MW	SG 14-222 DD	14.0 MW	222 m	UK, 2024
Siemens-Gamesa[1]	497 MW	SWT-7.0-154	7.0 MW	154 m	France, 2021
Siemens-Gamesa[1]	496 MW	SG 8.0-167 DD	8.0 MW	167 m	France, TBC
Vestas	336 MW	V162 / V150	5.6 MW / 4.2 MW	162 m / 150 m	USA, 2021
Vestas	249 MW	V136	4.2 /3.45 MW	136 m	USA, 2021
Nordex	90 MW	AW132	3.5 MW	132 m	Brazil, 2022
Nordex	43 MW	N149	4.8 MW	155 m	Finland, 2021
Nordex	27 MW	N149	4.0-4.5 MW	149 m	Germany, 2020
Vestas	18 MW	V136	3.6 MW	136 m	Italy, 2021

Additionally, one of the biggest Chinese wind turbine manufacturer Mingyang Smart Energy has a turbine with 4.0 MW capacity and 156 m rotor for onshore and up to 7.0 MW capacity and 180 m rotor diameter for offshore projects in their product line (Mingyang, 2020).

Besides the wind turbine technology development, the renewable energy industry is shifting from a single technology mindset towards system approach where multiple technologies are combined and the infrastructure is jointly used. As an example, the first hybrid power plant in Africa is being planned to Kenya, with 65 MW of wind power capacity, 20 MW of solar PV capacity and 5 MW storage system with expected commission in 2022. (GWEC, 2020)

Lastly, the hot topic throughout the energy sector and the likely key enabler for the energy transition is in green hydrogen. Now, when due to climate change, renewables are principally replacing the fossil fuels in power demand by 2050, the ways to decarbonize the other areas of energy use i.e. transportation, manufacturing and heating needs to be found. Green hydrogen is zero emission hydrogen produced from the electrolysis of water using renewable energy such as wind power. In **Figure 8** is presented an example process of green hydrogen production. This technology provides relevant solutions for particularly offshore wind power where the needed elements coexists. (GWEC, 2020)

[1] An offshore project.

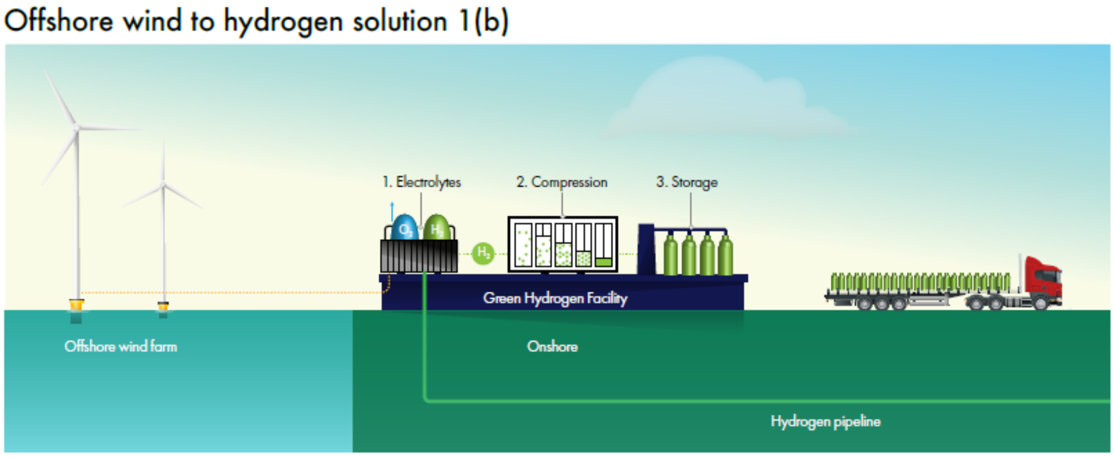

Figure 8. Green Hydrogen Solution Possibilities (GWEC, 2020).

2.2 Research Methodology

The possible research methods for this study were mapped to find the most suitable platform for the process. As the target country was predefined as the input and the practical nature of the study was explicit, the natural research method to be applied was a case study with a single case. The case research types were chosen to be exploration due to the need for uncovering the new areas for research and theory development and theory testing to test the theoretical framework in the case. Moreover, the case study was defined as qualitative instead of quantitative due to the nature of the data available in the study.

Qualitative research is usually concentrating on the nature of the problem and examining it where it differs from quantitative research that bases the problem solving in the numerical or statistical – quantifiable facts. Huopainen (2014) lists the typical characteristics of qualitative research as follows.

- Research is comprehensive acquiring of information by nature
- Human beings are favored as a data collection instrument
- Inductive analysis
- Qualitative material collection methods
- Expediently chosen target group
- Research plan along conducting the study
- Cases are handled unique and data is interpreted accordingly

A typical deductive research process starts from the theory and concludes to it at the end. Qualitative research is anyhow inductive by its nature thus it starts with the data collection out of which the research question is asked. Further on, the data is categorized and searched for patterns that can at the end be formed as theories. (Huopainen, 2014)

A case study is a methodology for research questions such as how and why and the finding a solution for the case is the goal of the study. The study can be characterized as mapping, explanatory, describing or predictive depending on the researched phenomena. The number of the cases can be one or more resulting a single case study or a multiple case study respectively. A single case study is reasonable if the case is critical or unique, if the case is representative or revealing or if the case is longitudinal. (Huopainen, 2014)

In this thesis the case is at least as unique as the market area and the country geography are unique. Also, the case is representative as there are other developing countries in a similar socio-economic situation.

Case studies also consists of the data collection and the data analysis. The data is usually researcher's observations about the research object that is the primary data but there may also be secondary data collected by others. The goal of the data analysis is to clarify the qualitative data to produce the input for the inductive reasoning. The processes of data collection and analysis can be repeated until the final conclusions are achieved. Ultimately, the reliability and the validity of the results are assessed when the research questions are answered. (Huopainen, 2014)

2.3 Structure of the Study

The study is divided into the theory part and the case study followed by the result and conclusions. In the theory part the context is explained in the extent that is applicable in for the case study. Then in the case study, the studied market area is explained, and the theory is proposed to be implemented in a sufficient way. The results are explained in the following section. Moreover, the research is concluded and discussed in the final chapter of the study.

Chapter three describes the theoretical framework of the study opening the contexts of project, project management and portfolio management as how they are recently described in the research papers and traditionally in the universal standards of the field. Additionally, the key processes of the wind power project development are described in this chapter from a chronological life-cycle perspective. The part ends with the review a sample of the previous case studies done to find wind power production development possibilities in Ghana.

Chapter four opens the case study starting with an introduction to the target country Ghana. The socio-economical status of the country is described together with the very latest electricity profile including the capacity and production review as well as the consumption perspective of the topic. Moreover, the wind power project development is studied with the contents of wind assessment, electricity grid capacity, environmental assessment, land acquisitions. This part gives the insight of theory implementation into the target country. At the end, based on the project development analysis, the wind power project development portfolio is assessed.

Chapter five presents the data collection, where the results of the theoretical framework and the case study are summarized, and the analysis is explained in detail.

Chapter six describes the results in and answers the research questions. In this chapter the outcome of the national wind power project development portfolio analysis is presented.

Chapter seven concludes the results from the theoretical and practical perspective. Also, limitations, further research and conflict of interest are presented.

3 THEORETICAL FRAMEWORK

This chapter contains a thorough review of the context of the project portfolio management in the extent that is applicable in for the case study. The PPM's main characteristics are explained together with the project management concept overview since it is essential to understand the phenomenon appearing in the project portfolios. Additionally, the review of the wind power market is presented at the end of chapter to rationale the need for the case study.

3.1 Project

A project is a temporary process of actions to create product, service or result with some with five foundational characteristics. Below are the fundamentals explained as described in the one of the most used project management standards, A Guide to the Project Management Body of Knowledge (PMBOK Guide; PMI, 2017) by the Project Management Institute Inc. (PMI).

Uniqueness of the produced product, service or result is first characteristic of the project foundation. A project is a creation process of tangible or intangible deliverables that are required to achieve the objective. The deliverable may be a unique product such as new item or a component or correction to the item (e.g. wind turbine transformer correction). Secondly, the deliverable may be a unique service or a capability to do a service (e.g. natural study to an impact assessment report). Thirdly, the deliverable may be a unique result such as a document (e.g. wind resource assessment report). Additionally, the deliverable may be a unique combination of different variations of the mentioned deliverables (e.g. Balance of Plant (BoP) design, execution and documentation). The deliverables may be repetitive in nature, but the characteristics are always unique.

The second foundational characteristic of the project is its temporary nature meaning that is has definite start and end. The project starts with the initiation process and ends when the set objectives are achieved, or they cannot be met anymore, or the funding of the project ends, or the project is no more needed, or the resources are lacking or some due to contractual or legal termination.

Before the project starts the organization is in the current state and by doing the project the organization moves towards a more desirable future state. The third foundational characteristic for the projects is their drive for change. By doing the project activities, the organizations achieve objectives to improve the organizational state, as presented in **Figure 9**.

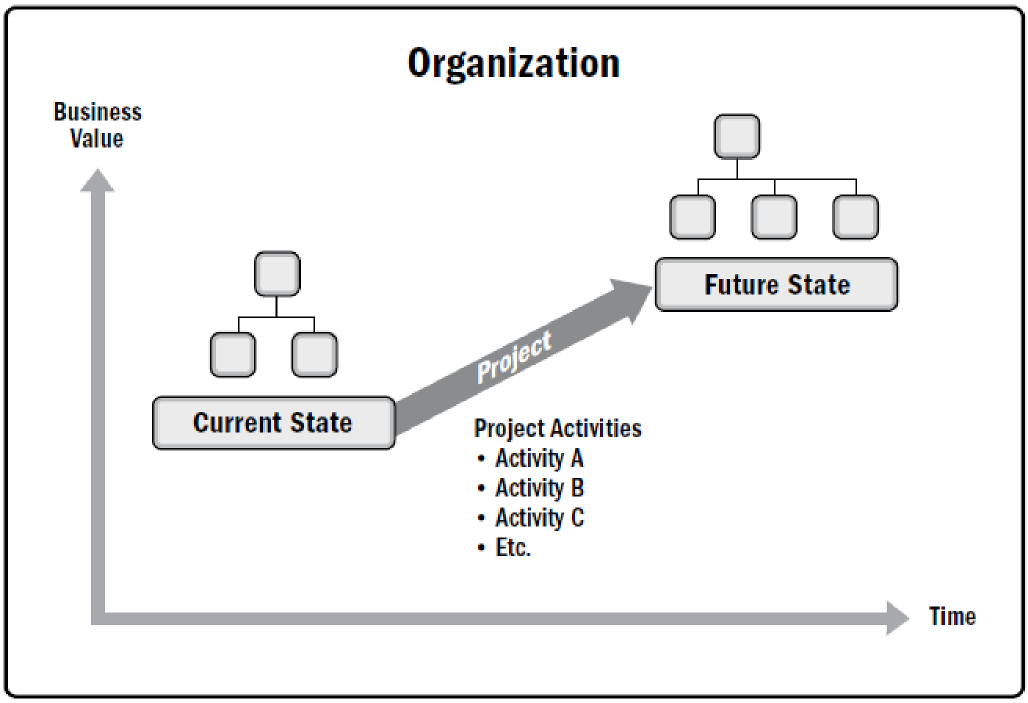

Figure 9. Organizational State Transition via a Project (Skillsvault; org. PMI, 2017).

The projects fourth foundational characteristic is their power to enable business value creation as the net quantifiable benefit derived from a business endeavor as defined by PMI. Business value can be tangible such as e.g. monetary assets, stakeholder equity or utility but it can also be intangible such as e.g. goodwill, brand recognition or public benefits.

The final foundational characteristic of a project is the organizational initiation context. There is always some factor creating a need to initiate the project and they can be categorized as follows:

- The project meeting the regulatory, legal or social requirements
- To satisfy the stakeholders requests or needs
- To implement or change business or technological strategies
- To create, improve, or fix products, processes or services

3.2 Project Management

Project management is the application of knowledge, skills, tools and techniques to project activities to meet the requirements and with competent project management organizations execute their projects effectively and efficiently. It helps organizations to meet business objectives, satisfy stakeholders, resolve problems and issues, optimize the use of resources and manage change well to name a few of project management's pros. As a contrast, the deadlines may be missed, costs overrun, projects expanding, or rework being needed if the projects are not managed or they are managed poorly. Managing a project typically includes (referred as knowledge areas (PMI, 2017) or subject groups (SFS, 2012)):

- Integration of the project processes
  - Including the identification of the project requirements
- Stakeholder and project communication
  - Addressing the stakeholders needs, concerns and expectations
- Handling the project procurements
- Balancing the project constraints
  - Scope
  - Schedule
  - Cost
  - Quality
  - Resources
  - Risks

As described earlier, projects are always unique endeavors, so the content of the needed project management is always project specific. (PMI, 2017)

Appropriate and competent project management is driven by a standardized system known as processes that are divided chronologically throughout the project life cycle. International Standard ISO 21500:2012 “Guidance on project management” (SFS, 2012) divides the project life cycle into five distinct process groups that interact with each other, initiating, planning, implementing, controlling and closing process group. The initiating processes start and authorize the project and the planning processes develop the project plan in a sufficient detail to be implemented, controlled and managed. Further on, the implementing processes guide and support the project management activities within the project plans framework and controlling processes monitor, measure and control the project performance against the project plan and trigger the possible preventive or corrective change actions to achieve the project objectives. Finally, the closing processes formally end the project phase or project and reflect the before mentioned processes by providing the lessons learned output. The interaction of these project process groups is presented in **Figure 10** below. Each process group contains a set of processes that are applicable to any project and project phase.

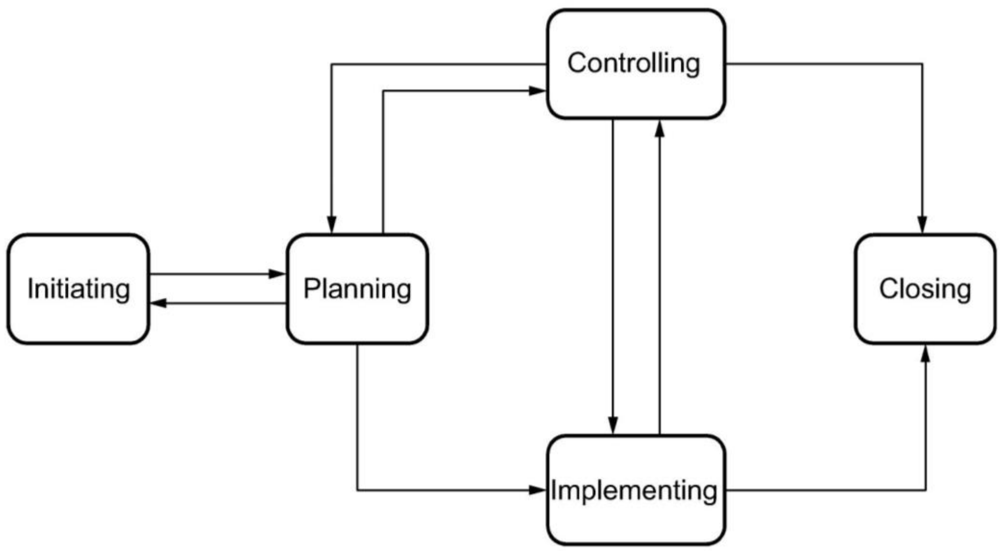

Figure 10. Process Groups Interactions (SFS, 2012).

The main context of the project management process groups is similar throughout the different standards, but some definitions vary. For example, the PMBOK Guide (PMI, 2017) refers the actual project implementation as *the execution process group* and the controlling is extended as *the monitoring and controlling process group*. The PRINCE2 process model also ads up *the managing a stage boundary* process group (activity group) to the process to strengthen the project governance (ILX, 2017).

