WIND FARM REPOWERING
A STRATEGIC MANAGEMENT PERSPECTIVE

Dissertation in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE WITH A MAJOR IN ENERGY TECHNOLOGY WITH
FOCUS ON WIND POWER

UPPSALA
UNIVERSITET

Uppsala University
Department of Earth Sciences, Campus Gotland

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2015-06-15
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Approved by:

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Examiner, Heracles Polatidis

2015-06-15
ABSTRACT

With an estimated wind turbine service life of 20-25 years, it is evident that in the coming years, an increasing number of wind farm owners will have to make a decision between decommissioning and repowering their wind farms. Even though repowering is underlined with a highly complex decision making process, a review of the literature suggests that it is mainly regarded as an engineering feat with a lack of discussion in the strategic and project management context.

The objective of this thesis is to provide a framework that demonstrates the applicability of fundamental strategic and project management concepts on repowering and present a new perspective on this activity with a relatively short and promising history. In an effort to accomplish this, an extensive literature review analyzed different aspects of repowering through the lenses of strategic and project management. These concepts were then combined into the Repowering Strategic Project Management (RSPM) framework to guide the decision maker in selecting and implementing the optimal repowering strategy by establishing a repowering project early in the existing wind farm’s operational life.

The RSPM framework presents a step-by-step guidance tool that demonstrates the process from envisioning an optimal end of service life (EOSL) solution to the repowering execution. In an effort to verify its suitability, the framework has been implemented, demonstrating the wide range of aspects the decision maker has to take into consideration suggesting that an early development of the repowering strategy and its corresponding project could help the owner to repower the wind farm in the most time-efficient manner. Lastly, while the thesis did not emphasize the evaluation and selection of strategy, the implementation of the RSPM framework provided guidelines for these tasks.

Key Words: Wind Farm Repowering, Repowering Strategy, Strategic Management, RSPM Framework, Wind Power Project Management.
ACKNOWLEDGEMENTS

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Last, but certainly not least, a huge thank you goes to my parents Suzana and Zoran, and to my sister Maša. Without their love and support, I would not have been able to spend a fifth of my life living and studying abroad. Volim vas.
## NOMENCLATURE

<table>
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<tr>
<th>Acronym</th>
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<tbody>
<tr>
<td>AWS</td>
<td>AWS Scientific, Inc. (now AWS Truepower)</td>
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<td>BNEF</td>
<td>Bloomberg New Energy Finance</td>
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<td>CalWEA</td>
<td>California Wind Energy Association</td>
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<td>CEC</td>
<td>California Energy Commission</td>
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<td>DECC</td>
<td>Department of Energy &amp; Climate Change</td>
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<td>DENA</td>
<td>Deutsche Energie Angentur</td>
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<tr>
<td>EOSL</td>
<td>End-of-service life</td>
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<td>EWEA</td>
<td>European Wind Energy Association</td>
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<td>GWEC</td>
<td>Global Wind Energy Council</td>
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<td>IEC</td>
<td>International Electrotechnical Commission</td>
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<td>IRENA</td>
<td>International Renewable Energy Agency</td>
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<td>LWFL</td>
<td>Lincs Wind Farm Limited</td>
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<td>NREL</td>
<td>National Renewable Energy Laboratory</td>
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<td>OSPAR</td>
<td>OSPAR Commission</td>
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<td>PMI</td>
<td>Project Management Institute</td>
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<td>UK</td>
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<td>US</td>
<td>United States of America</td>
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<td>WWEA</td>
<td>World Wind Energy Association</td>
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1 INTRODUCTION

Chapter 1 will lay foundations for the thesis and provide the reader with the necessary background and terminology to follow and assess the subsequent chapters. The chapter will introduce research problem and objectives accompanied by its justification. Lastly, the introduction will briefly describe the methodology, delimitations and key assumptions.

1.1 History and Background

1.1.1 Repowering History

With the exception of the year 2013, the global annual installed wind capacity has been consistently rising over the last two decades, with major increases in the past decade (Figure 1). This growth has been in large part attributed to the substantial improvements in wind power technology as a result of an increase in the size of wind turbines and improved knowledge in wind resource modeling and wind farm design (del Río et al., 2011).

Figure 1. Global Annual Installed Capacity.
Source: GWEC, 2015.
The technological developments that lead to the increase in capacity and size of turbines have contributed to a repowering boom in the first decade of the 21st century in Denmark, Germany, Spain, and California (Ibid.). Repowering origins can be traced back to the early 1990s in California and Denmark, after whom Netherlands and Germany followed in the 1990s and 2000s (Lantz et al., 2013), as well as Spain with the approval of Royal Decree 661 in 2007 (del Río et al., 2011).

Repowering has proven itself as a good onshore solution for increasing the power production whilst reducing the number of wind turbines (WTs), and the biggest accomplishments have been witnessed in Denmark and Germany. During the first phase of the Danish early repowering program, between 2001 and 2003, 1480 WTs with a total capacity of 122 MW were replaced with 272 new WTs with total capacity of 332 MW (BWE, 2010, cited in Ortegon et al., 2012). Meanwhile, the amendment of the Renewable Energy Law in 2004 that provided incentives for repowering projects marked the start of wind farm repowering in Germany (WWEA, undated). By 2007, 108 old turbines had been replaced by 45 new ones. The new turbines increased the total output by 2.5 despite the reduction, from 41 MW to 103 MW (Goyal, 2010). While a review of the literature provides no examples of offshore repowering, the market for it is estimated to emerge around 2021 in Germany (VDMA, 2005, cited in Hulshorst, 2008). Even though the history of repowering started in California with the scraping of the first and second generation of wind turbines of the oldest plant and resale of usable plant in 1993 (WWEA, undated), the state has not been successful in developing a strong repowering market due to a variety of policies and regulatory challenges (Lantz et al., 2013).

1.1.2 Strategy and Scenario History

Strategy has a long history, mainly in a military context, with Alexander the Great being one of the main examples of its inception. However, the term can be traced even further back with initial interpretations referring to a role of a general and ‘the art of the general’, while its origins as a managerial skill are linked to the time of Pericles, around 450 BC (Mintzberg et al., 1998). Strategic management has a drastically shorter
history that dates to 1979, when Schendel and Hofer (1979) redefined the field of business policy as strategic management and proposed a new school of thought centered on the concept of strategy upon which extensive research has been done in the field (Nag et al., 2007).

The concept of scenarios is also traceable to the writings of early philosophers, such as Plato, and visionaries such as Thomas More to George Orwell (Bradfield et al., 2005). On the other hand, scenario planning in the context of a strategic planning tool, besides its military roots, can be traced back to the period after the Second World War. After the war, RAND Corporation's Hermann Kahn introduced the idea of "future-now" thinking, where the aim was to produce a futuristic report through the use of detailed analysis and imagination. The term "scenario" was added to these stories and introduced by writer Leo Rosten (Ringland, 1998). Scenario reached a new dimension in the early 1970s with the work of Pierre Wack, who was a planner in the London offices of the international oil enterprise Royal Dutch/Shell and its Group Planning department, which focused on looking for events that might affect the price of oil (Schwartz, 1996).

1.2 Research question

A review of the literature demonstrates the general lack of discussion of wind farm repowering in a project management context. The paper will not attempt to analyze why this has been the case, but rather address the many critical repowering questions that will be of interest to the wind power industry.

This research addresses three basic questions:

- Can repowering be analyzed from a strategic management perspective?
- What tools and concepts can the fields of strategic management and project management offer to the wind power industry and specifically to repowering?
- Besides the theoretical links and implications, can these tools be utilized in practice?
The objective of this paper is to demonstrate the applicability of fundamental strategic and project management concepts on wind farm repowering and present a new perspective on this activity with a relatively short, yet promising history.

1.3 Justification

As many authors contend, a general estimate of wind turbine’s service life is approximately 20-25 years (Giovannini, 2014; Hulshorst, 2008; Lantz et al., 2013), while repowering has been deemed economically viable only after 15 or more years of operation (IRENA, 2012). Having taken all of this into account and re-assessed the historical installation trends from Figure 1, it can be inferred that repowering will be a topic of many discussions in the years to come. In fact, research shows that repowering will present a significant market in the US and Europe over the course of the following 15 years as a result of many existing older turbines being located in sites with great wind resources (BNEF, 2011). Moreover, the majority of repowering investment in the US is expected to occur in the second half of 2020s (Lantz et al., 2013).