Now, with these two perspectives of the project management processes, subject groups (knowledge areas) and process groups, the actual processes can be presented as an interlinked list. The different standards emphasise different aspects during the project life cycle thus there are totally different processes in the standards but also the connections between the distinct groups slightly vary.

The processes of the ISO 21500 standard are presented in **Table 3-1** and the processes of the PMBOK Guide are presented in **Table 3-2**.

Table 3-1. Project Management Processes Cross-referenced to Process and Subject Groups (SFS, 2012)

Subject groups	**Process groups**				
	Initiating	**Planning**	**Implementing**	**Controlling**	**Closing**
Integration	4.3.2 Develop project charter	4.3.3 Develop project plans	4.3.4 Direct project work	4.3.5 Control project work 4.3.6 Control changes	4.3.7 Close project phase or project 4.3.8 Collect lessons learned
Stakeholder	4.3.9 Identify stakeholders		4.3.10 Manage stakeholders		
Scope		4.3.11 Define scope 4.3.12 Create work breakdown structure 4.3.13 Define activities		4.3.14 Control scope	
Resource	4.3.15 Establish project team	4.3.16 Estimate resources 4.3.17 Define project organization	4.3.18 Develop project team	4.3.19 Control resources 4.3.20 Manage project team	
Time		4.3.21 Sequence activities 4.3.22 Estimate activity durations 4.3.23 Develop schedule		4.3.24 Control schedule	
Cost		4.3.25 Estimate costs 4.3.26 Develop budget		4.3.27 Control costs	
Risk		4.3.28 Identify risks 4.3.29 Assess risks	4.3.30 Treat risks	4.3.31 Control risks	
Quality		4.3.32 Plan quality	4.3.33 Perform quality assurance	4.3.34 Perform quality control	
Procurement		4.3.35 Plan procurements	4.3.36 Select suppliers	4.3.37 Administer procurements	
Communication		4.3.38 Plan communications	4.3.39 Distribute information	4.3.40 Manage communications	
NOTE: The purpose of this table is not to specify a chronological order for carrying out the activities. Its purpose is to map subject groups and process groups.					

Table 3-2. Project Management Process Group and Knowledge Area Mapping (New Line Technologies, 2017; org. PMI, 2017)

Knowledge Areas	Project Management Process Groups				
	Initiating Process Group	Planning Process Group	Executing Process Group	Monitoring and Controlling Process Group	Closing Process Group
4. Project Integration Management	4.1 Develop Project Charter	4.2 Develop Project Management Plan	4.3 Direct and Manage Project Work 4.4 Manage Project Knowledge	4.5 Monitor and Control Project Work 4.6 Perform Integrated Change Control	4.7 Close Project or Phase
5. Project Scope Management		5.1 Plan Scope Management 5.2 Collect Requirements 5.3 Define Scope 5.4 Create WBS		5.5 Validate Scope 5.6 Control Scope	
6. Project Schedule Management		6.1 Plan Schedule Management 6.2 Define Activities 6.3 Sequence Activities 6.4 Estimate Activity Durations 6.5 Develop Schedule		6.6 Control Schedule	
7. Project Cost Management		7.1 Plan Cost Management 7.2 Estimate Costs 7.3 Determine Budget		7.4 Control Costs	
8. Project Quality Management		8.1 Plan Quality Management	8.2 Manage Quality	8.3 Control Quality	
9. Project Resource Management		9.1 Plan Resource Management 9.2 Estimate Activity Resources	9.3 Acquire Resources 9.4 Develop Team 9.5 Manage Team	9.6 Control Resources	
10. Project Communications Management		10.1 Plan Communications Management	10.2 Manage Communications	10.3 Monitor Communications	
11. Project Risk Management		11.1 Plan Risk Management 11.2 Identify Risks 11.3 Perform Qualitative Risk Analysis 11.4 Perform Quantitative Risk Analysis 11.5 Plan Risk Responses	11.6 Implement Risk Responses	11.7 Monitor Risks	
12. Project Procurement Management		12.1 Plan Procurement Management	12.2 Conduct Procurements	12.3 Control Procurements	
13. Project Stakeholder Management	13.1 Identify Stakeholders	13.2 Plan Stakeholder Engagement	13.3 Manage Stakeholder Engagement	13.4 Monitor Stakeholder Engagement	

Projects shall be managed in a way that each process used during the project life cycle is appropriately aligned and connecter to other processes. All the processes are not necessarily used in every project and some processes may be repeated to meet the project objectives. It is project manager's responsibility to ensure that the right processes are used in the applicable extent and that the tailoring is accomplished in accordance with the relevant organizational policies. (SFS, 2012)

Moreover, to understand the nature of the processes better they usually fall into three categories as follows.

- Single-use or predefined processes such as closing the project
- Periodically performed processes such as acquiring resources that is performed when needed
- Continuously throughout the project used processes such as many of the monitoring and control processes that are used from the start until the end of the project (PMI, 2017)

3.3 Project Portfolio Management

The projects can be managed as a stand-alone project or within a portfolio (or within a program). In a portfolio, the projects (and/or programs, subsidiary portfolios and operations) are managed as a group to achieve the objectives in the organizational strategy. In **Figure 11** there is an example situation of the relation within the portfolio. (PMI, 2017)

Portfolio management is a dynamic process where the portfolio manager's expectations about the future balances the investor's objectives (Baker and Filbeck, 2013). The theoretical focus of the portfolio management is on the risk mitigation. In the context of project management, the PPM also provides tools for effective use of shared resources as presented in **Figure 11** below.

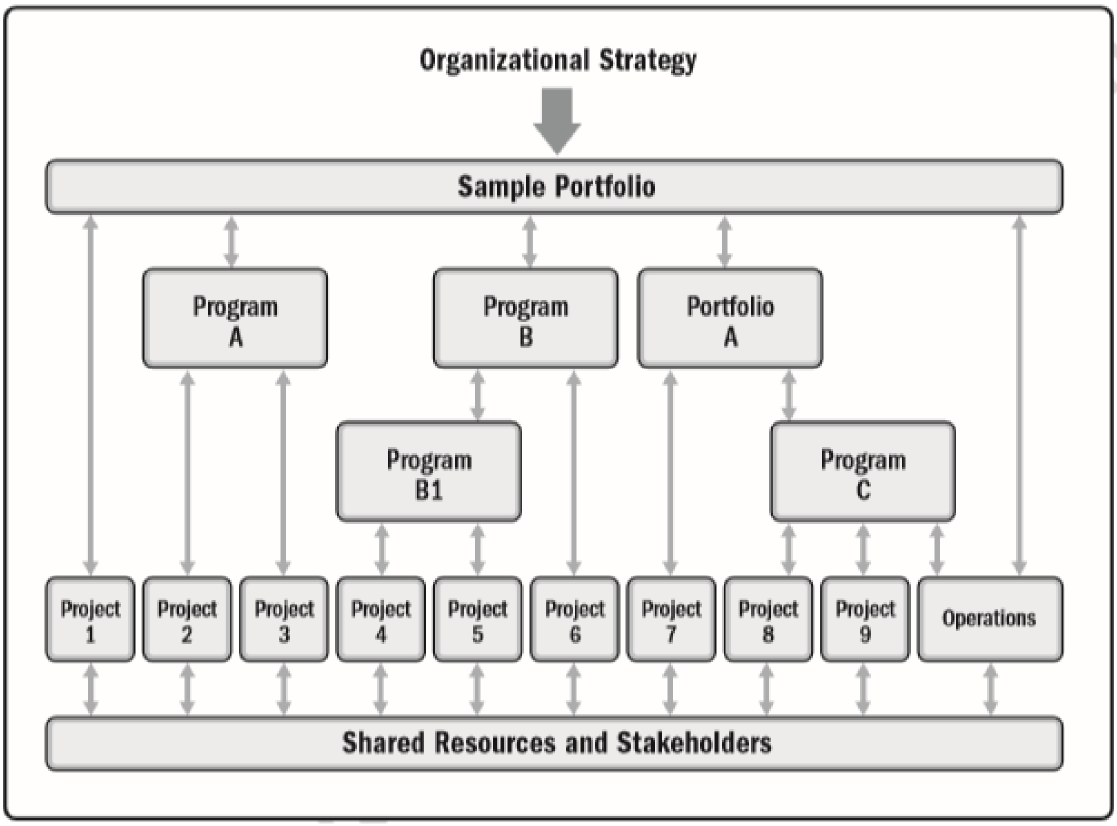

Figure 11. Portfolio, Programs, Projects and Operations (Bapat, 2020; org. PMI, 2017).

For example, multiple projects may need to be completed to achieve portfolio goals or the stakeholders for different projects may be the same or the resources used to achieve certain project activities are same for several projects causing a conflict in the organization. Therefore, to increase the coordination between the projects the portfolio management is implemented. (PMI, 2017)

Moreover, as Enoch (2015) argues, just choosing the right components to the portfolio is not enough but the ultimate success comes by terminating, accelerating or delaying the portfolio components in the right manner.

The portfolio theory has been used in the finance sector ever since initially presented by Dr. Harry Markowitz in the year 1952 (Baker and Filbeck, 2013), but the project management implementations have been developed just within the last two decades. This chapter presents the background of the implementations when it concerns the PPM in the context of projects.

3.3.1 Modern Portfolio Theory and Wind Farm Investments

Markowitz's modern portfolio theory is used for optimizing the profitability of the financial asset portfolios by reducing the level of risk to the wanted level. It is a model of diversification where risks and returns are assessed in the portfolio level instead of individual assessment. (Baker and Filbeck, 2013)

In 2013 Dr. Patricia Chaves-Schwinteck made a research "The Modern Portfolio Theory Applied to Wind Farm Investments" where she studied the applicability of the portfolio theory approach that is designed for financial assets to a physical asset such as a wind farms and the relevance of diversification in wind farm investments. She discusses the differences between typical financial assets and wind farm projects where the first ones are rather short term investments that can be motivated with the numerical methods such as mean-variance simulation and second ones are long term initiatives with plenty of project specific technical risks. Dr. Chaves-Schwinteck concludes that "the establishment of an efficient frontier of wind farm portfolios, even if mathematically possible, is far from the reality of wind energy investors". However, the diversification in a technical perspective was a possibility for the wind farm portfolio risk mitigation. With a proper diversification the wind regime and other project specific risk factors may be optimized to improve the performance of the portfolio. (Chaves-Schwinteck, 2013)

3.3.2 Choosing the Portfolio Components

When creating a wind power project development portfolio, the pre-feasibility study phase is of importance. Whether the projects in the portfolio are chosen to be greenfield, brownfield or repowering projects, the probability of successful development until the operational wind farms is crucial for the portfolio performance thus the input for the portfolio decision making shall be studied thoroughly. The different project initiation types are described in the chapter 3.4 in detail. The case study in the chapter 4 covers the topic in the practical level.

3.3.3 Decision Making

In the year 2015 Clive N. Enoch (2015) proposes in his handbook a model for improved decision making for the PPM. He acknowledges the importance of the earlier approach in PPM of selection and categorization of the projects in portfolio, but the wrong decision making afterwards makes well-structured portfolio meaningless. The key to successful decision making is the understanding of "the individual and cumulative contribution of portfolio components to organizational objectives and the likely impact of such decisions on the achievement of these objectives".

Enoch (2015) uses the decision-making model with Fuzzy Logic process which follows a combination of the systems approach, multicriteria utility theory and complexity theory. The complex relationship of organizational objectives and portfolio components forms a group of interacting parts that behave according to rules and forces. He extends the model from the single objective to multiple objective contribution of the component. When reflecting the model to a real-life example the result can be visualized as in **Figure 12**.

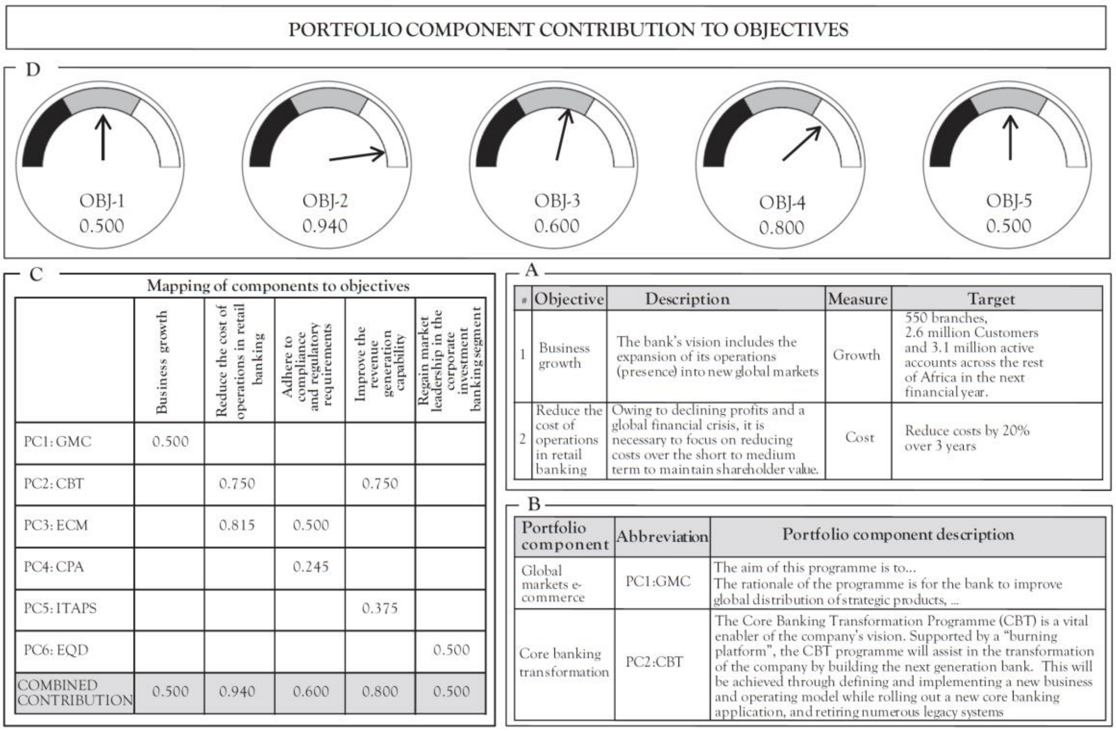

Figure 12. A Sample Dashboard of the Portfolio Component Contribution to Objectives (Enoch, 2015).

In the previous figure, the section A presents the organizational objectives and the section B explains the portfolio components that contribute to the objectives. In the C-section, the individual and combined component contributions per objective are listed. Finally, the section D shows the gauge charts representing the level of the objective achievements. With the dashboard, the alternatives and outcomes of terminating, accelerating or delaying the portfolio components can be evaluated and prioritized. (Enoch, 2015)

Without the clear vision of the relationships of the component’s contributions to the portfolio objectives and the degree of the effect, the decisions may decrease the organizational performance or even lead to the objective failures. With this method, the project portfolio manager can decide with confidence the prioritisation of the portfolio components as which ones to fast-track or terminate. (Enoch, 2015)

3.3.4 Portfolio Performance

The determination of the success in one of the most common challenges in the PM and PPM. The successfulness can be followed with the traditional metrics of PM (**Figure 1**) and the completion of the project objectives also indicates the level of success. The success can be monitored also on the organizational level with following the strategy, goals and objectives. (PMI, 2017)

Increasingly the stakeholders demand the measurability of the actual success. The measurable items related to the business case and the project finances are:

- Net present value
- Return on investment
- Internal rate of return
- Payback period
- Benefit-cost ratio (PMI, 2017)

Managing the project or portfolio in a proactive manner provides the best chances to success but the final achievements can only be measured at the end of the process. (PMI, 2017)

3.4 Wind Power Project Development

Wind power project development is a set of interactive processes that are performed in a chronological order towards to the ready-to-built project. The order and the actual need for each process varies by the country where the projects are developed but the framework remains the same. The processes for the wind power project development are:

- Pre-feasibility study
- Permitting
    - Environmental impact assessment (EIA)

  - Land use planning
- Financing and Contracts
- Final feasibility study
- Total engineering, procuring and constructing agreement (EPC) or separately
  - Final design
  - Balance of Plant procurement agreement
  - Turbine procurement agreement
- Possible project transaction

After the actual project development, the wind farm life cycle continues with the construction and operation phases. In some cases, the project developer carries on the process until the operational phase, but in this research the constructions and operations are left out of scope.

3.4.1 Pre-feasibility Study

In the pre-feasibility process the project constraints are checked in a general level to find so called red flags, the elements that clearly indicates the unprofitability of the project. In this process it is crucial to understand the country specific regulation and the structure of the energy markets to motivate the feasibility.

The basic fundament for a wind power project is the local wind resource. If the wind speeds at the wind turbine nacelle altitude are not on a feasible level, there's nothing else that can save the project. Not even the size of the blades, the rotor diameter can increase the production efficiently enough yet that is the second greatest factor in the formula of wind power generation. This can be investigated by deriving the formula of the wind power generation from the classic mechanical definition of kinetic energy as done by several authors before i.e. Chaves-Schwinteck (2013) and Safo (2013).

$$P = \frac{1}{2} \cdot C_p \cdot \rho \cdot A \cdot v^3 \ (W) \qquad \text{Equation 1}$$

The power (P) equals to the mass flow with the specified density (ρ) through the area (A) of the rotor in this case, at the speed of wind (v) raised to the third power, taking the capacity factor (C_p) into consideration.

Based on this, the criticality of the wind conditions of the project area is clear and even a slight increase in the wind speed may gain significant benefit to the project feasibility by the production increase. In the other hand, the technology selection and the site suitability for a larger wind turbine are of great interest when doing the pre-feasibility study for the potential site.

The preliminary wind assessment is usually made without on-site wind measurements, relaying on the national or international wind databases that has been prepared using re-analysis datasets and mesoscale climatic information. As a result, based on the wind conditions of the potential project area, the suitable wind turbine type can be assessed to further assess the production estimates and the project feasibility.

The preliminary natural and environmental constraints are assessed without detailed field work usually performed as a desktop study founding on the existing databases and studies. The grid capacity and the site access are evaluated as a desktop study as well. The assessments are studied more thoroughly during the permitting phase and in the actual feasibility study.

Land acquisition is a natural continuum for the pre-feasibility study due to the importance of the land use rights in any infrastructure project.

3.4.2 Permitting

In some countries, i.e. in Finland, the EIA and the land use planning can be synchronized from the schedule point of view but also in the regard of the process contents. In these processes the project area is examined thoroughly for the possible environmental, natural, social restrictions and for the conflicts with the current or planned land use of the area.

The field work takes place during the permitting phase. The findings are taken into consideration when doing the micro siting, the placing of the turbines and ultimately the wind turbine layout plan for the land use plan. During the permitting the stakeholders interact actively - that is project owner (project or portfolio manager) managing the interfaces of different levels of authorities, local communities and landowners, consultants, the press and other possible project specific stakeholders.

The goal, fully permitted project is achieved when the plans and permits are legally in force and the project area is at ready-to-build state. Chronologically, together with the permitting phase, the financing and project contracts are negotiated and if the pre-feasibility has shown optimistic results, the feasibility study is conducted.

3.4.3 Financing and Contracts

Due to fact that the wind power projects are most often guided by the classic principles of capital budgeting as project financing, the base for the project financing is generated through the permitting process and the feasibility studies by increasing the bankability of the project by eliminating the project risks and finally with the critical project contracts such as the EPC, the turbine supply and the power purchase agreements.

3.4.4 Feasibility Study

When all of these processes are performed successfully with approvals from the authorities, local people and the project owners or investors, the project is ready for the final feasibility study where the actual project finances are estimated based on the bankable wind resource assessments and energy yield assessments with an extensive risk assessment.

The wind resource assessment follows the local wind measurement campaign conducted locally at the site for at least one uninterrupted year. The financing normally requires the used equipment to be a meteorological mast (met mast) and depending on the size and complexity of the project area sometimes several met masts (Measnet, 2016). Nowadays, the technology of the remote sensing devices, light detection and ranging (LiDAR) and sonic detection and ranging (SoDAR) devices, has been developed and approved to the level of accuracy and reliability that they may also be accepted as the wind measurement equipment. The measurements are well standardized by Measnet and International Electrotechnical Commission (IEC).

In the wind resource assessment, the measured data is being analyzed and verified against the standards. The possible errors in wind speeds and directions as well as in other condition parameters are filtered out to clean the data and the remaining gaps are filled with the data from supporting devices. The clean timeseries of wind data is then extrapolated into eligible altitude. (Measnet, 2016)

Now, with the one-year (or more) data, the local wind condition for the measurement period is recognized, which then gives already an idea of the site suitability of the area, but the temporary nature of the result contains great uncertainties. To reduce the uncertainties and to prepare the data for the energy yield assessment (EYA) and the feasibility study the timeseries is normalized with a long-term reference meteorological data. With this process the past mesoscale climatic condition data is used to predict the conditions for the actual operational period of the wind farm. A Measure-Correlate-Predict (MCP), where the relationship of the two datasets is evaluated and extrapolated to correspond each other, is commonly used method for this purpose (Measnet, 2016). After the normalization process the data is ready for the EYA.

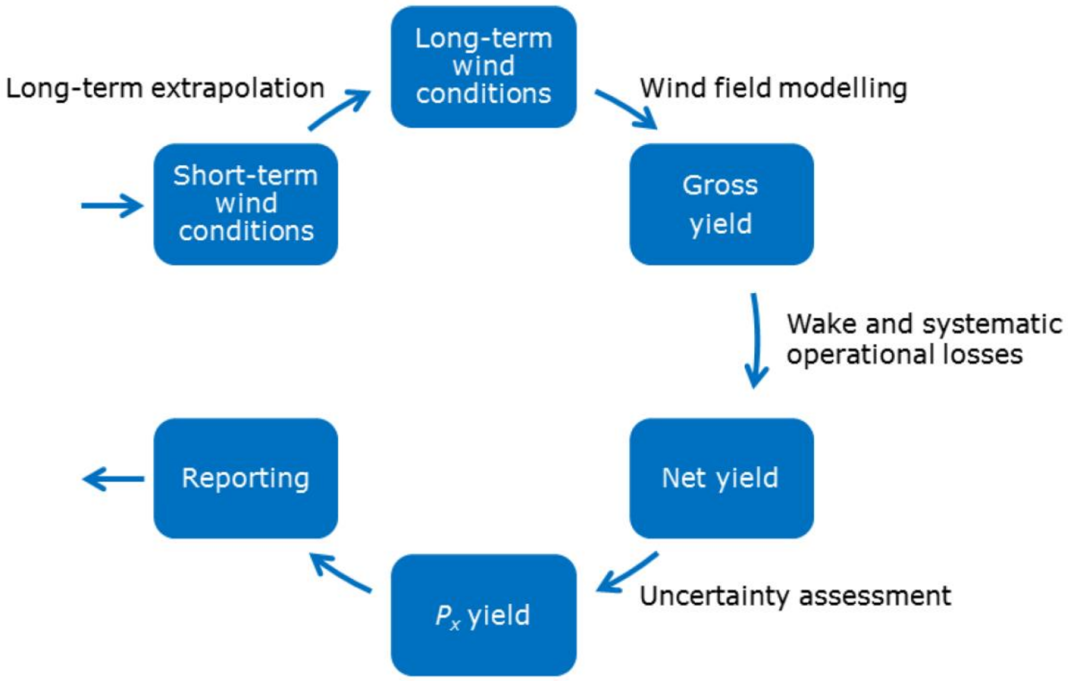

Figure 13. Main Steps in the Energy Yield Assessment Process (Measnet, 2016).

As presented in **Figure 13** above, the process continues with the modelling of the wind fields resulting the gross energy yield. The wind fields are modelled with a linear tool such as WaSP or for complex sites with a computational fluid dynamic tool (CFD), by horizontal extrapolation. The gross energy yield is calculated by introducing the power curve of the modelled wind turbine into the flow model. The power curve represents the power of the wind turbine as a function of wind speed.

Further on the net energy yield is calculated by multiplying all the applicable losses to the gross energy yield. Measnet (2016) lists the losses as follows:

- Wake losses
- Availability
- Losses due to the turbine performance
- Electrical losses

- Curtailments

The net energy yield itself is already a good tool for a project valuation and it is commonly referred as a P50 value, meaning that the probability of exceeding this amount of energy yield is 50 %. Anyhow, for the project financing, the sensitivity analysis is needed to discover the uncertainties of the energy production (ultimately the cashflow) and their effect to the energy yield. Chaves-Schwinteck (2013) uses the following uncertainties:

- Wind measurements
- Long-term extrapolation of measurement data
- Flow modelling
- Wake models
- Power curves

The other probabilities of exceedance are determined by defining the root mean square of all uncertainties and by assuming the Gaussian distribution of these errors. Normally P75 is a sufficient value for the project financing where the probability of exceeding the amount of energy yield is 75 %, but sometimes P90 is also regarded.

3.4.5 Project Transaction

The project transaction where the project developer sells the project to the third party can be take place principally at any time of the project lifecycle, but it is likely to happen right after the final feasibility study results or later on after the finalization of the EPC agreement.

3.4.6 Development Approaches

When creating a wind power project development portfolio, choosing the right projects or components is one of the key criteria for the success. The wind power project development portfolio can be created based on three distinct areas: greenfield, brownfield or repowering.

Greenfield project development stands for the development type where totally new areas are explored in a purpose of project execution. The area can be used for agriculture or forestry but there is no existing built infrastructure. In the other hand, brownfield project development is planned for the urban or semi-urban areas where there is existing infrastructure, or the existing buildings are demolished, and area is planned for new purpose. In the brownfield projects, the existing infrastructure may remain in which case the joint impacts shall be assessed. For wind power projects there is also possibility for repowering the worn-out projects. Usually in these cases, the old turbines are demolished, and the same site is planned for the updated wind turbine type.

As mentioned earlier, the portfolio can also be procured via project transaction with a mix of different types of project.

3.5 Previous Case Studies

Energy Commission of Ghana conducted wind resource measurement campaigns at eight interesting locations along the coastal area at the 60 m altitude above ground level. The measurements were conducted during the period from 2011 to 2013 as one to two years measurements. Results were indicating higher wind speeds for the eastern part of the coast compared to the central area. The locations of the measurement sites are shown in **Figure 14** and results listen in **Table 3-3**. (Energy Commission, 2014)

Safo (2013) studied the whole country with a reference to the existing measurement data around the country and nationwide wind map by National Renewable Energy Laboratory of U.S. Department of Energy. He found that the Volta region was most potential for wind energy generation and took specifically the Nkwanta North District for a closer study. Based on the financial calculations, he concluded that the studied region was very good for wind energy generation. Moreover, the estimated wind power capacity was 5.64 GW for the whole country. Comparing the estimate to the country’s total electricity generation capacity of 5.17 GW in 2019 puts the figures into a positive perspective. Worth noticing is also, that Safo studied only onshore wind power capacity.

Table 3-3. The Wind Measurement Sites in the Energy Commission’s Wind Resource Assessment (Energy Commission, 2014)

#	Site Name	Location	Coordinates	Period	Monthly Average Wind Speed @ 60m (m/s)
1	Ekumfi Edumafa	Mfantsiman Municipality, Central Region	(5.208°N; 0.950°W)	2011-2012	4.67
2	Gomoa Fete	Gomoa East District, Central Region	(5.446°N; 0.458°W)	2011-2012	4.53
3	Avata	Ketu South Municipality, Volta Region	(6.060°N; 1.005°E)	2011-2012	5.01
4	Sege/Ningo	Dangme West District, Greater Accra Region	(5.872°N; 0.345°E)	2011-2013	5.46
5	Atiteti/Dzita	Keta Municipality, Volta Region	(5.774°N; 0.714°E)	2011-2013	5.98
6	Anloga	Keta Municipality, Volta Region	(5.787°N; 0.919E)	2012-2013	6.01
7	Mankoadze	Winneba Municipality, Central Region	(5.317°N; 0.700W)	2012-2013	5.05
8	Denu	Ketu South Municipality, Volta Region	(6.112°N; 1.141°E)	2012-2013	5.17

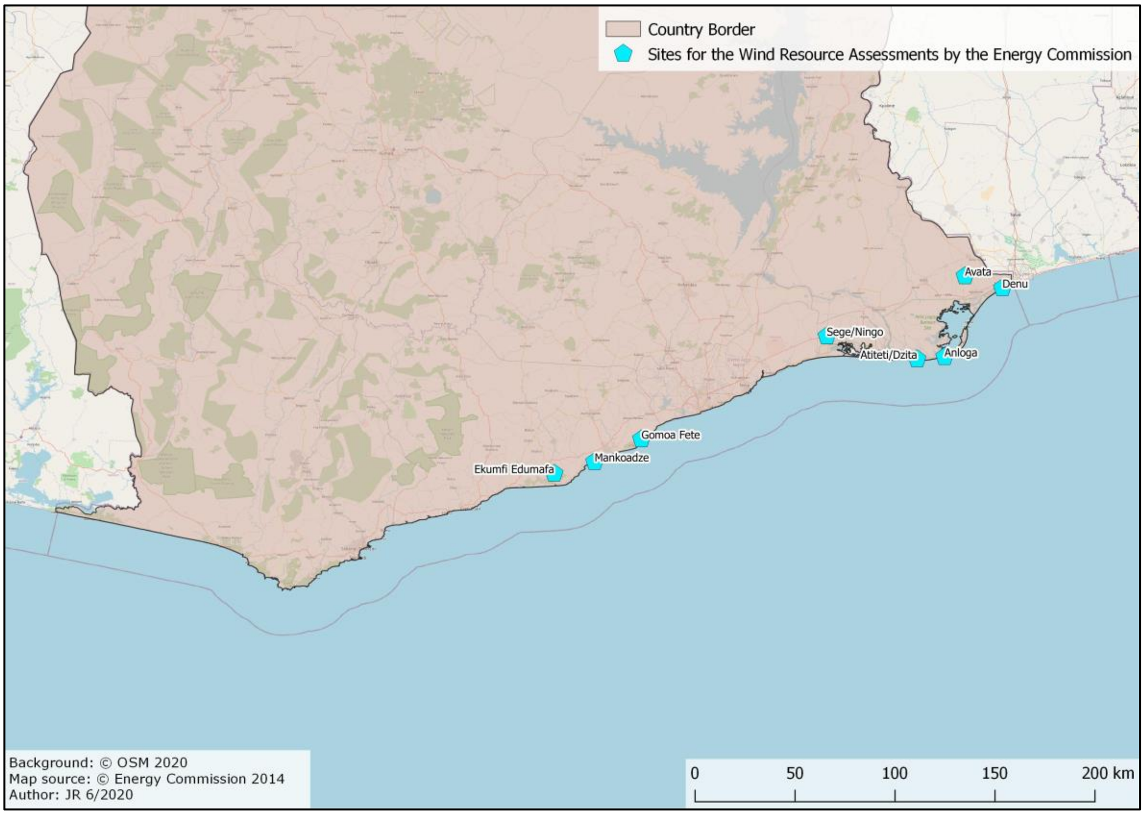

Figure 14. The Wind Measurement Sites in the Energy Commission's Wind Resource Assessment (Energy Commission, 2014).

Isaiah Kabutey Kabu (2016) took three regions of Ghana, Volta, Eastern and Greater Accra regions for his research with a goal to find the most suitable areas for the wind power generation. The main method used was spatial analysis with an extensive category of restrictive and enabling inputs i.e. the protected sites, wind resources and existing electricity grid. As a result, he found the most suitable areas and estimated the capacity for these regions to be 10.5 GW of wind power.