As wind farm repowering projects promise to grow both in number and size, so will the complexity of their underlying decision making processes. The existing literature on repowering has observed it primarily as an engineering process, with secondary focus on its economics, environmental aspects, and policy issues. While all of these focus points are important, the lack of a strategic project management perspective comes as a bit of a surprise, as this and its related fields can offer a lot of useful tools and concepts that can be used to facilitate repowering activities. Even though repowering activities could be over a decade away for some wind farms, the magnitude of work involved in transitioning from an old to a new wind farm requires long range planning, extensive project management skills, and an implemented program to enable a seamless transition by addressing it in both current and future management regimes.

The coming urgency in global repowering in the coming five to ten years presents an opportunity to address the project management issues now and fill some of...
the existing void. Ultimately, this thesis aims to provide a strategic framework for wind farm repowering that will serve as the foundation for forward thinking decision making processes in anticipation of the end of the wind farm's lifetime. Furthermore, it could serve to justify or refute the option of repowering, and if repowering is indeed justifiable, the framework could be extended to fit the needs and characteristics of wind farms of interest.

1.4 Methodology

The literature review, in Chapter 2, will serve as the cornerstone of this paper as it will provide a wide overview of relevant strategic and project management concepts and demonstrate their interdependencies and applicability to wind farm repowering. The methodology in Chapter 3 will outline the tools and methods that will be used to expand on this theoretical foundation.

1.5 Outline of the report

The outline of the thesis is as follows: Chapter 2 will review the literature; Chapter 3 will present the methodology for utilizing the concepts covered in the literature review, whereas Chapter 4 will implement the developed methodology. Further, Chapter 5 will provide discussion and analyze implications, and finally Chapter 6 will conclude the paper and offer recommendations. It is worthwhile noting that the chapters are interdependent modules of information and should be followed in their respective order to track the overarching themes and implications.

1.6 Definitions

A review of literature shows inconsistencies in project and strategic management terminology, with a plethora of terms, such as plan and strategy, or project and program management, being used interchangeably and often indiscriminately. Since this paper relies heavily on this type of terminology, some basic definitions will be provided for two reasons; first to set a standard for the use of these terms, and second, to enable the
reader to follow the remainder of the paper more comfortably. However, the author does not claim that the choice of definitions is the only correct interpretation and acknowledges the existence of other interpretations.

1.6.1 Project Management vs. Program Management Definitions

A project is a temporary endeavor undertaken to create a unique product or service. Furthermore, projects are often implemented as a means of achieving an organization's strategic plan by responding to the requests that cannot be addressed within the organization's normal operational limits (PMI, 2000). Project management is "the planning, monitoring and control of all aspects of a project and the motivation of all those involved in it to achieve the project objectives on time and to the specified cost, quality and performance (BS 6079-1, 2000; cited in Gardiner, 2005).

On the other hand, a program denotes a group of projects managed in a coordinated way to obtain benefits not available from managing them individually (PMI, 2000). Program management¹, like project management, is aimed at achieving change in a controlled manner, but in a continuous, often repetitive mode of operations. Despite the interchangeable interpretations, the key distinction is that a project has a definite beginning and end, whereas a program is an ongoing undertaking with new projects joining and existing ones finishing (Gardiner, 2005).

1.6.2 Strategy-oriented Definitions

Common and seemingly casual use of the term strategy in literature implies many interpretations, but strategy is generally defined as “a plan of action or policy in business or politics” or “a general plan or set of plans intended to achieve something over a long period” (Hawkins & Le Roux, 1986; University of Birmingham, 1995).

According to Teece (1990), “strategic management can be defined as the formulation, implementation, and evaluation of managerial actions that enhance the

¹ In its original version, the term was written as ‘Programme management’, since the author (Gardiner, 2005) used British English. For the purposes of this paper, this and several other terms will be transferred to American English.
value of a business enterprise”. On the other hand, Jemison (1981) claimed that “strategic management is the process by which general managers of complex organizations develop and use a strategy to coalign their organization’s competences and the opportunities and constraints in the environment” (Teece, 1990, Jemison, 1981; both cited in Nag et al., 2007).

Strategic planning is "a set of decision rules which guide the company's resource allocation process, taking into account both the short and long term, with emphasis on allocating resources in uncertain conditions to achieve future objectives. The company which uses a form of strategic planning does not simply react to events in the present, but considers what should be done in order to achieve future objectives" (Scott, 1997, cited in Gardiner, 2005).

1.6.3 Scenario Definitions

According to (Porter, 1985), a scenario is “an internally consistent view of what the future might turn out to be – not a forecast, but one possible outcome” (Porter, 1985, cited in Ringland, 1998). One of the definitions of scenario planning describes it as “that part of strategic planning which relates to the tools and technologies for managing the uncertainties of the future” (Ringland, 1998).

1.7 Delimitations of scope and key assumptions

Given the absence of opposing information in the literature search, the key assumption is that having a repowering strategy and its corresponding program is not a common practice in the wind power industry. The author acknowledges the possibility that this strategy exists but is being kept confidential for competitive advantage or other purposes.

As part of its strategic management perspective, this paper will focus on strategic management activities that lead to strategy evaluation and subsequent implementation. The paper will also address the relationship between strategic and project management and link the corresponding processes while keeping them in a repowering context. Tools
for strategy evaluation and implementation framework will be presented, but the actual evaluation and implementation processes are multi-sequential in nature and outside the intended scope of this paper, as these activities require confidential site-specific information.

1.8 Conclusion

Chapter 1 laid the foundations for the thesis. The research questions have been introduced and addressed in concert with the justification of the research. In order to help the reader follow the subsequent chapters, key definitions and delimitations of scope have been presented along with the outline, and historical background was provided to set the theme and put the topics in a time perspective. The paper continues with the conceptual overview of key concepts in Chapter 2.
2 LITERATURE REVIEW

2.1 Introduction

The aim of Chapter 2 is to build a theoretical foundation that will support further analysis by reviewing relevant literature. However, while the literature search provides numerous examples of repowering installations it reveals no specific project-centered past or current case studies of wind farm repowering project strategies. Nevertheless, conceptually segmenting the topic and explaining the parts individually can achieve the necessary theoretical foundation. Specifically, concepts of strategy and strategic management will be fundamentally analyzed and consequently put into a repowering context.

2.2 Repowering and Decommissioning

At the end of service life of wind turbines, there are two possible outcomes, repowering or decommissioning (Ortegon et al., 2012). Both outcomes have two main alternatives – partial and full, and both are governed by policy and procedure of the country where the wind farm is located. Partial repowering refers to replacing selected turbine or plant components to extend the life of a given facility, and full repowering entails complete dismantling and replacement of turbine equipment at an existing project site (Lantz et al., 2013).

Full repowering has historically been the more prominent choice which is understandable given the rapid advancements in wind turbine technology. For example, in 2005, a wind turbine could have had a nominal power of 3 MW and a hub height of 105 meters, whereas modern turbines can have nominal power of up to 8 MW with a 149-meter hub height (DENA, undated). If the focus of repowering lies strictly in optimum turbine performance and maximum profit, a higher hub height is desirable, as it places the rotor of a wind turbine in stronger and more consistent winds, thereby increasing the number of operational hours per year (Jha, 2011).
Some of the key drivers of onshore repowering have been higher capacity and production efficiency, lower investment costs, second-hand turbine market, O&M costs, and risks (del Rio et. al., 2011). Even though a literature search does not provide examples of offshore repowering to date, these drivers are generally applicable to the offshore industry. More analysis is needed regarding the second hand market and risks since the condition of offshore turbines at the end of their service life has not been investigated and the complexity of these projects involves a great deal of risk. Onshore turbine siting comes with an increased level of social issues since these turbines are sometimes placed quite close to inhabited areas.

Securing the plausibility of decommissioning as an end-of-service life (EOSL) outcome has been common practice in countries such as Canada, Italy, Germany, Sweden, UK, and the US, in turn this is generally accomplished by requiring the owner-operator to submit a decommissioning program when applying for a construction permit and establishing a decommissioning bond (Drew, 2011; Giovannini, 2014; Kaiser & Snyder, 2012; LWFL, 2010; OSPAR, 2008; Stecky-Efantis, 2013).