4 CASE STUDY

In this chapter the case country Ghana is studied in the wind power project development perspective. First, the market area is studied focused on the national energy generation to motivate the wind project development to the area. Secondly, the wind power project development framework is implemented to the case country. Thirdly, the input is used to propose a successful wind power project development portfolio to the case country.

4.1 Country Profile

The Republic of Ghana (Ghana; formerly Gold Coast) is a democratic country in the West Coast of Africa (**Figure 15**) that was the first country in the sub-Saharan Africa to gain independency in 1957. First decades of the country's independent history and the democratic experiments were shaded by military takeovers until 1992 when the latest democratic period started (GhanaWeb, 2020). The country is divided into ten administrative regions out of which the capital Accra is located to the Greater Accra region in the southern coastal area (**Figure 19**). The border countries are Burkina Faso, Cote d'Ivoire and Togo.

The population of Ghana is slightly over 29 million in 2020. Country's demographic profile shows young age structure with approximately 57 % of the population under the age of 25 as shown in **Figure 16**. The population is unequally spread around the country – the polarization between the north and the south is clear. Despite the poverty generally declining in Ghana, it remains predominant in the northern regions due to droughts and floods as well as the poorer transportation and economical infrastructure and the social difficulties. (CIA, 2020)

The total area of the country is almost 240 000 square kilometers (Finland being approx. 340 000 square kilometers). The water areas cover 11 000 square kilometers of the country including world's third largest artificial lake, Lake Volta. (CIA, 2020)

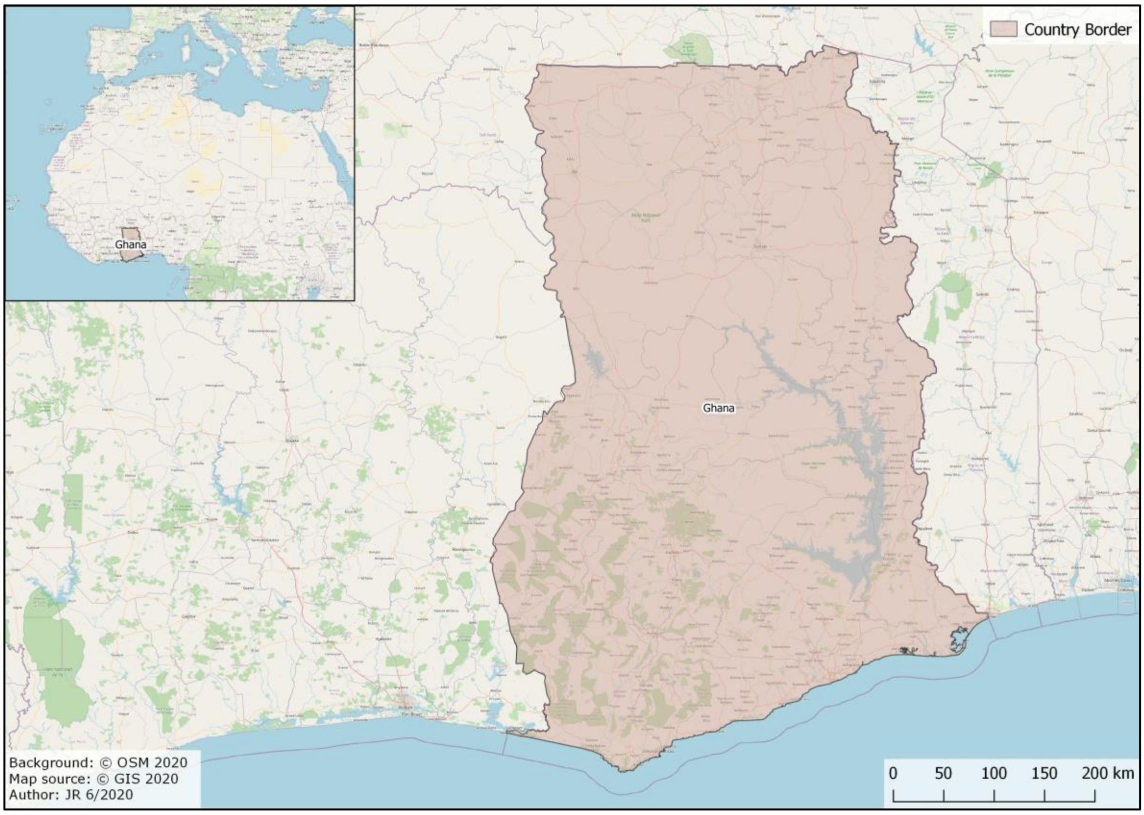

Figure 15. Ghana's Location on the Map (own elaboration).

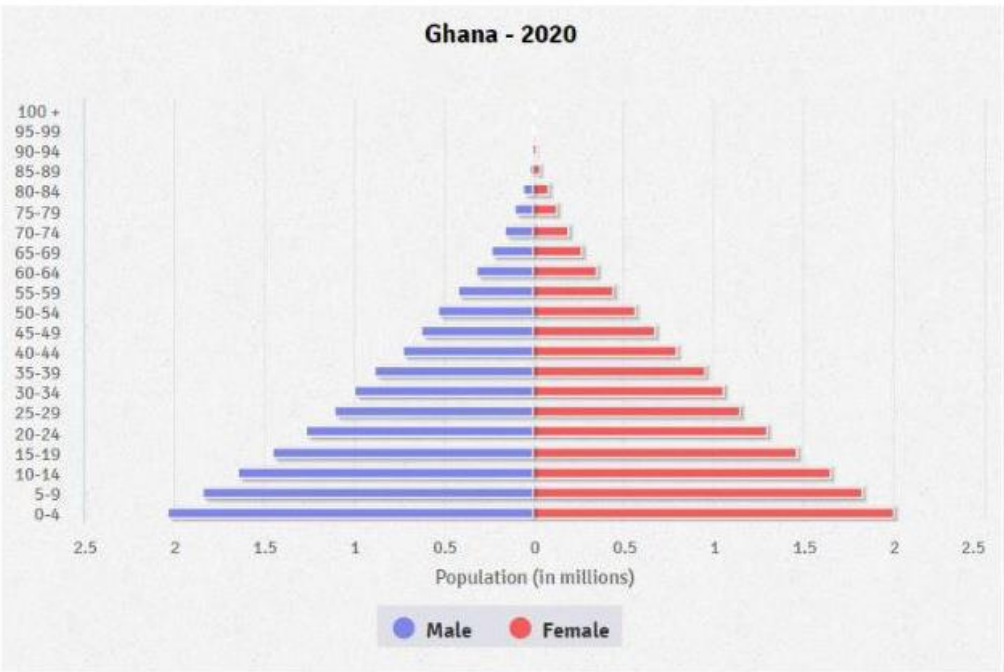

Figure 16. Ghana's Demographic Profile (CIA, 2020).

4.2 Ghana’s Electricity Profile

This chapter presents the latest statistics provided in April 2020 by the Energy Commission of Ghana in the report National Energy Statistics 2000 – 2019 (Energy Commission, 2020). All the references are related to that report unless otherwise mentioned.

The energy commission of Ghana made a strategic national energy plan 2006 – 2020 in the year 2006 to meet the targets of the Ghana Poverty Reduction Strategy (GPRS). The electricity related key challenges in the plan were:

- Rapidly growing demand in all sectors
- Risk of imbalance between the production and indigenous supply sources
- Inadequate investments due to the lack of capital
- Inefficiency of
    - End-use
    - Pricing of the services
    - Operational utilities
- Poorly commercialized solar energy possibilities

The plan proposed the 200 MW’s of wind power capacity installations to be commissioned by 2012 and being at the same level throughout the decade. (Energy Commission, 2006)

In the year 2019 the electricity generation capacity in Ghana was 5 172 MW and comparing the previous year, the annual growth rate was 6.2 %. The greatest part of the capacity is covered by thermal generation followed by hydro which covered 3 549 MW and 1 580 respectively in 2019. The total generated electricity was 18 189 GWh having increased 5 % from the previous year. The thermal electricity production covered 59.8 % of the total generated electricity, hydro having a share of 39.9 % as shown in **Figure 17** below.

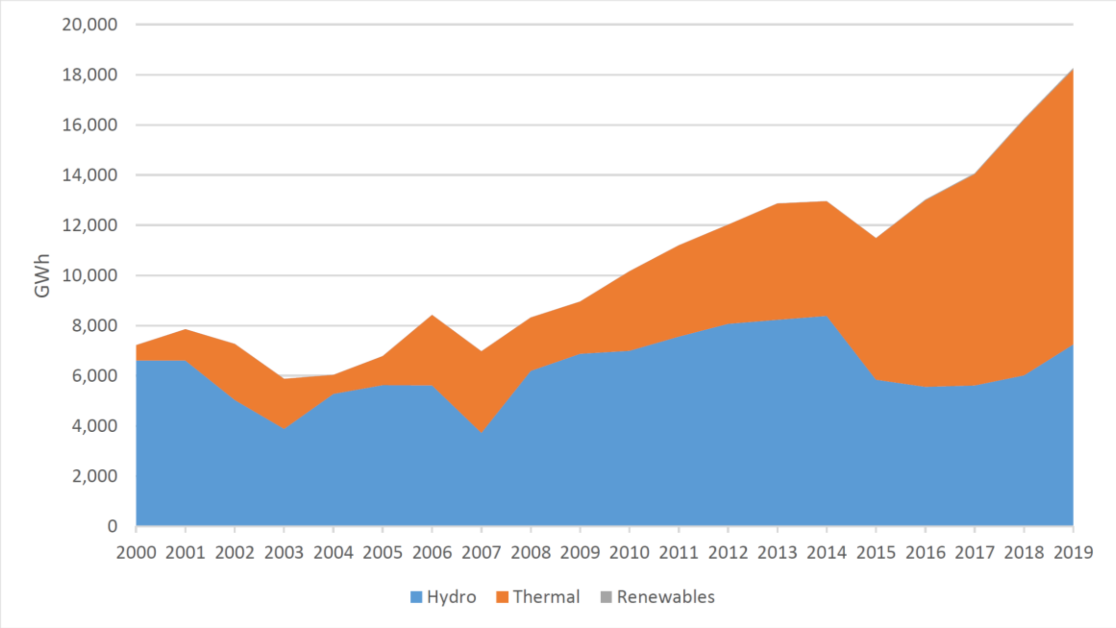

Figure 17. Trend in Grid Electricity Generation.

Renewable electricity generation capacity that is connected to the grid had increased from 2.5 MW in 2013 to 42.6 MW as at the end of 2019. When adding the off-grid and mini-grid installations, the renewable generation capacity was 78.6 MW in 2019. With new installations of an additional 40 MW of solar capacity and a 100-kW biogas plant the total renewable generation was 52 GWh by the end of 2019 being 0.3 % of the total electricity generated in Ghana. The mix of the renewable energy generation capacity is presented in **Table 4-1**. The only wind energy generation is the off-grid and mini-grid projects having 20 kW and 11 kW capacity respectively.

Table 4-1. Installed Renewable Generation Capacity (kW)

Year	Off-grid		On-grid				Mini-Grid		Installed
	Solar	Wind	Dist. SPV	Utility Solar	W2E	Hydro	Solar	Wind	
2013	-	-	495	2,500	-	-	-	-	2,995
2014	1,350	-	443	-	-	-	-	-	1,793
2015	4,003	20	700	20,000	100	4,000	256	11	29,090
2016	1,238	-	2,626	-	-	-	-	-	3,865
2017	678	-	4,266	-	-	-	58	-	5,002
2018	4	-	9,441	20,000	-	-	-	-	29,445
2019	-	-	6,426	-	-	-	-	-	6,426
TOTAL	**7,273**	**20**	**24,396**	**42,500**	**100**	**4,000**	**314**	**11**	**78,614**

NB: Dist. SPV = Distributed Solar PV; W2E = Waste – to – Energy

Source: Ministry of Energy & Energy Commission

The comprehensive list of the electricity generation of Ghana is presented in **Table 4-2**. Notable matter is that the Meinergy power plant is producing solar energy thus there is no on-grid wind power production at all in Ghana.

Table 4-2. Total Installed Generation Capacity at the end of December 2019

Plant	Installed Capacity (MW)	Dependable Capacity (MW)
Hydro		
Akosombo	1,020	900
Kpong	160	105
Bui	400	360
Total	**1,580**	**1,365**
Thermal		
Takoradi Power Company (TAPCO)	330	300
Takoradi International Company (TICO)	340	320
Tema Thermal 1 Power Plant (TT1PP)	110	100
Cenit Energy Ltd	110	100
Sunon Asogli Power (Ghana) Limited	560	520
Tema Thermal 2 Power Plant (TT2PP)	87	71.5
Kpone Thermal Power Plant	220	200
Karpowership	470	450
Ameri Plant	250	230
Trojan*	44	39.6
Genser*	95	85
Amandi	203	190
AKSA	370	350
Cenpower	360	340
Total	**3,549**	**3,296.1**
Renewables		
Safisana Biogas*	0.1	0.1
VRA Solar*	2.5	2
BXC Solar*	20	16
Meinergy*	20	16
Total	**42.6**	**34.1**
Grand Total	**5,171.6**	**4,695.2**

*Connected at the sub-transmission level

The final electricity consumption of all sectors in 2019 was 13 942 GWh. The residential share of the electricity consumed was 45.6 % followed by industrial sector having the share of 30.4 % representing 6 357 GWh and 4 242 GWh respectively. The consumption share of the service sector was 3 318 GWh (23.8 %). The growth of the consumption during the decade concentrates to the residential and the service sectors which were on the level of 2 026 GWh and 476 GWh respectively in the year 2000. **Figure 18** presents the shift of the consumption share during the last decade.

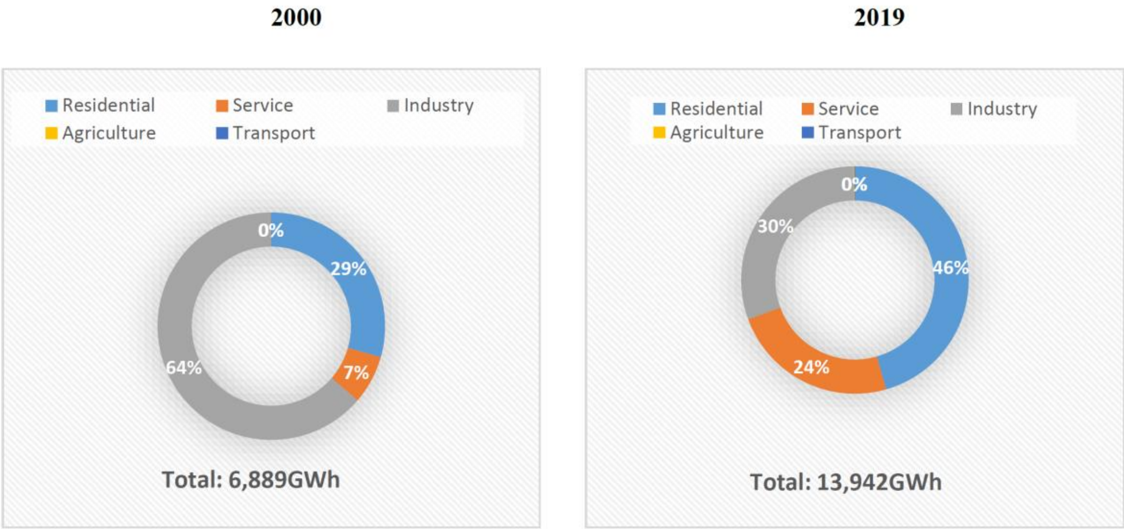

Figure 18. Electricity Consumption by Sectors in the Year 2000 and 2019.