Since some form of decommissioning is necessary for repowering to occur, the term ‘Decommissioning for Repowering (DfR)’ is introduced for the decommissioning outcome wherein the wind farm is repowered. This term is based on the assumption that some procedures, namely the activities that are not related to the turbine removal might differ from regular decommissioning as means of performing this activity in the most effective way. For example, the repowering plan for Taff Ely wind farm outlines that the “farm site will be reinstated to its pre-wind farm condition as far as practicable, and in accordance with an agreed Habitat Restoration/Management Plan” (RWE Innogy, 2012). The main purpose of the term DfR is to help the reader make a distinction between decommissioning that leads to repowering and decommissioning that implies the end of wind farm's lifecycle. Even though DfR precedes repowering, the two activities should be seen as interdependent, since the type of decommissioning can affect repowering plans, and the decision to repower can affect how decommissioning is performed.
Due to the regulations governing the post-operational norms, decommissioning, in whatever form, is inevitable. The choice of whether or not to repower is the result of a complex decision making process that depends on both its feasibility and the company’s long-term business strategy. The complexity of the process suggests that reaching the decision can take a considerable amount of time, and if the company is interested in repowering, timing becomes another crucial variable. In order to avoid delays when transitioning from the old to the new wind farm, this decision making process should be planned to commence in a timely manner so that the decision is executed on schedule. A review of the literature shows no evidence of this being the case, but the author acknowledges the possibility of companies having a repowering strategy that is kept confidential for competitive advantage or other purposes.

2.3 Strategy

Strategy, from a managerial perspective, can take five different forms - intended strategy, realized strategy, deliberate strategy, unrealized strategy, emergent strategy (Figure 2). *Intended strategy* combines an organization’s aspirations with its plans for future actions. *Realized strategy* reflects on past events and demonstrates organization results regardless of its initial intentions. *Deliberate strategy* refers to elements of intended strategy that become realized. *Unrealized strategy* explains the plans that never materialize. *Emergent strategy* explains the unplanned developments that take shape over time without specific initiation. (Mintzberg and Waters, 1985, cited in Miller, 1998).
Putting this into a repowering strategy context, the path from the intended strategy, or the initial repowering idea, to the realized strategy, or the outcome after the old wind farm has been decommissioned, is seen as the result of the unrealized strategy, or setbacks, and emergent strategy, or unplanned developments, to the deliberate or general strategy that is being developed throughout the project’s lifetime.

### 2.4 Strategic Intent

Rational planning can be understood as a process or a system for logically approaching the task of identifying the ends an organization pursues and determining the means by which those ends can be reached. Furthermore, the ends of an organization can be "stacked" in a hierarchy and the collection of ends being pursued by an organization is its strategic intent (Miller, 1998).

Strategic intent envisions a desired leadership position and establishes the criteria that the organization will use to chart its progress, but it also encompasses an active management process. While strategic intent is clear about ends, its means can be flexible since current capabilities and resources might not suffice, consequently forcing the organization to make the most of limited resources (Mintzberg et. al, 1998).
In order for an organization to successfully pursue its goals, it needs to have a consistent set of narrow intentions that progress into broader intentions. These intentions can be achieved by shaping the values, motives and actions of others throughout the organization. This progression is best illustrated in a hierarchy of strategic intent, which has five main elements - vision, mission, goals, objectives, and plans, see Figure 3 (Miller, 1998).

2.5 Hierarchy of Strategic Intent

Vision is an articulation of a company's desired future and two of its key functions are to give the company direction and serve as the basic premise for the success of mission statement (French, undated). Mission, generally expressed in the form of a mission statement, establishes the overarching purpose of the organization (Gardiner, 2005). Similar to the notion of how mission statements are more specific than the vision, goals attempt to improve an organization's performance by making mission statements more concrete (Miller, 1998). The role of objectives is to link the mission of
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the organization with the operational scene, and translate its purpose into a series of operational goals (van der Heijden, 1996). These operational goals represent the bottom level of the hierarchy of strategic intent, or the plans that are used to accomplish higher-level intentions (Miller, 1998).

The hierarchy of strategic intent can differ considerably depending on the life cycle phase of a project. For an operating wind farm, the vision would be establishing the optimal EOSL solution. The choice of the optimal solution would have to satisfy all of the relevant stakeholders, towards whom a firm has a social responsibility, and not merely the stockholders towards whom it has a fiscal responsibility (Miller, 1998). Assuming favorable conditions, the company's mission would be to continue production and repower the wind farm in the most effective way, since the company could keep generating revenue from the said wind farm. For this mission statement to be achieved, a company would have to set a goal of choosing the optimal type of repowering, either partial or full repowering. Consequently, in order to materialize the mission, certain repowering alternatives would have to be considered to identify the available alternatives, which would be the objective in the hierarchy. Lastly, all of the mentioned levels would have to be supported by the plans where the alternatives would be evaluated, the appropriate strategy chosen and implemented in order to achieve the intended mission.

2.6 Strategic Management

With the understanding of strategic intent and its importance in an organization, the focus can shift to a related concept of strategic management. The key difference from strategic intent is the absence of vision, however, most visions are not written statements and they become more tangible in the form of a mission statement (Miller, 1998). Strategic management has been a widely researched topic with numerous theories that can be split into three main schools of thought on how managers view them - rationalist, evolutionary and processual; with rational paradigm being the most popular since the
largest part of the strategy literature and reporting reflects this point of view. Some of the main assumptions underlying the rationalist school are (Mintzberg, 1990; van der Heijden, 1996):

- Predictability, with no outside interference
- Clear intentions
- Implementation follows formulation, while independent of action
- Full understanding throughout the organization
- Reasonable people will do reasonable things

The strategic management process can be split into two main portions, the strategic planning process and the implementation process (Deresky, 2014). A key part of strategic management is strategic programming, which entails planning how the deliberate strategy can best match the realized to the intended strategy, and in accordance to the rational paradigm, it can be split into strategy formulation and strategy implementation (Miller, 1998). On the other hand, strategy formulation process is part of the strategic management process in which most firms engage (Deresky, 2014). Due to the interchangeable nature of specific terminology and the overlap between the concepts, the difference between strategic programming, strategic planning, and strategic management can be challenging to grasp, as illustrated in Figure 4.
From a visual analysis of Figure 4, it can be seen that strategy implementation is quite similar to that of a sequential process, from the beginning to the implementation stage following virtually the same logic as the hierarchy of strategic intent. Strategic programming, in the context in the figure, is most appropriate in organizations facing stable and/or simple conditions and it has several required conditions: stability, simplicity, industry maturity, capital intensity, tightly coupled operations, and powerful external control (Miller, 1998). While this approach could find companies and/or industries in which it would be applicable, its limitations do not make it entirely applicable to the wind power industry.

Nevertheless, since the decision making sequence that underlines wind power repowering is a complex multi-level process, the sequential breakdown of strategy formulation will be used to explain it. In order to link strategy formulation to strategic
planning, and consequently make a more impervious strategy selection, the analysis of the external and internal factors must be taken into consideration. These two steps comprise an assessment of the external environment that the firm faces in the future and an analysis of the firm's relative capabilities to deal successfully with that environment (Deresky, 2014). While represented as two steps, the external and internal analysis are complementary and necessary components of a complete strategic analysis and manager's goal is to develop strategies that build strengths and overcome weaknesses in order for the company to take advantages of its opportunities and avoid its threats (Miller, 1998). This analysis is typically done using a SWOT (Strengths, Weaknesses, Opportunities, Threats) matrix, see Figure 5.

<table>
<thead>
<tr>
<th>Positives</th>
<th>Negatives</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Internal</strong></td>
<td>STRENGTHS</td>
</tr>
<tr>
<td><strong>External</strong></td>
<td>OPPORTUNITIES</td>
</tr>
</tbody>
</table>

Figure 5. SWOT matrix.  
Source: Miller, 1998 (Adapted by Author).