Ghana was a net electricity exporter in the year 2019 likewise in the year 2018. The electricity import was 127 GWh and the export was 1 430 GWh. The electricity export in 2019 was higher than before during the last decade and it has exceeded 1 000 GWh limit only once in the year 2010 being then 1 036 GWh.

In the year 2019 85 % of total population of Ghana had access to the electricity corresponding 82.5 % national household electricity access. The electricity access is one of the key elements effecting to the country's division to the south and the north. The proportion of the households having the electricity access decreases when heading towards the north of the country as seen in **Figure 20**. Similarly, the number of highly populated cities decrease towards the north at the same time the number of off-grid villages increases as seen in **Figure 19** below.

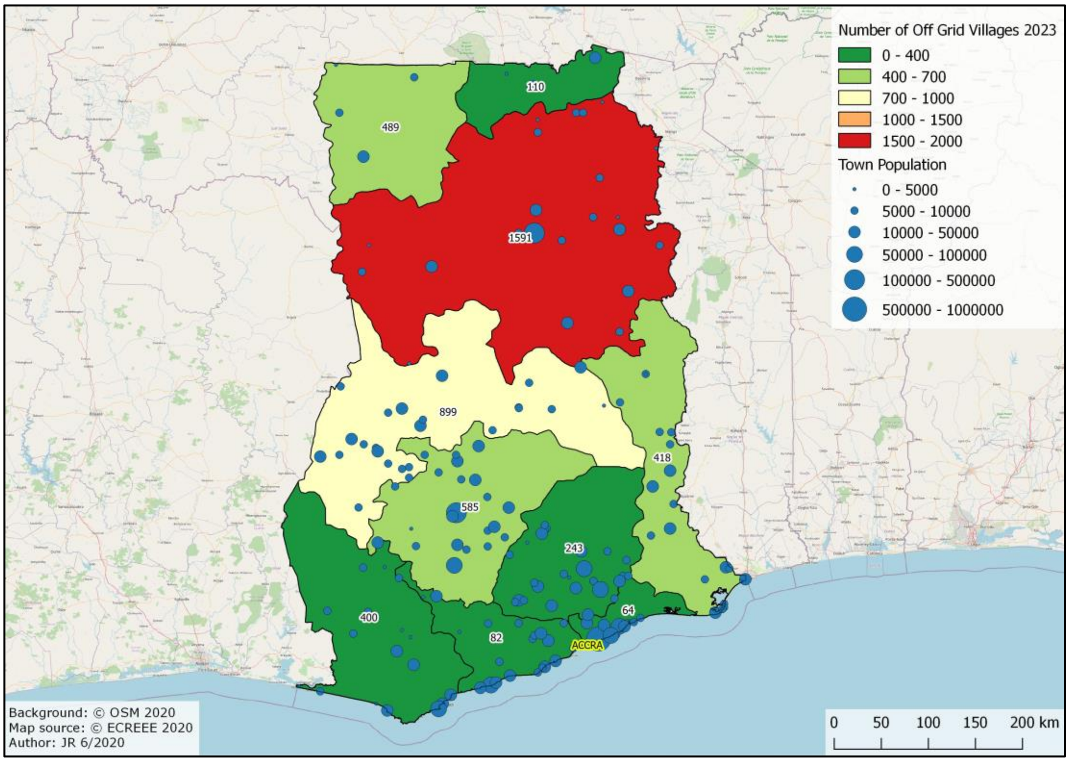

Figure 19. Number of Off-Grid Villages and the Most Populated Cities in Ghana (ECREEE, 2020).

Figure 20. Proportion of Households with Access to Electricity.

4.3 Wind Power Project Development

In this chapter, the wind power project development strategy for the target country is developed based on the country profile and the obligatory assessments needed to evaluate the feasibility of the project. The chapter is divided based on the assessment categories into wind assessment, grid capacity, environmental and land acquisition parts.

In the technical section of the study, the country is studied in the perspectives of the wind conditions and electricity grid capacity. The environmental part contains an evaluation of natural restrictions, that guides or restricts the wind power production in the specific areas. The part with land acquisitions covers the country specific characteristics and references.

Based on the previous studies described earlier in chapter 3.5, there is prefeasibility assessment data available for some parts of the country such as Kabu's (2016) research for the regions Greater Accra, Volta and Eastern and Safo's (2013) studies that were relaying on the governmental measurements in the coastal areas. There is also available data covering the whole country for specific topics such as wind speeds and protected sites (ECREEE, 2020). However, the different data sets have not been presented together in purpose of building a feasible wind power project.

4.3.1 Wind Assessment

In the technical perspective, the main feasibility indicator for a wind power project is the wind resource of the area. In the theoretical wind power generation calculation formula (Equation 1), the wind speed is raised to third power so seemingly insignificant wind speed change may be important for the project outcome.

For Ghana, there are several nationwide wind resource models that can be used in the prefeasibility phase of the project development. The models base their estimates to the actual short-term wind measurements and estimate the mean wind speeds at the modelled altitude with a reference to long term wind data, meso scale wind model and the topological datasets. In **Figure 21**, there is a wind speed estimates for 50 m altitude above ground level (ECREEE, 2020) and in **Figure 22** the estimates are presented at the altitude of 100 m (DTU Wind Energy, 2019).

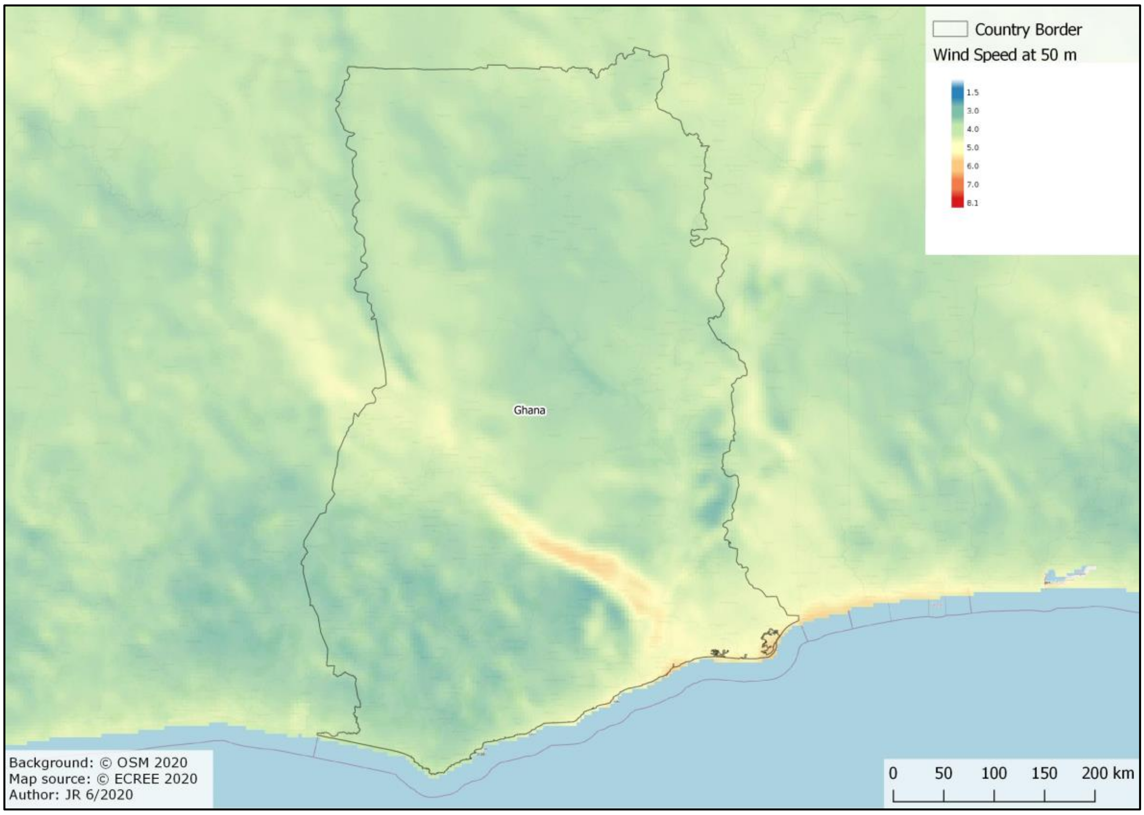

Figure 21. Nationwide Wind Resource Map at 50 m Altitude for Ghana (ECREEE, 2020).

The wind speeds have tendency to follow the ground elevation which is well seen in **Figure 22**. Also, a difference in the calculation resolution of the wind resource grid appears as a difference in the resulting wind maps.

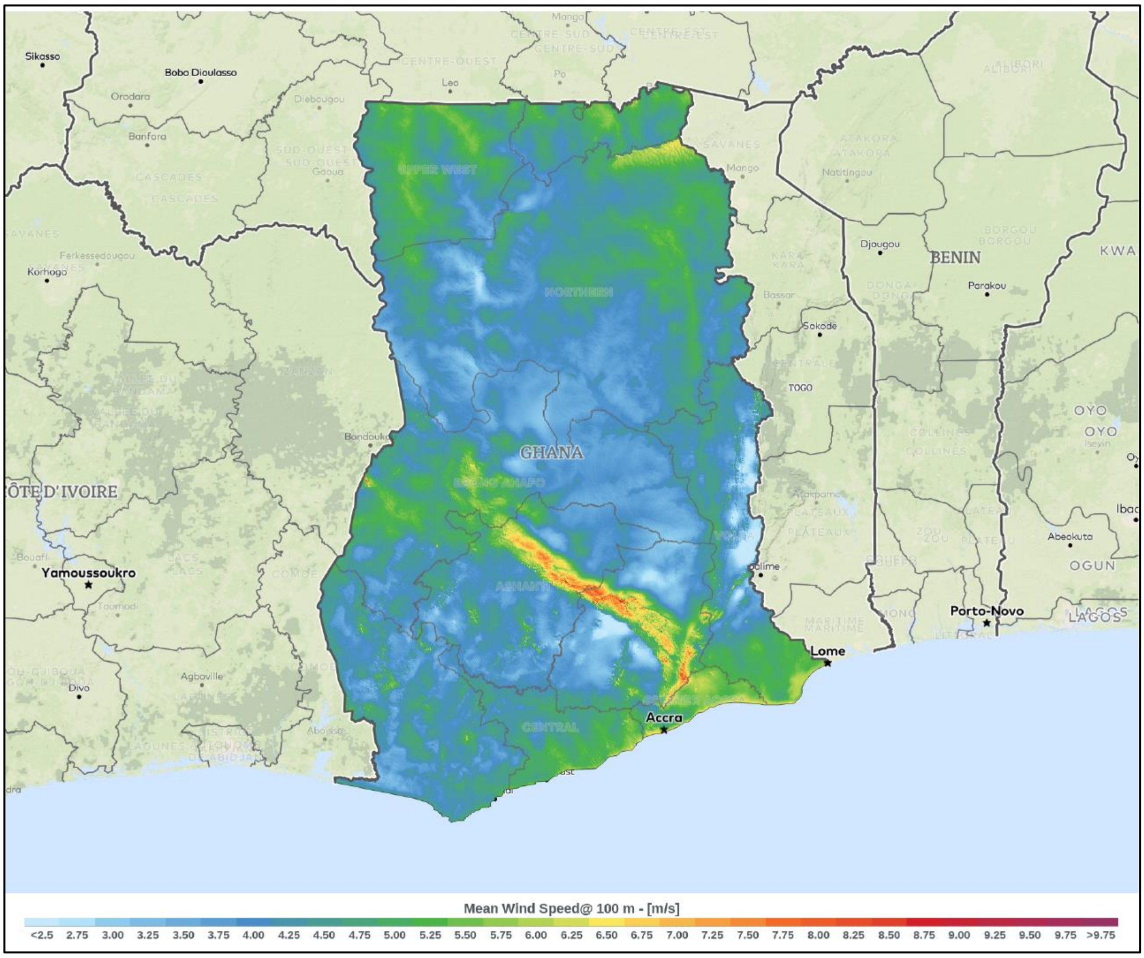

Figure 22. Mean Wind Speed at 100 m Altitude in Ghana (DTU Wind Energy, 2019).

These two large-scale wind speed estimates are used as a basis for the wind power project development strategy. It shall be regarded that the actual site-specific wind measurements together with the energy yield assessment will give the bankability input for the final investment decision. This takes place later in the permitting process.

4.3.2 Electricity Grid Capacity

As described earlier in **Table 4-1**, the installed wind power capacity is based on the stand-alone and mini-grid solutions. These off-grid systems help in the country’s electrification when the distances are long, and the generation is unevenly located around the country. The systems give solutions to challenges such as electricity cost and load variation due to length of the main grid. (Verma and Singh, 2013)

In this case study the focus is anyhow on the main grid, the national interconnected transmission system (**Figure 23**). Firstly, because the multimegawatt wind power projects demand a sustainable grid to be connected to ensure the return on investment by enabling the consistent electricity intake. Secondly, when the optimal wind power generation areas are widely spread around the country, the main grid follow to more distant location enhancing the democratic electrification.

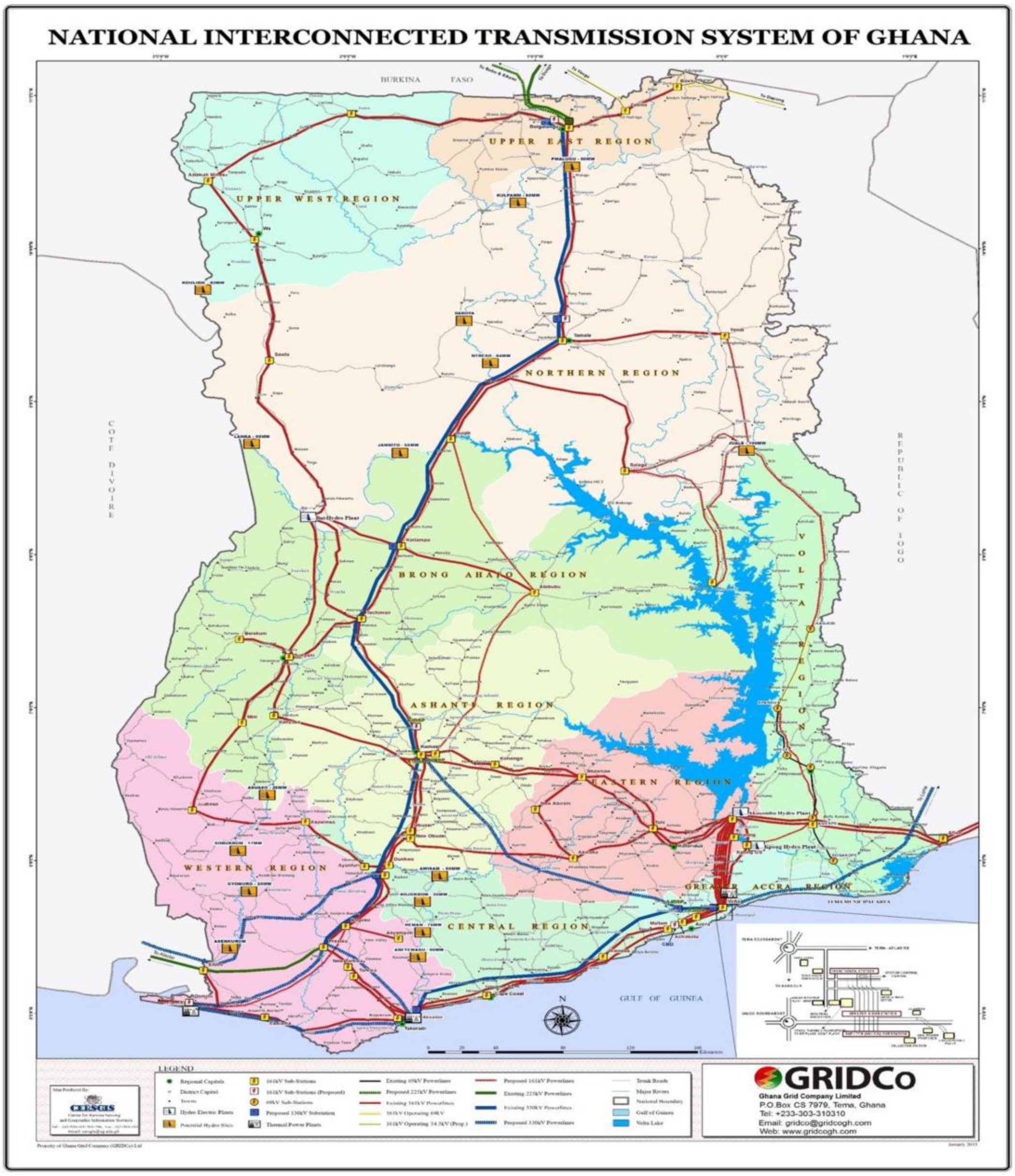

Figure 23. The Existing and the Proposed Transmission System of Ghana (Energy Commission, 2019).

As the population is concentrating to the south of the country, the electricity grid is more widely spread there as well. There are proposed grid extensions in the southern regions but also in the east, in Volta Region and Northern Region. Anyhow, for example the relatively big city of Damongo, in the east of Northern Region, remains outside the main grid among few others.

The distances from the existing electricity grid is investigated with the spatial analysis and the wind power projects are proposed based on the results. The primary distance buffer is 10 km and secondary buffer is 20 km from the existing grid. The motivation for different buffers is that when the project's capacity increases the longer grid connection are possible without decreasing the project feasibility. The result of the buffer analysis is presented in **Figure 24** below.

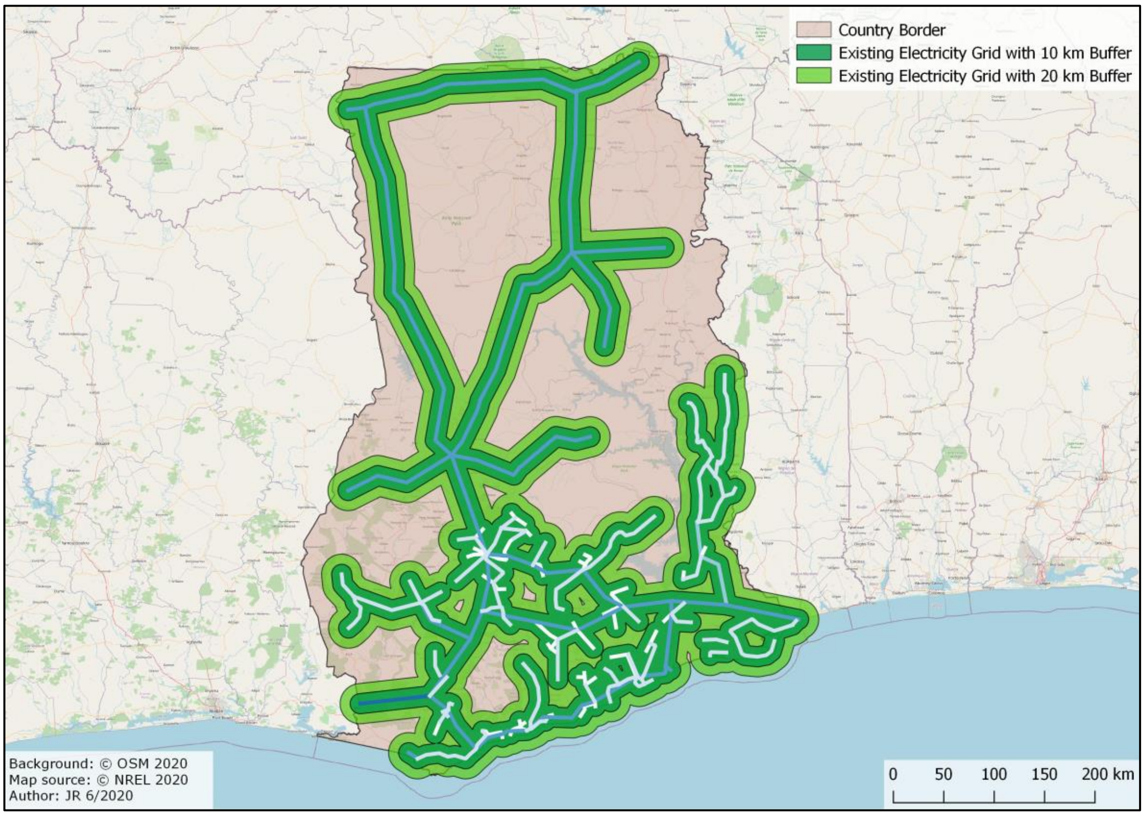

Figure 24. The Result of the Spatial Analysis Based on the Existing Electricity Grid (NREL, 2020).

4.3.3 Environmental Assessment

The Ghanaian environmental policies rely on the Environmental Protection Agency Act 1994 (Act 490) and the Environmental Assessment Regulations (1999) which together makes the framework of the governmental governance of i.e. wind power project development. The legislation describes the scope of reporting and permitting processes in detail. However, the actual governmentally supervised environmental impact assessment (EIA) takes place later in the project development together with the municipal planning and, thus, it is out of the scope of this research.

In this case study the focus is on the recognized natural protection areas that are accessible for the whole country. The most extensive data is collected for NREL by the Ghana Energy Commission in the year 2005 (NREL, 2020). This dataset contains both the water and land bodies and is presented in **Figure 25** below.

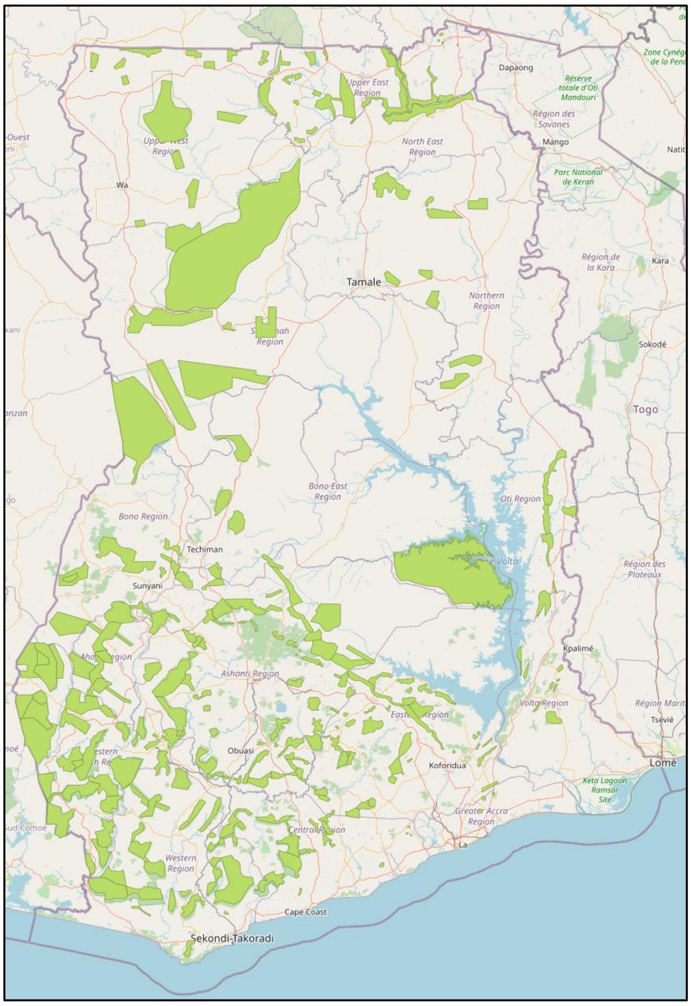

Figure 25. Protected Areas of Ghana Marked with a Green Colour (NREL, 2020).

The social impact assessment shall be made in conjunction with the actual EIA, but social risks shall be considered throughout the project development process, i.e. when it comes to land acquisition that is discussed in the following chapter.

4.3.4 Land Acquisition Assessment

In the early phase of the project development, the land use rights shall be clarified and agreed. Based on the recent study by Boamah and Amoako (2019), the Ghanaian legal land system has its challenges. They argue that the state places itself both between and outside the statutory planning laws and same applies for the customary authorities. This causes a paradox enabling for example authorities to lease the same land to several developers. Thus, the importance of the secured land acquisitions is highlighted throughout the project development process.

Emmanuel Mate-Kole (2018) summarizes the impregnable and indefeasible land certification process into these six steps:

1. Conduct a search at the Land Use and Spatial Planning Authority
2. Conduct a search at the Lands Commission
3. Conduct a litigation check
4. Confirm whether the seller has a good title or an indefeasible title
5. Buy land from authorized persons and obtain the requisite consents
6. Register the land

The legislation related to the land acquisitions are the Land Title Registration Act 1986 (PNDCL 152) and the Land Registry Act 1962 (Act 122).

However, for the project development purposes the land could be and perhaps primarily should be rented instead of buying. In this case the most important step is to check the validity of the land certificate with the help of authorities. This approach would also mitigate the social impacts of the projects by improving social acceptance with the local participation.

4.4 Wind Power Project Development Portfolio

The wind power project development portfolio is made based on the socio-economical input of the country profile and the technical information and analysis explained earlier having the theoretical framework as the basis.

The portfolio creation is established as a greenfield project development framework where all the areas can be totally new to infrastructural land use. However, the exact local land use status is not studied for this research.

Safo (2013) classified the wind scale of Ghana as presented in **Table 4-3**. The lowest limit for the moderate wind regions was 6.4 m/s at 50 m altitude and an approximation of this limit is also applied for this case study. It shall be noted that the technical development of the wind turbines has been exponential during the last decade when it comes to the blade and tower dimensions; thus the capacity estimates in the previous studies are estimated to be on a low side.

Table 4-3. Wind Scale of Ghana Wind Resource Data as Presented by Safo, 2013 (NREL)

Wind Resource Scale	Wind Class	Wind Power at 50 m W/m^2	Wind Speed at 50 m m/s*	Total Area km^2	Percent Windy Land	Total Capacity (MW)
Moderate	3	300 – 400	6.4 – 7.0	715	0.3	3,575
Good	4	400 – 500	7.0 – 7.5	268	0.1	1,340
Very Good	5	500 – 600	7.5 – 8.0	82	<0.1	410
Excellent	6	600 – 800	8.0 – 8.8	63	<0.1	315
					Total	5,640

In **Table 4-3** above, the wind speeds are based on a Weibull k value of 2.0 and basic assumption is that installed capacity per square km is 5 MW, total land area of Ghana being 230 940 square km. (NREL)

5 DATA COLLECTION

In this chapter, the data from the previous chapters is summarized and described together with the methods to generate an applicable format for the analysis. The actual outcomes are presented afterwards in the chapter 6. The list of the data is:

- Previous case studies' quantitative information
    - Power generation capacity
    - Geographical differences
    - Wind speed estimates
- Socio-economical and technical input of the country profile
    - Population spread
    - Electricity grid capacity
    - Power consumption
- Geospatial databases
    - Wind speed databases
    - Protected natural areas
    - Topographic database

Firstly, the quantified information from the previous studies is referred as mentioned in the source without further manipulation. This data was used to motivate portfolio's component selection.

As throughout the paper, the spatial analysis tool and map creation tool is QGIS-software (2020). The geographical information system (GIS) data has been downloaded from the web map services (WMS), the web feature services (WFS) as well as directly from the service data providers web pages.

The GIS data was gathered into the software and the formats and coordinate reference systems (CRS) were translated into the uniform systems. The data was further analyzed with different geoprocessing tools to i.e. clip and difference the layers to get the desired output. The following **Figure 26** visualizes the processes.

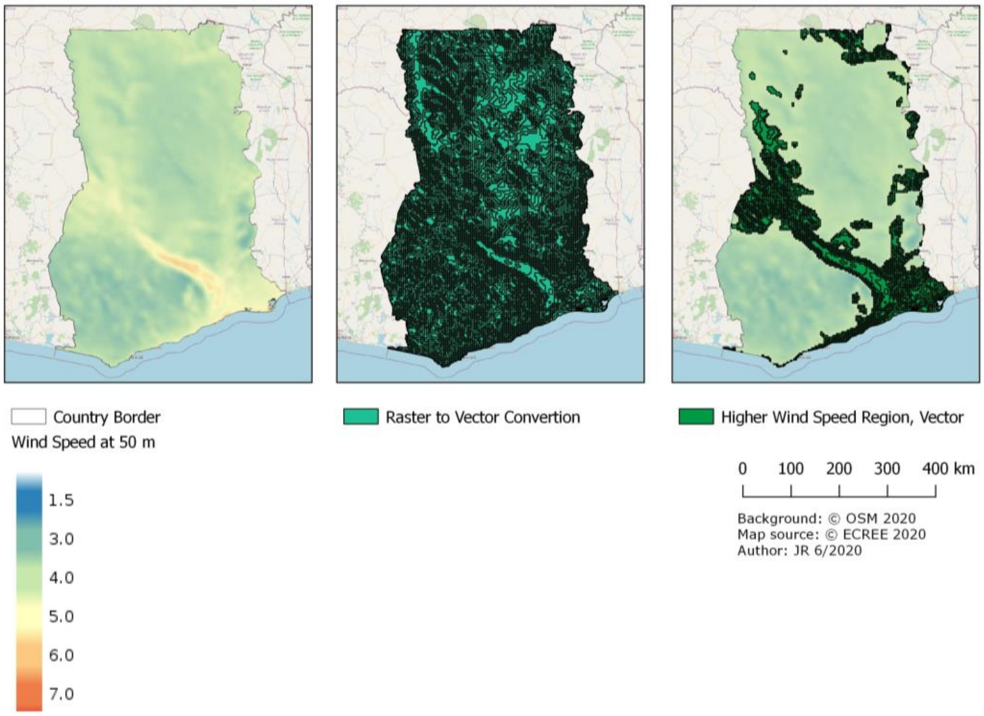

Figure 26. Raster to Vector Conversion and Clipping the High Wind Speed Region (own elaboration).

Figure 26 presents the wind map for the whole country (ECREEE, 2020) first in the raster format being converted into vector format and further clipped to cover only moderate and above wind speed regions based on Safo (2013).

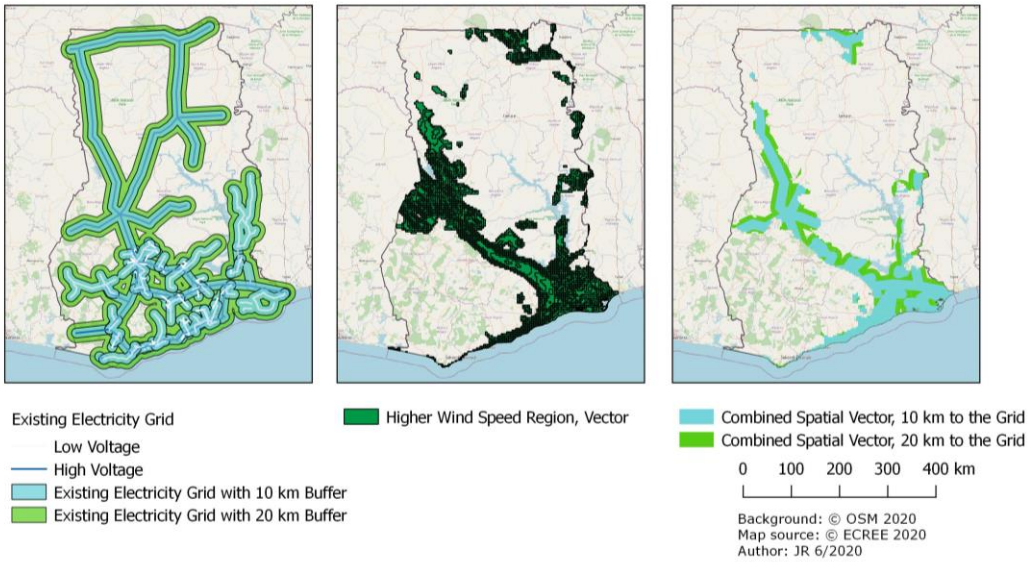

Figure 27. Buffer Analysis and the Layer Combination (own elaboration).