Given the understanding of differences between strategic programming and strategic planning, the strategic management process will be slightly modified to better fit the purposes of this paper. The repowering strategic management process can be outlined to serve as the foundation for the development of repowering strategy, see Table 1.
### Table 1. Repowering Strategic Management Process

<table>
<thead>
<tr>
<th>Strategic Management Process</th>
<th>Key Process Steps</th>
<th>Repowering Context</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strategic Planning Process</strong></td>
<td>Mission statement</td>
<td>Continue production and repower wind farm.</td>
</tr>
<tr>
<td></td>
<td>Stakeholder Analysis</td>
<td>Identify the stakeholders and analyze their potential influence.</td>
</tr>
<tr>
<td></td>
<td>SWOT Analysis</td>
<td>Analyze strengths, weaknesses, opportunities, and threats of repowering strategy.</td>
</tr>
<tr>
<td><strong>Strategy Analysis</strong></td>
<td>Identification of alternatives</td>
<td>Specific repowering considerations to support higher-level intentions.</td>
</tr>
<tr>
<td></td>
<td>Evaluation of alternatives</td>
<td>Compare alternative repowering strategies using several types of analyses.</td>
</tr>
<tr>
<td></td>
<td>Selection of strategy</td>
<td>Choose the optimal repowering strategy.</td>
</tr>
<tr>
<td><strong>Strategy Formulation</strong></td>
<td>Implementation</td>
<td>Design a repowering strategic plan and implement the strategy through complementary structures.</td>
</tr>
</tbody>
</table>

#### 2.7 Project Management Components

#### 2.7.1 Strategic Management Aspect of Project Management

Despite being a crucial part of strategic management, strategic planning on its own is not sufficient for a successful implementation of strategy. Strategic management consists of developing visions and mission statements; formulating, implementing, and evaluating; making cross-functional decisions, and achieving objectives. The identification of these qualities infers that projects reflect strategy and shows a clear link
to project management (Pinto, 2010). In the context of a strategy implementation vehicle, most strategic initiatives can be conceived and handled as projects, from tangible issues to the ‘softer’ aspects of an organization (Pellegrinelli and Bowman, 1994).

Furthermore, management of projects must be aligned with strategic mission, goals, and objectives of a company in order for projects to move recognizably closer to achieving its business results (Callahan & Brooks, 2004). The connection between project management and strategic management can be better understood through the Strategic, Tactical, and Operational (STO) model (see Figure 6) which identifies the three levels of operations and deals with the typical communication problems between different levels of operation. Strategic refers to the executive level, where decisions are made about the purpose and direction of the organization. Tactical is the management level of a company, describing the decisions on how strategy should be carried out, and Operational level represents where actual work is performed. While the original purpose of the model may have been more in line with addressing communication problems, the mere identification of the levels could be utilized for conceptualizing the bigger picture in terms of understanding where strategy lies in regards to projects and programs.

This paper simultaneously analyzes the initiation and planning phases of the repowering project used to implement the repowering strategy, and this conceptually matches the notion of strategic project management. “Strategic project management is the use of appropriate project management knowledge, skills, tools, and techniques in the context of a company’s goals and objectives, so that project deliverables will contribute to company value in a way that can be measured” (Callahan, 2002, cited in Callahan et al., 2011). While an argument could be made that good project management should automatically take all of this into account through correct project processes, research has shown that strategic project management does not exist in many companies, and that project management is seen as a process at the tactical and operational level, and not executive’s concern (Callahan et al., 2011).
2.7.2 Project Life Cycle

Understanding the functionality of each of the three levels is contingent upon understanding project life cycle as a sequential process with a set of phases, each marked by the completion of one or more deliverables, through which a project typically progresses. A life cycle approach to project management has been credited for ensuring that difficult issues will not be overlooked, better allocation of time and money, and more effective employment of resources. Despite some variations, a project life cycle has four phases, Initiation, Planning, Execution and Control, and Closure (Gardiner, 2005).

In the initiation phase, the project charter, or project statement, is established. A project charter contains all of the relevant project information, including deliverables, stakeholders, and the definition of success for the project, which typically includes a description of financial success and how it will be measured (Callahan et al., 2011). The planning phase focuses on issues that will form the basis of project control throughout project execution and delivery. Essential elements of this phase are the creation of all the necessary plans to support the project, mobilization and organization of resources, and establishment of an infrastructure to support those resources and ensure that effective communication can be maintained across the network of project stakeholders (Gardiner, 2005). Examples of project management documents that are created during the planning stage are work breakdown structure (WBS), project schedule, project budget and cash flow, resource plan, procurement plan, quality plan, and risk response plan (Callahan et al., 2011).

Execution and control is a phase where the rate of expenditure is at its greatest and it is generally the phase during which the actual “work” of the project is performed, for example, a project created and completed. Closure, or termination, occurs when the completed project is transferred to the customer, its resources reassigned, and the project formally closed out (Pinto, 2010). This phase is generally accompanied with project

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2 The phases in their original form are: Initiation and definition, Planning and Development, Execution and Control, Closure. Minor variations were made for simplicity and in order to remain consistent with the rest of the literature.
history documentation and project evaluation report (Gardiner, 2005), thus completing the project life cycle.

When the three levels of the STO model are properly aligned with project life cycle phases, the company is able to “think strategically, plan tactically, and act operationally”, see Figure 6 (Callahan & Brooks, 2004). These three simple and straightforward “action plans” can be linked to the key questions of strategic, tactical, and operational level which are “What is the result wanted?”, “How will this get done?”, and “What must I do?”, respectively (Callahan et al., 2011). The focus of this paper can be interpreted as aiming towards answering the first question and addressing some aspects of the second question in order to establish a foundation for the execution and the remainder of the operation level.

Assuming the appropriate conditions are in place, the outcome of a repowering project would inherently be a new wind farm. The project life cycle phases of a new wind farm project typically entail conducting a survey for suitable sites and feasibility study in the initiation\(^3\) phase; detailed planning and application for permission in the planning phase; contracting, purchasing, and constructing in the execution phase; and transfer and operation in its closure phase (Wizelius, 2007). A repowering project would follow the same phases, with some differences along the way. A key difference would be that the owner would not have to conduct a survey looking for sites since the wind farm already has its own site. Given that repowering is a combination of decommissioning the old wind farm and constructing the new one, carrying out a repowering strategy would in turn require several interdependent projects and/or sub-projects.

\(^3\) The original source referred to this phase as the ‘Pre-Study’.
Nevertheless, implementing a strategy generally involves defining and undertaking a range of projects each addressing a component of the strategy, and the relationship between said components can be complex, overlapping and interdependent. On the other hand, strategy is subject to modifications during implementation as a response to changing circumstances. A way of answering these two difficulties has been through program management, as this approach can ‘operationalize’ strategy by creating a framework for strategy implementation process and making project definition more systematic and objective (Pellegrini & Bowman, 1994).

2.7.3 Program Management as a functional component of Project Management

Given the multi-project nature of repowering, as well as the owner’s intention to implement the most effective repowering strategy, establishment of an operational program through which a wind farm would be managed by a series of impendent project modules presents itself as an interesting and likely way of developing and implementing the said strategy. To put this into a timeline perspective, the program would commence with the closure phase of the original wind farm project. When the original project would reach its closure phase, (when the wind farm is operational), the repowering project would commence, albeit in a somewhat passive way, since there would likely be no urgency to repower at that point in time. The initiation and planning phases would then expand over the entirety of original wind farm’s projected service life in a progressive event scenario. Subsequently, the execution phase of the repowering project would commence with a DfR sub-project, to replace old components of the wind farm. The DfR sub-project’s closure phase would mean the beginning of the execution phase for constructing the new wind farm. However, an overlap in the execution phases of the two sub-projects is possible, given that the decommissioning process, especially the turbine removal, is seen as the reversal of the installation, or construction, process and is subject to the same constraints (Kaiser & Snyder, 2012; Januário et al., 2007; Pearson, 2006). After the new wind farm has been constructed and put in operation, planning of a repowering project could commence if it is in line with company’s vision and overall strategy. This would not have to mean the end of the program, since a program does not
necessarily need to have a single objective nor a finite time horizon (Pellegrini & Bowman, 1994).

To summarize, a strategy helps a company pursue its vision. Programs, specifically program management offer approaches to implementing the intended strategy, and projects both support and constitute program components. These relationships are best visualized via McElroy’s hierarchal model of ‘vision-strategy-programs-projects’\(^4\), as seen in Figure 7.

### 2.8 Scenario Planning

Every strategy is accompanied by uncertainty. Uncertainty is something that needs to be taken into account before deciding which strategy option to pursue. Organizations can limit uncertainty by improving information on trends and factors relevant to their line of business or via alliances and partnerships (Andersen, 2008). In addition to these methods, dealing with uncertainties, as well as strategic planning and the consequent implementation, could be improved by introducing scenarios and employing scenario, or scenario-based, planning.

In contrast to the traditional strategic planning approach that tries to eliminate uncertainty from the strategic equation, scenario-based planning assumes an irreducible indeterminacy and ambiguity for any situation that a strategist might face. Inherently, a successful strategy can only be developed in an ongoing dynamic response to these assumptions. Scenario-based planning is an approach towards dealing with acknowledgment of aims, assessment of the organization’s characteristics and its fit with the environment, invention and development of policies, and decisions and action to implement the strategy (van der Heijden, 1996).

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\(^4\) The original version of the model is named ‘aim-strategy-programme-projects’. Modifications were made to match terminology used in the paper.
Scenarios can be seen as tools for improving the decision-making process against a group of possible future environments, and they benefit the organization by stimulating managers to think together in systematic and disciplined ways (Schoemaker & van der Heijden, 1992). Furthermore, scenarios can be used as tools for steering strategy implementation as they focus on discontinuity and change and can involve exploring how the underlying systems in the business environment may generate change (Grundy, 1998).

As means of improving strategic planning, scenarios can be used in several ways, of which three will be highlighted. Sensitivity/Risk Assessment refers to using scenarios as a “wind tunnel” and its optimal use is evaluating a specific decision via computer modeling or simple judgment assessments. Strategy Evaluation relates to testing a strategy made on the basis of forecasts against possible other outcomes and its optimal use is as “test beds” to evaluate the viability of an existing strategy by playing a companywide strategy against the scenarios to assess the strategy’s effectiveness in a range of business conditions. Lastly, Strategy Development can be used to build a more robust strategy through development of a “resilient” strategy that can deal with wide variations in business conditions (Ringland, 1998).

However, if an organization wants to use scenarios, it is up to its members to construct their scenarios since they have the best perspective of their internal characteristics. Scenario construction stimulates thinking about alternatives, which could have otherwise been ignored by identifying trends and uncertainties in an organization’s macro environment (Haycock et al., 2012). As evidenced by Amer et al. (2012), there is no single approach to scenario planning and several methodologies for generating scenarios with many common characteristics have been identified. However, since the paper does not focus on scenario construction, the approach that International Computers Limited (ICL) used is presented for illustrative purposes. ICL’s approach began with identification of factors that were seen as important, but had unpredictable outcomes. For each of those uncertain factors, a correlation matrix was built to investigate how they related to each other and this served as a basis for sorting the factors. As a result, a pattern was observed with emergent themes, which helped group the major range of
uncertainties into four broad headings, and this served as an important precursor in building a storyline for how the world might look in two different scenarios (Ringland, 1998).

While scenario construction is external to the scope of this thesis, understanding how it is performed and how scenarios relate to strategic planning is helpful and necessary for any implications of this work. Scenarios will be addressed in the later parts of this paper, but in the form of a proposal as to when they should be constructed and implemented with an example of scenarios for the UK offshore wind power industry.

2.9 Conclusion

Chapter 2 covered fundamental concepts such as strategy, strategic intent, strategic management, program and project management, scenario planning, and analyzed how they are connected in order to gain a better oversight of the “bigger picture”. Furthermore, repowering has been defined and linked to the mentioned fundamental concepts.

This chapter has been an attempt to view the field from a broad perspective in order to better understand repowering as a strategy and its corresponding project management activities from different angles.

Chapter 2 sets the foundation for the following chapter, Methodology. Since this paper is of theoretical nature, the applied methodology relies heavily on literature review and it expands on key issues in a repowering context.
3 METHODOLOGY

3.1 Introduction

As part of the process of answering the research questions, Chapter 3 combines concepts from Chapter 2 as “building blocks” for outlining the remainder of the paper through the Repowering Strategic Project Management (RSPM) framework.

3.2 RSPM framework

![Diagram of RSPM framework](image)
The RSPM framework demonstrates the proposed framework for development, evaluation, selection and implementation of repowering strategy. While this paper will not encompass repowering execution, the aim is to demonstrate the complexity of the underlying decision-making process and provide suggestions for undertaking different steps of that project. As it can be noted from Figure 8, the RSPM framework combines several fundamental models and processes that have been explained in Chapter 2. While it might not be explicitly stated, the thought process will follow the ‘vision-strategy-program-project’ hierarchal model (McElroy, 1995, cited in Grundy, 1998), which is the reason for making a distinction between different levels of the RSPM framework. The larger box in the figure, which covers the scope of the thesis, can be regarded as a form of an extended feasibility or justification study, as its intention is to select and implement the optimal repowering strategy and ultimately narrowing down the repowering execution to a go/no-go decision.

Following McElroy’s hierarchal model and Pinto’s (2010) notion that the strategic vision is the driving force behind its project development, the analysis part of this paper will commence with the discussion regarding the EOSL outcomes. Once this has been explained, two fundamental repowering types will be introduced with an elaboration on the positives and the drawback of each choice. Consequently, the paper will lead to the strategic planning portion, which will cover strategy analysis through a stakeholder and SWOT analysis.

With a better understanding of the internal and external factors affecting the strategy, some key repowering alternatives will be identified and presented. Due to the time constraints and author’s intent to make a general conceptual model that can be applied to a wide spectrum of projects, the alternatives will be simplified into four main groups of considerations, where each group will have two possible choices, which are more applicable to full than to partial repowering. After all of the alternatives have been explained and identified, the paper will propose ways of evaluating them.

Since the paper will merely explain how the alternatives could be evaluated, the later intent will not be choosing one, but rather demonstrating how the selection and implementation could be facilitated through a hypothetical wind farm’s program.
Finally, as part of this program, the principal projects and sub-projects will be identified and presented in a timeline format. After the main analysis is completed, the findings will be discussed and recommendations for future work will be addressed.

3.3 Conclusions

The Methodology chapter addressed the method followed in this paper and the general logic and thought process that culminated in the RSPM framework and its approach. Due to the postulatory nature of the thesis, the methodology overlaps and is highly dependent on the review of literature, as the proposed framework combines the fundamental concepts outlined in Chapter 2. Some of the covered concepts, namely scenario planning has not been addressed in this chapter, but will be re-introduced in the later stages of the paper.

Having presented the necessary background and the method of how it will be utilized, Chapter 4 brings the results of research through demonstration of the decision making process and suggested manners of evaluation and implementation.
4 APPLICATION OF METHODOLOGY

4.1 Introduction

Having established the methodology in the previous chapter, Chapter 4 will establish and investigate the levels of the RSPM framework in their hierarchal order. The analysis will present the decision-making processes occurring at each level and some general guidelines regarding strategy evaluation and implementation will be proposed. This chapter will present results of the research, implicitly sharing Andersen’s approach of letting planning address what, or global, tactical and goal-oriented planning, before analyzing how, or the activity and operational planning (Andersen, 2008).

4.2 Vision - Optimal EOSL solution

As mentioned, the owner-operator has two options at wind turbine’s EOSL and the choice between these options has to be in accordance with the social responsibility towards the stakeholders. Meanwhile, since the decommissioning outcome is established (secured) through governing norms, in order for repowering to become the optimal EOSL outcome, a mission for continuing production and repowering the wind farm would be made and the appropriate repowering strategy would have to be formulated, planned, and implemented to ensure its execution. In other words, repowering would have to be deemed feasible and profitable to be pursued, and the underlying assumption is that if these conditions were satisfied, the owner would pursue this option.

However, if repowering is not deemed feasible, the owner can either attempt selling the wind farm or proceed with decommissioning. If the sale is successful, the new owner can proceed with repowering, and if it is not successful, the process would continue with decommissioning. The impact that ownership would have on repowering solutions is hard to estimate in advance without a thorough understanding of the vested interests of each stakeholder and potential conflicts across the stakeholder matrix. In addition to the potential changes in legal structure, public acceptance could be affected as the notion that local ownership is preferred over corporate ownership has been widely
accepted by many commentators (Strachan et al., 2010, cited in Szarka et al., 2012). The author acknowledges ownership as an interesting topic whose impact should be evaluated, however, due to the time constraints multifaceted subsets of the topic it will not be investigated further in this paper.