In **Figure 27** above the ECREEE (2020) data of existing electricity grid network was first buffered with 10 km and 20 km distances and then clipped to cover the high wind speed regions.

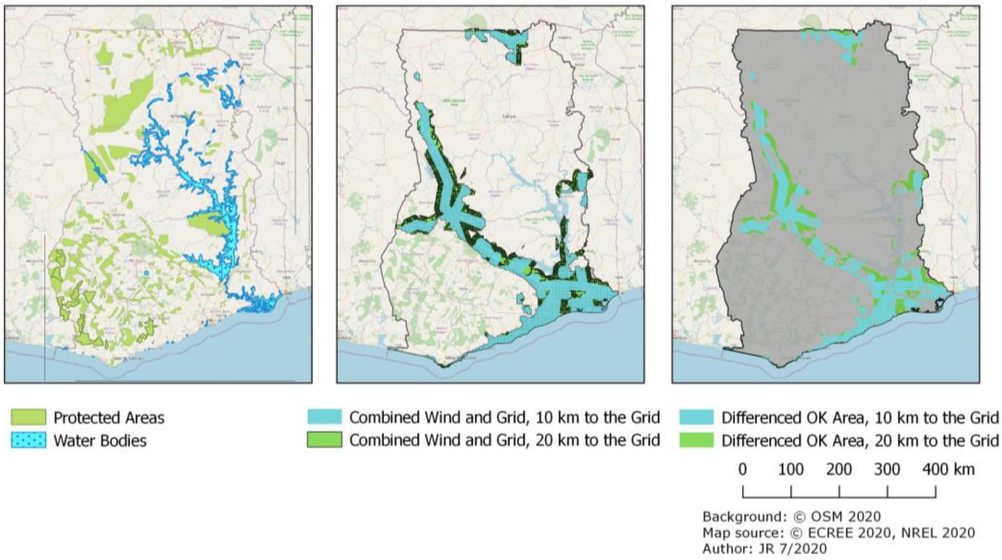

Figure 28. Differencing the Layers (own elaboration).

The resulting layers were differentiated with the protected area and water area data (NREL, 2020) to get the final layer with the possible areas for the wind power projects. The result is presented in **Figure 29** together with the road network.

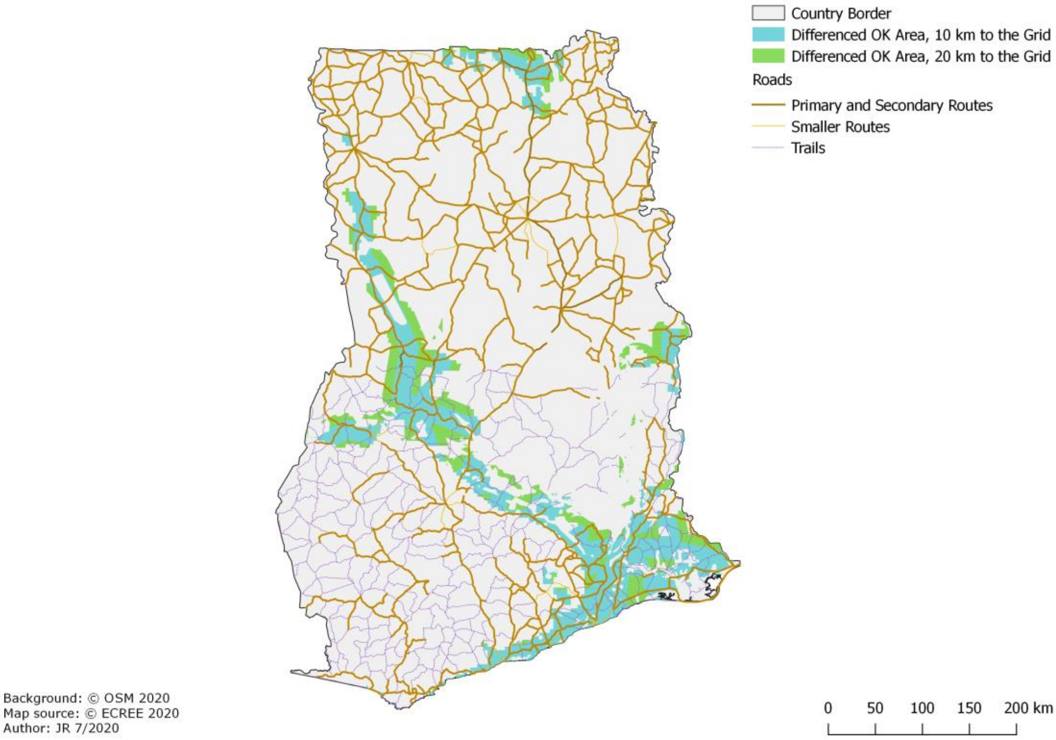

Figure 29. Higher Wind Speed Regions Close to the Grid with the Roads (own elaboration).

6 RESULTS

The case study results are presented in this chapter. The research questions are answered, and the topics are further explored.

The first part of the case study presented the country profile of Ghana, the target country. It is clear that the Ghanaian government has now and has had throughout the past decade a clear vision and roadmap towards the sustainable society by providing democratic prospects for everybody to have access to a stable electricity grid and produce the electricity in the most sustainable way from the techno-commercial perspective (Energy Commission, 2016). The latest statistics show the trend of growing electricity consumption, yet the new generation renewable generation is conspicuous by its absence from the current capacity (Energy Commission, 2020).

The results of the analyses in the case study show that there are regions with higher than moderate wind speeds within a feasible distance to the existing electricity grid. **Figure 30** below shows the higher wind speed regions of Ghana, close to the electricity grid in relation to the existing roads and the mostly populated cities. As introduced in the country profile, the country is polarized into the north and south by the population but interestingly the electricity grid and the high wind speed regions follows the belt of highly populated cities from the south-east coastal area towards the north-west, the region of Brong-Afaho via Eastern and Ashanti regions. The feasible area continues towards north by the eastern country border to the Northern region almost until the Upper West region. There are additional areas in the Upper East and Volta regions that could be harnessed into the wind power generation. Moreover, besides the good wind region in the coastal area, the offshore option is noted when creating the wind power project development portfolio.

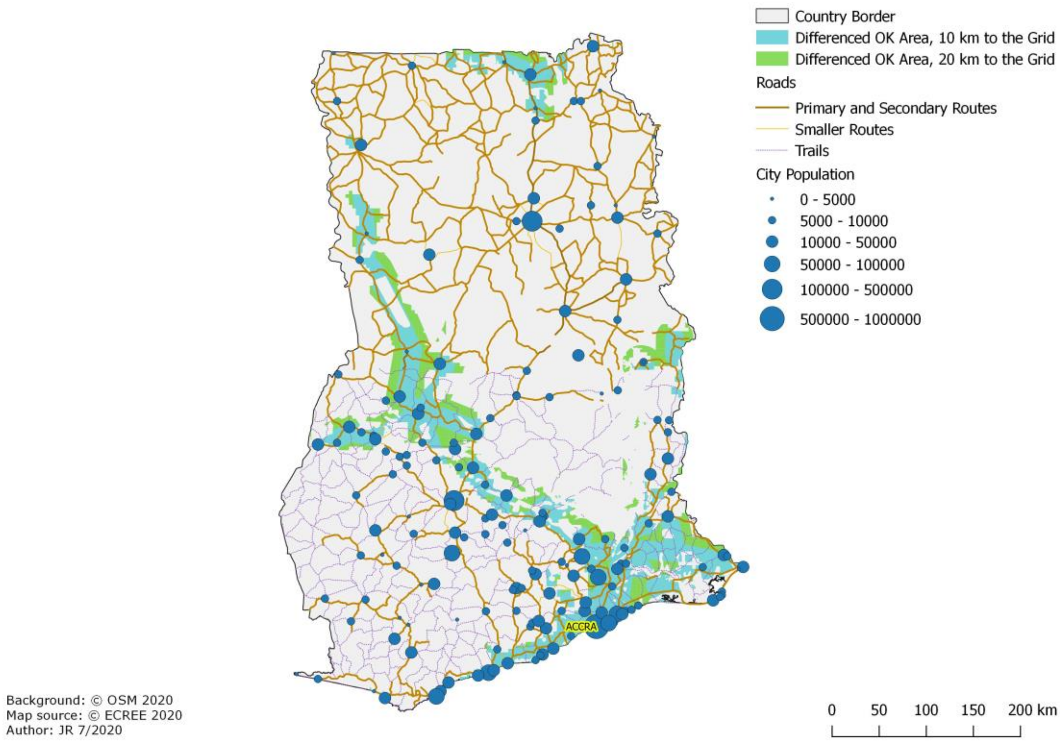

Figure 30. Higher Wind Speed Regions Close to the Grid with the Roads and the Population (own elaboration).

RQ1. In what way the project portfolio management theory shall be implemented to the wind power project development portfolio?

When it comes to the theoretical framework of the portfolio creation most of the actual PPM activities takes place after the actual project initiation thus cannot be implemented in this case study. Decision making is in the important role when approaching the project portfolio proposal in the organizational perspective but Enoch's (2015) model is more applicable when there are already clear objectives to be evaluated. However, by choosing the objectives in the national or regional perspective i.e. providing electricity to a certain area or improving the grid stability or covering the grid losses, the model could be implemented in this case study's decision making as well. Additionally, Chaves-Schwinteck (2013) summarizes in her research that diversification of the project portfolio effects positively to both the portfolio's total investment and the internal rate of return.

Choosing the right projects to the portfolio is crucial for the project success. That is because of the traditional target of risk decentralization in the modern portfolio theory (Baker and Filbeck, 2013), but also due to the fact that the projects may turn out to be unfeasible at any phase of the project. Therefore, the portfolio needs a critical mass of projects in it and the pre-feasibility studies described in the theoretical study shall be conducted in a proper way.

As the answer to the first research question, the theory-based management of projects and portfolios starts when the actual processes are initiated, and the implementation requires the organizational structure.

When considering the wind power projects, the wind resource is the most vital element in the total feasibility being also the most determining uncertainty for the investment decision. Therefore, the significance of the feasibility shall be emphasized in the process of creating a wind power project development portfolio, but also the fact that with the geographical diversification, the uncertainties of the wind speeds can be optimized. Additionally, the technological risk can be minimized by diversifying the wind turbine types and manufacturers of the portfolio. However, as Chaves-Schwinteck (2013) concludes, the portfolio theory does not provide the comprehensive solution to the uncertain assets as wind farms but gives a tool for the diversification and the rest of the risk assessment strategies requires further research.

As a summary of the answer to the first research question, **Figure 31** is presented. In here, the theoretical implications are separated into the pre-feasibility study and the feasibility study phases.

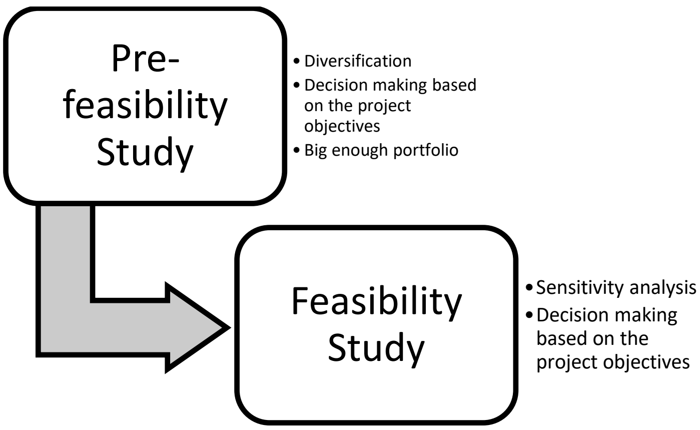

Figure 31. The Essential Theory Implementation to the Project Phases (own elaboration).

RQ2. How does the wind power project development portfolio look like in the case study market area?

As a result of the case study, total of 12 projects (**Table 6-1**) were found and proposed to the wind power project development portfolio. The projects' locations are presented in **Figure 32**. Project 1 is located in the Greater Accra region and projects 2 and 3 are in the Central region. Projects 4 and 5 are in Eastern and Ashanti regions respectively whereas 6 and 7 are both in Brong-Ahafo region. Project 8 is the only one in the vast Northern region and projects 9, 10 and 11 are in the Volta, Upper West and Upper East regions respectively. The additional project 12 is a generalized offshore project that could be located at the coastal area of Greater Accra or Central regions.

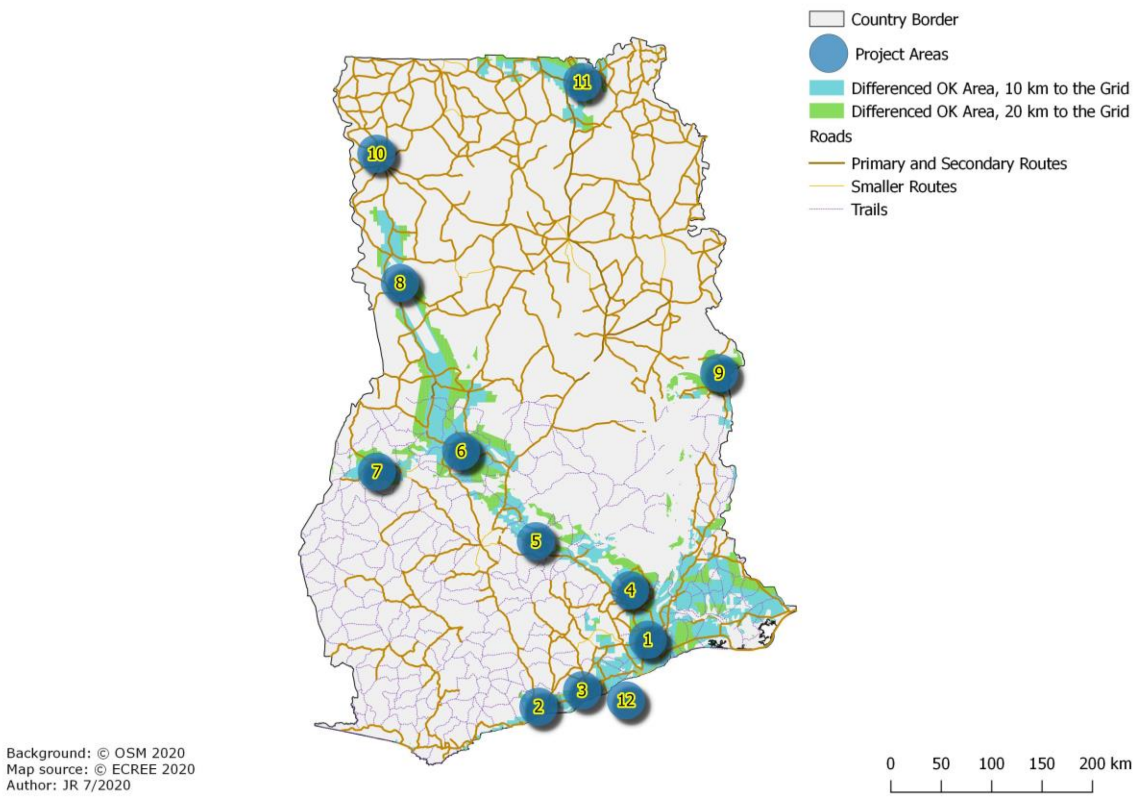

Figure 32. Wind Power Project Development Portfolio on the Map (own elaboration).