Both repowering and decommissioning outcomes involve the dismantling, separation, recovery, and management of used wind turbines (WTs). EOSL alternatives include recycling for material recovery, reconditioning to extend the service lifetime, reuse of some of the components, and even the remanufacturing of the entire WT system (Ortegon et al., 2012). This suggests that there is another area of consideration in the decision making process, which focuses on end-of-service life of wind turbines (EOSLWTs) alternatives and its outcomes which could affect repowering plans. Moreover, if remanufacturing is a possible and attractive option, the owner-operator could potentially use some of the parts for repowering. Another benefit is a potential to offset repowering costs by recycling or selling the older equipment (Lantz et al., 2013), but it should be kept in mind that the option of selling the equipment depends on the modernity of technology and size (Habig⁵, cited in NREL, 2013). While this paper will not further investigate this implication, the logistics that illustrate the decision making process of this stage can be seen highlighted in Figure 9.

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⁵ Neil Habig, alongside Don Bain and Mark Jacobson, was one of the industry representatives interviewed for NREL’s article.
4.3 Repowering Strategy

Having formulated a vision for finding the optimal EOSL solution where some form of decommissioning is inevitable, the owner-operator must establish a repowering strategy to ultimately justify or refute this option. As established in Chapter 2, every strategy has to come with a mission statement to represent the organization’s vision, and in this case, the mission is to continue production and repower the wind farm. In the interest of making the mission statement more concrete, first step would be establishing the goal of choosing the optimal repowering type.

4.3.1 Repowering Type

The overall outcome and complexity of both the decision making process and construction work is highly dependent on the type of repowering the owner pursues. While some authors like Grontmij (2000) suggest five different repowering alternatives (Hulshorst, 2008), this paper will begin by looking at the two fundamental types of repowering, partial and full (Lantz et al., 2013). On a hierarchal scale, the most
fundamental choice the owner-operator has to make after deciding the optimal EOSL outcome is to determine whether to dismantle old wind turbines and replace them with new ones or upgrade some component(s) of the existing units by, for example, installing a bigger rotor. One of the underlying assumptions behind full repowering is that some of the existing project infrastructure, as in roads, buildings, and interconnection equipment could be utilized in the new project without modification. On the other hand, partial repowering allows existing wind power projects to be updated with equipment that increases energy production and improves project reliability, but the performance improvements are assumed to be lesser than under full repowering, even though greater than the original design of the machine (Lantz et al., 2013).

One of the complications of partial repowering, or retrofitting, as it is sometimes referred to, is that some turbine manufacturers have halted turbine production or entirely disappeared. The development of full repowering has been hindered by the height restrictions, insufficient capacity and logistics (Windpower Monthly, 2014). Another important area of consideration is the changes in certification of turbines that type of repowering can affect, as an exchange of the controller [example of partial repowering] can require a complete re-certification in Germany, whereas not be mandatory in the United States (Schwarzer, cited in WindPower Monthly, 2014).

Given the rapid improvements in wind turbine technology and increase in the size of the WTs, partial repowering is becoming less viable since some of the old towers and foundations could be too small to support newer and bigger blades. In addition, while partial repowering is generally less complex, and thus less expensive, it achieves lower energy production improvements, as evidenced by NREL’s case study (see Lantz et al., 2013). Considering all factors, the paper will address partial repowering as alternative solution, but the focused analysis of repowering alternatives will be on full repowering.

4.3.2 Repowering Strategic Planning

Repowering strategic planning consists of two main sections, repowering strategy analysis and repowering strategy formulation. Repowering strategy analysis
entails the analysis of stakeholders and assessment of the external environment and internal characteristics, facilitated through a SWOT analysis. With a suitable strategy analysis, the formulation could commence by identifying the repowering alternatives, after which they could be evaluated in order for the optimal alternative to be chosen.

4.3.2.1 Repowering Strategy Analysis – Stakeholder Analysis

The decision making process leading up to the construction of a wind farm, regardless of whether it is being built for the first time or being repowered, requires the owner to identify all stakeholders and explicitly determine their engagement in the process as to when and to what extent (MCDA-RES, 2002). Stakeholders\(^6\) encompass individuals, groups of individuals, institutions and administrative authorities that influence the decision making process both directly and indirectly through their priorities and value systems (Georgopoulou et al., 1997). Furthermore, they constitute a basic element in formulating and evaluating alternative strategies in electricity generation, as they are opposed to support specific proposals according to their personal value system (MCDA-RES, 2002). Lastly, it has been demonstrated in land-use planning that the way developers engage with local residents is a crucial element in molding public acceptance of large-scale renewable energy projects (Devine-Wright, 2011, cited in Szarka et al., 2012).

While the definition of stakeholders can imply a wide array of individuals, the arguments for adding or excluding a stakeholder have to be explicit, and any arguments for either case provides the owner-operator with useful information about the problem (Lahdelma et al., 2000). Predominantly contingent upon the geographical area, the stakeholder profile can vary significantly, but there are six main stakeholders, or groups of stakeholders, that can be identified for nearly every wind farm.

\(^6\) The term “Actors” was used in the original source.
Owner-Operator

The owner-operator is the person or entity that owns the wind farm and, in this case, the same person or group in charge of operating the existing wind farm and being the developer for the repowering project. Even though there might be several entities involved, all of them can be grouped together, since it can be assumed that they have the same interests. This owner-operator has the responsibility of determining the feasibility of repowering and creating its strategy. While this stakeholder, or someone on his behalf, is the one that is actually conducting the stakeholder analysis, presenting his viewpoints and responsibilities is crucial for further investigation.

From the owner-operator’s point of view, having a repowering strategy can be beneficial if they decide to proceed with repowering. On the other hand, having this strategy implemented early can help justify or refute repowering. Besides carrying out the repowering strategy, it is this stakeholder’s responsibility to either appoint someone or to personally instigate communication and engagement with the other stakeholders, as the final outcome will likely be the result of negotiations between different stakeholders.

Local Population

One of the key stakeholders with significant influence on outcome of the wind farm design is the local population, since they can affect the size of the farm design and whether it is actually built. This group of stakeholders is not easily definable and its size varies tremendously between projects. Generally, this group includes, but not limited to, people living near the wind farm, people that have holiday houses there, and landowners.

Local population opinion on repowering is most likely similar to their initial thoughts on the existing wind farm and it depends on the experiences during the operational life of the old wind farm, mainly the community funds and benefits. If the locals are positive towards repowering, they would likely welcome the repowering

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7 The term owner has been mentioned earlier in text, and these two terms can actually be used interchangeably.
strategy as a tool which could give them more confidence in the project. If the locals are not interested in repowering, a repowering strategy might have a negative impact and seem that they do not have a say in the process.

_Governing Authority_

Depending on the location, there could be more than one governing authority. Nevertheless, the importance of this stakeholder lies in the fact that it is the one that issues the permissions and construction consent. This stakeholder can represent national, regional and local interests, and thus if repowering of a wind farm is in line with the national energy goals, the authority would likely be in favor of repowering, but even more so, the repowering strategy.

_Environmental Groups_

This group of stakeholders represents the agencies, public and private environmental organizations, foundations and private citizens that protect or hold otherwise vested interest in the flora and fauna around the site and they can be the most strongly opposing stakeholder, singularly or collectively. While the initial reaction towards having a repowering strategy might be negative if they are against having a new wind farm, it might help the developer in the negotiation process. With a presumably good experience with the current wind farm, this group could potentially be more open to the idea of repowering, since it has the advantage of an existing foundation of data on bird and bat use (CEC, 2007). Furthermore, even though one might assume that this group would be more likely to choose partial over full repowering, the latter has proven to be a promising way to reduce avian mortality, as the studies taken in Altamont have shown (CalWEA, undated).
Grid Operator

Assuming that repowering is in fact possible from the transmission standpoint, having a repowering strategy prepared well in advance would be welcomed by the grid operator. This is a very important stakeholder that should be engaged early in the process, especially if the developer intends to increase the capacity of the new wind park. The grid operator would decide if increasing the site capacity is possible and in line with national goals and demand for energy production. Furthermore, the grid operator would have to make sure that the existing infrastructure and cabling can support continuation of operations and potential expansion.

Supply Chain

Including this group of stakeholders early in the process is vital for its success. This can help increase the viability of repowering in the sense that they can make longer contracts and establish a better line of cooperation. This could be in the owner’s interest as well, since moving away from lump sum contracts may lead to cost reductions (Crown Estate, 2012). Furthermore, this group of stakeholders is responsible for execution throughout the whole process, which is why their timely inclusion can help in the overall planning process, as well as with scheduling activities for which several contractors are required. Members of this group can affect nearly all of the repowering considerations that the owner-operator, or someone on his behalf, has to take into account. Their influence can be interpreted as somewhat indirect, since the developer would still be the one making the decisions; however, this group would provide the necessary input for these decisions to be made.