The project 1 is the one located closest to the capital city of Accra. This area is one of the highest wind speed areas throughout the country surrounded by also other highly populated cities such as Tema, Teshie and Koforidua. However, the project is located further away from the urban areas to mitigate the social impacts as well as the environmental impacts to the urban residences. The high voltage electricity grid is less than 10 km away from the area thus the grid connection is initially evaluated to be feasible. The challenge for this project is the relatively closely located Akosombo Dam as the hydro power was still in the end of 2019 producing 40 % of the Ghanaian electricity (Energy Commission, 2020).

Projects 2 and 3 are located close to the coastline in the Central region. The Energy Commission of Ghana (2014) made three of their wind measurement campaigns in this area the years 2011 and 2013. The measurements were located rather close to the coastline but to the estimated national wind resources (ECREEE, 2020; NREL, 2020) propose higher wind speeds when approaching the inland, which is most probably due to the higher elevation. Based on this as well as increasing the distances to the urban areas the projects are located approximately 10 km from the coastline and close to the existing electricity grid.

Project 4 is even closer to the Akosombo Dam than project 1 thus it is phasing the same challenges. Additionally, some parts of the higher elevated area from Eastern to Ashanti region is protected and may therefore restrict project area to some extent. In the other hand, the strengths are the strong electricity grid and high wind speed region as well.

In the Ashanti region, approximately 50 km from the city of Kumasi is located project 5. Project is surrounded by smaller towns and strong grid is placed close to the area. There are same challenges with the protected sites as for project 4 but the wind speeds are relatively high.

In the Brong-Ahafo region, there are two projects proposed, projects 6 and 7. Wind speeds are slightly reducing when heading towards north from the Ashanti region, but being still on moderate level for project 6. This area is close to the city of Techiman again, less than 10 km from the existing grid. Project 7 is as well close to the existing grid but the area anyhow isolated from the main grid heading to north close to project 6. Therefore project 7 is proposed to be planned as a mini-grid or off-grid project since there are several moderately populated cities around the area.

Project 8 is the only project in the Northern region located close to the city of Bole and there is another bigger city, Damongo, approximately 50 km to the east. This project is still less than 10 km from the electricity grid, but the possibility of mini-grid or off-grid shall be taken into consideration when planning the project.

In the mountains of Volta region close to the border of Togo, there is project 9. The closest city is Dambai approximately 30 km from the project area. The area is located closer than 10 km from the existing electricity grid but is worth noticing that there are plans for the grid extension from Volta region to Northern region towards the city of Salaga (Energy Commission, 2019). In the case of grid extension, the region would become more populated and the project would benefit the grid stability and answer to the growing demand.

Project 10 is located approximately 10 km from the city of Wa which is the biggest city in the Upper West region. Even though the northern part of the country is not as densely populated as the southern part, the democratic electricity demand shall be fulfilled, and this project is the most potential to do it in the Upper West region. Alternatively, the demand could be covered with the generation of the project 11 that is located to the Upper East region, approximately 200 km from the project 10 and only 10 and 60 km away from the cities of Bolgatanga and Bawku respectively. Additionally, close to the project 11, there is a grid connection to Burkina Faso which may be a point of electricity export in case needed.

All in all, the onshore wind power development projects are scattered around the country within the best wind regions and feasible distance to the existing electricity grid. All other regions got at least one project proposal except the Western region in the south-west of the country. Western region has an extensive electricity grid network with a connection to Côte d’Ivoire, but the wind speeds are relatively low due to low elevations. Also, the majority of the Northern region was left empty without a project specially the region around the city of Tamale due to fact that even with the strong electricity grid, the wind speeds are lower than in the regions of the proposed projects.

Even though the data of the analysis only produced the result for potential onshore wind project areas, project 12, possible offshore project is presented to the project portfolio. As introduced in the chapter 2, the wind turbine technology is evolving fast and new innovations i.e. in the field of green hydrogen are developed thus the feasibility of the offshore projects may increase significantly in the coming years. This together with the better social acceptance may lead to success of project 12.

Now, with all the 12 projects, the portfolio components presented the wind power project development portfolio is ready for the further analysis. Through the detailed pre-feasibility studies, the project areas may be concluded as infeasible but also the areas may be shifted slightly or more to avoid the impacts or to improve the efficiency.

The geographical risk of the portfolio was mitigated by choosing the portfolio components from different regions. Political and initial social risks were assessed in through the data of the country profile and thus mitigated to some extent. However, these risks together with the financial risk shall be identified and managed after the project initiations.

Due to the qualitative nature of this research, the quantitative capacity estimates for the projects or the portfolio are not presented similarly as in the previous studies. Once again, the technological development of wind turbines as well as the local circumstances are changing rapidly thus not of interest nor in the scope of this research. Rather, the results show the proposal of the portfolio and further studies will declare the final executed capacity.

Table 6-1. Summary of the Projects (own elaboration)

Project #	Location	Strengths	Weaknesses
1	Tema, Greater Accra / Akwapim North, Eastern	High wind speeds Close to the electricity consumption	Predominant electricity generation, the Akosombo Dam, is located relatively close
2	Abura-Asebu-Kwamankese, Central	Close to the electricity consumption Good electricity grid capacity	Relatively low wind speeds
3	Gomoa, Central	Close to the electricity consumption Good electricity grid capacity	Relatively low wind speeds
4	Yilo Krobo / Fanteakwa, Eastern	High wind speeds Good electricity grid capacity	Predominant electricity generation, the Akosombo Dam, is located close to the project area Possible natural restrictions
5	Asante Akim North, Ashanti	High wind speeds Good electricity grid capacity	Possible natural restrictions
6	Techiman / Nkoranza, Brong Ahafo	Good electricity grid capacity	Relatively lower wind speeds
7	Berekum, Brong Ahafo	Possibility for an off-grid solution Smaller cities around the project area	Relatively lower wind speeds
8	Sawa-Tuna-Kalba, Northern	Possibility for an off-grid solution	Relatively low electricity consumption
9	Nkwanta, Volta	Possible grid extensions upcoming to the project area	Relatively low electricity consumption
10	Nadowli / Wa West, Upper West	Beneficial for the democratic electricity consumption	Relatively low electricity consumption
11	Talensi Nabdam / Bolgatanga, Upper East	Grid connection to Burkina Faso	Relatively low electricity consumption
12	Offshore	High social acceptance Possibility for new technical solutions	Relatively lower wind speeds

7 CONCLUSIONS

7.1 Theoretical Contribution

Appropriate project and portfolio management are essential elements for creating a successful project portfolio. When it comes to project management theory, the actual processes start from the project initiation process where the project charter is developed and the stakeholders are identified (PMI, 2017; SFS, 2012). The case study of this paper takes place just before the actual projects are initiated and therefore the project management theory as described in the standards cannot be implemented. However, by acknowledging the risk and stakeholder management in the early phase pre-feasibility study as in this case, the project initiation and the portfolio component selection is more efficient.

The same applies for the project portfolio management theory but interestingly the results directs the focus to the organizational management and the strategy creation of the organization. Choosing the portfolio components and making the decisions whether they concern the components, or the objectives shall be concentrated in the organizational context and shall chronologically take place in the early phase of the portfolio creation.

In the case study of this thesis the theory of the portfolio diversification was applied. As Chaves-Schwinteck (2013) noted the relation between the diversification and the portfolio performance indicators the early phase risk mitigation is likely to have a positive impact in the portfolio performance. However, the impact of the applied theory is not seen before the final phases of the project development process.

7.2 Practical Contribution

The result concluded the wind power project development portfolio of 12 projects in the target country Ghana. The data was analyzed more extensively than in previous researches covering the whole country and with a perspective of modern industrial wind power technology.

The results present a premise for commercial stakeholders to start fulfilling the national renewable energy generation roadmap’s demands and for the local officials the possible areas for marketing their wind power potential to be acknowledged in the national strategy.

Moreover, the national grid operator can utilize the results in improving grid stability in the weak spots of the grid and possibly encouraging the development of the mini-grid and off-grid wind power solutions in the process of electrifying the 100 % of the nation.

Why then, there are no active wind power projects in Ghana even if the result presents a positive insight for the industrial wind power market?

In the perspective of the electricity generation, the demand has been covered mainly with thermal and hydro generation and the national renewable strategies have been relaying on the major generation by Akosombo hydro plant. However, the Lake Volta is located only in the southeastern part of the country and the distribution needs long and strong electricity grid. Additionally, the electricity demand has been growing throughout the past decades as seen in **Figure 18** and if the trend stays the same the additions to the generations has to be planned. Finally, the wind conditions in the Sub-Saharan Africa are relatively poor compared to the North or South African regions, thus the business cases of the wind power production have not been equally tempting in Ghana.

The result of the 12 projects portfolio is founded on the facts presented in the chapter 2.1. The wind power is globally declared as a cheapest form of electricity production. This is partly due to the ideological and political shift of mindsets driven by the fight against the climate change. The main reason is though the fast, technological development of the wind turbines and rapidly applied project and portfolio management methods both in the technical and financial sides of the projects. All these together enables wind power projects to win the renewable energy auctions all over the world. The Ghanaian market can be part of the development with the country specific solutions such as large industrial wind power plants, smaller mini-grid solutions or fully independently operating off-grid solutions.

7.3 Limitations and Further Research

The case study is restricted to the data available and referenced at the moment of reporting. There is no financial aspect or feasibility analysis made for the portfolio components.

The technology of wind power plants is developing so fast that the research within the industry is inevitably following behind. Therefore, the results of this study shall be assessed again when the actual project work is started.

This fact also leaves a room for further research – since the wind industry as well as the energy sector as a whole is in a continuous shift towards renewable world, the markets shall be re-studied after a while. The while may be a short period of time and yesterday's infeasible project area may turn out to be a success story of tomorrow.

7.4 Conflict of Interest

This research is conducted completely independently thus there are no conflicts of interest.

REFERENCES

Baker, H. K., & Filbeck, G. 2013. Portfolio Theory and Management. Oxford University Press.

Bapat, S. 2020. PMP Prep: Project Governance and the relationship between Project, Program, and Portfolio management. Accessed on 12.6.2020. https://pmpgurukul.com/2020/04/26/pmp-prep-project-governance-and-the-relationship-between-project-program-and-portfolio-management/

Boamah, E. F., Amoako, C. 2019. Planning by (mis)rule of laws: The idiom and dilemma of planning within Ghana's dual legal land systems. Accessed on 23.6.2020. https://journals.sagepub.com/doi/10.1177/2399654419855400

Chaves-Schwinteck, P. 2013. The Modern Portfolio Theory Applied to Wind Farm Investments. University of Oldenburg.

CIA. 2020. Africa, Ghana Factbook. Accessed on 17.6.2020. https://www.cia.gov/library/publications/the-world-factbook/geos/gh.html

ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE). 2020. Accessed on 16.6.2020. The WMTS and WFS Interfaces at http://www.ecreee.org/

Energy Commission, Ghana. 2006. Strategic National Energy Plan 2006 – 2020.

Energy Commission, Ghana. 2014. Summary Results of Wind Energy Resource Assessment at 8 Locations Along the Coast of Ghana Conducted by the Energy Commission under Gedap/Moep. Ghana. Accessed on 29.6.2020.

Energy Commission, Ghana. 2019. 2019 Electricity Supply Plan for Ghana Power System. Ghana. Accessed on 21.6.2020. http://www.energycom.gov.gh/files/2019%20Electricity%20Supply%20Plan.pdf

Energy Commission, Ghana. 2020. National Energy Statistics 2000 – 2019. Accra, Ghana.

Enoch, C. N. 2015. Project Portfolio Management: A Model for Improved Decision Making: Vol. First edition. Business Expert Press, LLC. New York.

Environmental Assessment Regulations. 1999. Ghana. Accessed on 23.6.2020. http://www.epa.gov.gh/ghanalex/acts/Acts/ENVIRONMENTAL%20ASSESSMENT%20REGULATION,1999.pdf

Environmental Protection Agency Act. 1994. Act 490. Ghana. Accessed on 23.6.2020. http://www.epa.gov.gh/ghanalex/acts/Acts/ENVIRONMENTAL%20PROTECTION%20AGENCY%20ACT%201994.pdf

Finnish Standards Association SFS (SFS). 2012. SFS-ISO 21500, Guidance on Project Management. Helsinki, Finland.

GhanaWeb. 2020. Background Information about the Country Ghana. Accessed on 17.6.2020. https://www.ghanaweb.com/GhanaHomePage/country_information/

Global Wind Energy Council (GWEC). 2020. Annual Wind Report 2019. Published 25 March 2020. Brussels, Belgium.

Huopainen, P. 2014. Emotional Intelligence and Multicultural Project leadership in Finnish-Chinese MNC Context. Lappeenranta University of Technology. School of Business.

ILX Group plc. 2017. PRINCE2 Process Model. Updated 2017 Version.

Irena. 2020. Renewable Capacity Statistics 2020. Accessed on 10.6.2020. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Mar/IRENA_RE_Capacity_Statistics_2020.pdf

Kabu, I. 2016. Wind Farm Site Selection Assessment in the Greater Accra, Volta and Eastern Regions of Ghana: A GIS Spatial Multi-Criteria Assessment. Norwegian University of Science and Technology, Faculty of Natural Sciences and Technology, Department of Geography. Trondheim, Norway.

Land Registry Act. 1962 (Act 122). Ghana

Land Title Registration Act. 1986 (PNDCL 152). Ghana

Martinsuo, M. 2012. Project portfolio management in practice and in context. International Journal of Project Management 31 (2013) 794–803. ScienceDirect.

Mate-Kole, E. 2018. What you need to know about land ownership in Ghana. GhanaWeb. Accessed on 24.6.2020. https://www.ghanaweb.com/GhanaHomePage/features/What-you-need-to-know-about-land-ownership-in-Ghana-702623

Measnet. 2016. Evaluation of Site-Specific Wind Conditions. Version 2, April 2016.

Mingyang Smart Energy. 2020. Accessed on 28.6.2020. http://www.myse.com.cn/en/cplb/info.aspx?itemid=578

Ministry of Power, Ghana. 2015. National Renewable Energy Action Plans. Accra, Ghana. Accessed on 11.6.2020. https://www.se4all-africa.org/fileadmin/uploads/se4all/Documents/Country_PANER/Ghana_National_Renewable_Energy_Action_Plans.pdf

National Renewable Energy Laboratory (NREL). Wind Energy Resource Mapping Activity. United States Department of Energy. Accessed 21.6.2020. http://en.openei.org/datasets/files/717/pub/ghanawindreport_245.pdf

New Line Technologies. 2017. Project Management Process Groups. Accessed on 13.6.2020. https://newline.tech/wp-content/uploads/2017/12/1a.jpg

Nordex SE. 2020. Accessed on 27.6.2020. https://www.nordex-online.com/en/news-media/blog/

Project Management Institute, Inc. (PMI). 2017. A Guide to the Project Management Body of Knowledge (PMBOK Guide). Pennsylvania, USA. Sixth Edition.

QGIS Development Team. 2020. QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.osgeo.org

Safo, P. 2013. Wind Power Plant Potentials in Ghana. Vaasa University of Applied Sciences. Vaasa.

Siemens Gamesa Renewable Energy, S.A. 2020. Accessed on 28.6.2020. https://www.siemensgamesa.com/en-int/newsroom

Skillsvault. Organizational State Transition. Accessed 12.6.2020. https://skillsvault.com/wp-content/uploads/2020/03/change-of-state-pmp.png

Technical University of Denmark (DTU Wind Energy). 2019. The Global Wind Atlas. Accessed on 22.6.2020. https://globalwindatlas.info/

Verma, R. K., & Singh S.N. 2013. A Review of Mini-Grid Used for Electrification in Rural Area. Indian Institute of Technology Roorkee, Alternate Hydro Energy Center. Roorkee, India. Accessed on 23.6.2020. http://iasir.net/AIJRSTEMpapers/AIJRSTEM13-239.pdf

Vestas Wind Systems A/S. 2020. Accessed on 27.6.2020. https://www.vestas.com/en/media/company-news?y=2020&l=22#!article-3703592