As mentioned, these are the general individuals or groups that are typically members of the stakeholder list of virtually any wind farm. Stakeholder identification is the first step of project communications management, which is one of nine core component processes of project management (Pinto, 2010). Based on the geographical area and the type of wind farm, whether it is offshore or onshore, the list of stakeholders
could also include the fishermen, sailors, aviation (Moray Offshore Renewables Ltd., 2010), or in some cases even the military (Aldén, 2015). Of note is that stakeholder identification should be observed more as a current stakeholder profile that can be used from the old project, i.e. construction of the existing wind farm. Depending on the location, the stakeholder profile might change, and this is something that the responsible Project Manager has to take into account.

4.3.2.2 Repowering Strategy Analysis – SWOT Analysis

A SWOT analysis is a structured planning method used to evaluate the strengths, weaknesses, opportunities and threats of a project. SWOT analysis, or SWOT matrix, is often used in participatory planning approaches, despite being originally developed for strategic planning in business and marketing purposes. The SWOT analysis is only a tool and it has to be based on a sound knowledge of the present situation and trends (Terrados et al., 2007). Since this paper focuses on repowering strategy and its underlying program, the SWOT analysis will have the same focus, and thus, some of the strengths and weaknesses of repowering can be interpreted as strategy’s opportunities and threats, respectively.

**Strengths**

- *Available information from the existing wind farm*

  This is arguably the owner’s biggest strength and the foundation of a good repowering strategy. Assuming that the owner undertook a detailed Technical Due Diligence (TDD) prior to the construction of the existing wind farm, he should have a unique perspective on what challenges and opportunities his wind farm is facing and he could come up with appropriate measures. A TDD is an extensive document review process in which a complete assessment comprised of all potential risks to the realization or successful operation of a wind farm project (Lynch, 2011). Furthermore, as the owner-operator was likely required to prepare a proposed decommissioning program, it could be argued that the initial analysis of repowering project execution has been
implicitly performed, as repowering can be seen as a combination of decommissioning and construction.

A crucial strength that could be also observed as an opportunity is the actual wind statistics the owner will gather over the course of the existing wind farm’s service life that can help with project funding. The funding structure of most capital projects, including wind farm projects, entails a combination of debt and equity finance, and the gearing will describe the proportion of the two (Arapogianni & Moccia, 2013). When planning to construct a wind farm, the developer is required to take measurements for a minimum of one year, although two or more years produce more reliable results. The measurements are then long-term corrected with a reliable reference station to generally reflect the wind conditions at the site (AWS, 1997). These measurements, as part of a wind resource assessment would then be presented to the bank in order to get a loan [debt financing]. According to the credit risk associated with the measurements, the bank will form the credit ratings which determine the rate it will offer to the developer (S&P, undated). Taking all of this into account, it could be inferred that the actual wind statistics the owner has can be used as leverage in getting the best possible conditions from the bank.

➢ Simplicity

Given the amount of available information from the existing project, the owner should be able to begin formulating and developing the repowering strategy without any major issues. However, this does not imply that the implementation of the strategy would be simple.

➢ Low up-front investment

If a repowering strategy is introduced early, namely before an urgent need for repowering, it would require a fairly modest investment of time and resources, as the majority of the initial work have been covered through the old project.
Wind Farm Repowering: A Strategic Management Perspective

**Weaknesses**

- **Lack of experience with repowering strategy**

  With the assumption that this is not a common practice in the industry, strategy formulation might show itself to be more challenging than anticipated. A lack of experience in strategic management could have a negative effect on the entire process, thus weakening the chances of a better outcome.

  The author acknowledges that there are likely some owner- or site-specific characteristics in both the strengths and weaknesses sections. In order to take advantage of strengths and inhibit the weaknesses, it is highly important that the company performs a detailed, rather than pro forma SWOT analysis.

**Opportunities**

- **Additional incentives**

  As means of promoting repowering, and inherently the repowering strategy, the country in which the wind farm is located and permitted to operate, may opt to introduce additional financial incentives for repowered wind farms, as was the case in Germany and Denmark (Lantz et al., 2013).

- **Lower environmental impacts**

  Repowering leads to more efficient land use, higher power capacity per unit of land area, reduces noise levels and avian mortality (Larp & Bowen, 2006, cited in del Rio et al., 2011). A well-timed and carefully implemented repowering strategy could potentially help lower the environmental impacts further through its planning phase by optimizing the repowering workload at the site. The author anticipates that an optimized process should leave a lower environmental impact during the execution phase than if the wind farm was decommissioned and restored, and then a new wind farm built at the same site after a certain point in time. This could be even more prominent for offshore sites, as the sea disturbance created during both construction and decommissioning can
have a longer impact on the sea life. However, this is merely author’s hypothesis and it should be further investigated.

- **Second hand WT market**

  Development of the second hand WT market can impact the timing of the repowering project, as potentially good terms could inspire the owner to start the repowering execution earlier. One lesson from the Dutch company Windbrokers to keep in mind is that “at the first thought of repowering buyers must be found for the turbines to be replaced” (Knight, 2004). In recent years, the majority of used turbines the same company sold went to eastern Europe and Latin America (Daubney, 2013), and Vestas A/S has started its Wind for Prosperity project where the company intends to refurbish old turbines and install them in countries such as Kenya, Ethiopia, Yemen, Vietnam, and Nicaragua (Wang, 2013).

- **Cost reduction opportunities**

  As addressed in the previous section, the long term contracts with the supply chain can yield cost savings, and this can be better facilitated through wind farm’s program. Besides various long term commitments, an earlier involvement of the supply chain, for example joined-up scheduling or reduced over-ordering of materials through detailed procurement planning can also help reduce costs (Crown Estate, 2012).

- **Technological development**

  Technological development, namely the increase in rated capacity and size has been, and will likely still be one of the main drivers of repowering. Estimating what improvements and to what degree could affect the decision making process within repowering strategy will not be investigated in this paper. The main point to be made here is that the responsible project manager needs to identify this as an opportunity and keep track of any developments.
Threats

- **Lack of supporting incentives**
  
  Even with the numerous benefits identified with repowering, the owner is always faced with a threat of receiving no or insufficient incentives to pursue repowering, and would have to turn to decommissioning, as it has been the case with the Yttre Stengrund offshore wind farm in Sweden, since the current forecasts for electricity prices did not make building a new wind farm viable (Forslund, cited in Roupe, 2015).

- **Opposition from other stakeholders**
  
  The owner is always faced with a threat that certain stakeholders might oppose repowering, and thus it is important to assess the stakeholders’ viewpoints and potential impact. A stakeholder analysis can be used to generate assumptions about specific stakeholder positions in order to provide input to the uncertainty/importance analysis, and these positions can be also be mapped using an influence/attitude graph (Grundy, 1998).

- **Strategy not updated regularly**
  
  The proposed strategic framework relies on the early inclusion of the repowering strategy and regular updates throughout the program with the intent of being prepared for repowering if it is feasible. If the strategy is not updated regularly, chances of benefiting from its use diminish.

- **Technological development**
  
  Even though technological development has been praised as one of the drivers of repowering, certain discoveries create trends that can have a negative effect on repowering plans. One of the biggest market trends in the offshore wind power industry has been to move turbines into deeper waters, promoting the development of floating
structures (see Arapogianni & Genach, 2013). The continuation of this trend and its potential enhancements could cause the loss of incentives for repowering of existing offshore wind farms.

➢ Competing technologies

As with some technological developments in the wind power industry, the development of other renewable energy sources, such as solar, wave, tidal, etc., could make these sources more desirable than repowering a wind farm.

Similar to the strengths and weakness, there are likely some opportunities and threats that are applicable only for certain site. The external analysis is probably even more important in the early stages, as it can be impossible to affect some of the external changes. The owner should either rank these factors by importance or establish some system for tracking key trends. The list of all factors can be found in Figure 10.
4.3.2.3 Repowering Strategy Formulation – Identification of Repowering Alternatives

With a completed strategy analysis that assessed the internal and external forces characteristic to the company and its repowering strategy, the next step is to identify all of the possible alternatives with the aim of selecting the optimal one. These alternatives have been split into four broad groups of considerations that generally encompass all of the decisions the owner is faced with.
**Site Area Considerations**

As the wind turbines are reaching the end of their service life, land leases for onshore wind parks typically expire (Ortegon et al., 2012). Besides the land lease agreement, the developer has to analyze whether it is possible to expand the site area or not. Expanding the site area would allow the owner to install additional WTs, as well as to install more powerful WTs with bigger blades, since the distance between turbines is proportional to the rotor diameter and it can be in the range of 3-10 rotor diameters (Planning Portal, undated). If the expansion is possible and if the developer wants to use the additional area, the outcome would be either full repowering or a combination of partial or full repowering with construction of additional turbines.

The possibility of expanding the site area is location-specific, but it can be assumed that it is significantly lower for sites close to inhabited areas. Expanding the site area could potentially be easier for offshore projects; however, the plausibility would greatly depend on complete analysis of sea depth, seabed (soil) suitability, designated fishing grounds, shipping lanes, navigation markers, unrestricted access to supply base, protected marine life habitat, etc., as well as the existence of any nearby offshore wind parks. Gwynt y Môr offshore wind farm in the UK has a lease area of 124 km² and area within which turbines had to be constructed was reduced down to 79 km² due to the engineering benefits caused by moving some turbines away from areas of deeper water, as well as the greater separation from shipping passing (RWE Innogy, 2007). Lillgrund wind farm, located between Sweden and Denmark, has a “hole” in its layout due to the shallow water, which prevents vessels from being able to maneuver in that area (Jeppsson et al., 2008). The layouts of Gwynt y Môr and Lillgrund can be seen in Figure 11.
Wind Farm Repowering: A Strategic Management Perspective

Wind Turbine Selection

If the developer decides to pursue full repowering, the main decision with regards to this consideration to be made is whether or not the wind park will be repowered by using wind turbines of similar size and capacity or by bigger and more powerful WTs. For the purposes of this paper, the notion of a ‘similar WT’ will refer to the turbine with a modest capacity and size increase that would not entail substantial changes to the remainder of the wind farm. The actual differential range for which a WT would be ‘similar’ will not be calculated, as this is most likely site-specific. The increase in production when repowering with similar turbines could in some cases be virtually the same the increase with partial repowering, with the latter probably being more cost-effective.

For example, the only real difference between Siemens’ wind turbine models SWT-3.6-120, a 3.6 MW WT, and SWT-4.0-120, a 4 MW WT, is the generator, which makes partial repowering a more reasonable option in this case (Siemens website, undated). However, if the tower is not designed to be able to carry the additional weight.
in the nacelle, which would in this case be 15 tons, then full repowering would be required.

During the WT selection, the developer also has to decide whether to change the turbine manufacturer or keep the same one. Choosing the manufacturer is yet another complex decision-making process that depends on a plethora of factors, such as investment and operational costs, track record, and how operations and maintenance (O&M) is performed, to name a few. While this is a crucial decision, it will not be further investigated for the purposes of this paper. Lastly, turbine selection is affected by the wind conditions at the site. Based on the wind resource, namely the wind speed at the hub height, speed of extreme wind gusts over a 50-year period, and turbulence, the wind turbines are split into three classes defined by an International Electrotechnical Committee (IEC) standard (Centrum för Vindbruk, undated). Regardless of whether it is a similar or a bigger WT, its turbine class must match the wind conditions at the site.

**PPA Considerations**

A power purchase agreement (PPA) is a long-term agreement to buy power from a company that produces electricity (Thumann & Woodroof, 2009). Signing a PPA secures a long-term revenue stream through the sale of energy from the project and it is also the condition to any equity and debt financing of the project (Windy industry, undated).

Besides the PPA-specific topics, such as the length of the agreement, commissioning process, and sale and purchase, to name a few, the owner-operator is faced with one key decision - keep the same installed capacity or increase it. It should be noted that the owner could not make this decision without consulting the grid operator. If the owner keeps the same site capacity, the most likely decision would be to replace the old WTs with less bigger and more powerful turbines, which would be more cost-effective, as evidenced by Lantz et al. (2013). An example of this would be if a 90 MW wind park with thirty (30) 3 MW WTs had been replaced with fifteen (15) 6 MW WTs.
Foundation Considerations

This consideration is linked to WT selection and it influences that part of the decision-making process. The owner-operator has two main choices, either to use or upgrade the existing foundations, or to lay foundations for new WTs in different coordinates. A representation of the latter choice can be seen in Figure 12 were the new WT coordinates are marked with red stars; however, it should be kept in mind that Figure 12 should be merely used as an illustration of what the outcome might look like.

![Figure 12. Kentish Flats layout (Adapted by Author).](image)

Source: WindPower Program Website, undated.

The possibility of using or upgrading the existing foundation is site-specific and it depends on the engineering feasibility on one hand, and the soil and foundation conditions at the end of WT’s lifetime on the other. Assuming appropriate conditions, using old foundations could be possible for ‘similar WTs’ due to comparable characteristics. Upgrading foundations might be possible for onshore WTs due to the relatively simpler design and construction process than their offshore counterparts.

All of the choices under repowering considerations involve engagement of one or more stakeholder groups, as some of the decisions cannot be made without input and/or regulation from some of the stakeholders. For example, the owner has to include the
supply chain in all of the alternatives aside the PPA considerations. The grid operator is a potential source of information regarding the WT selection, and the Environmental groups might be engaged during foundation considerations in order to ensure that the best practice guidelines are followed. The engagement of stakeholders during different considerations can be found summarized in Table 2.\(^8\)

<table>
<thead>
<tr>
<th>Repowering Considerations</th>
<th>Local Population</th>
<th>Governing Authority</th>
<th>Grid Operator</th>
<th>Environmental Groups</th>
<th>Supply Chain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Area Considerations</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Wind Turbine Selection</td>
<td>✗</td>
<td>✗</td>
<td>✓ ✓ (✓)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>PPA Considerations</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Foundation Considerations</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✓ ✓ (✓)</td>
<td>✓</td>
</tr>
</tbody>
</table>

Lastly, it is important to note that all of the choices under repowering considerations are part of the same overall repowering strategy with a mission to repower the wind farm in the most optimal way. In an attempt to accomplish this mission, the owner must select the optimal repowering strategy alternative. As there are four groups of considerations from which the owner must select one of the two main options, a repowering strategy alternative would present a combination of choices made in each group. The choices across these groups are interdependent and the decision making order could affect the configuration of an alternative.

\(^8\) Symbols can be interpreted as follows: Yes ✓, No ✗, Maybe (✓).
4.3.2.4 Repowering Strategy Formulation – Evaluation of Repowering Alternatives

After identifying all of the possible alternatives, the owner would have to evaluate them in order to select the optimal repowering strategy for the said wind farm. One of the most widely used methods for project evaluation is a cost/benefit analysis (CBA). The value of the project is calculated by subtracting the costs from the benefits. Project’s benefit is its positive impact expressed in monetary terms, and project costs represent every sacrifice made for the sake of the project, also expressed in monetary terms (Andersen, 2008). In the context of repowering, the alternative with the highest value would be chosen, i.e., the alternative with the greatest benefit over cost evaluation. Despite the fact that it has not addressed earlier, it is important to note that a CBA underlines the entire repowering decision making process, as the value of the chosen alternative would still have to be compared with the value of decommissioning for finding the optimal EOSL outcome.

Even though CBA is mainly regarded as means of assessing the profitability of a project, it can and needs to be expanded to fit other stakeholders’ viewpoints, even the ones without a monetary stake in the project. Since the objectives of certain stakeholders can be intractable and difficult to quantify, certain techniques, such as the Multi-criteria analysis (MCA)\(^9\) can complement the CBA to help the owner in the decision making process (Florio et al., 2008). While the CBA focuses on a unique criterion (the maximization of social welfare), MCA is a tool for dealing with a set of different objectives that cannot be aggregated through a standard CBA (Sartori et al., 2014).

While both CBA and MCA are powerful evaluation tools, both methods depend entirely on their input parameters. If the input parameters do not represent the real values, the consequent analysis cannot yield correct results. This becomes an even bigger issue in repowering strategy, because its forward-looking approach would have to rely on forecasts with varying levels of uncertainty. While uncertainty cannot be completely eliminated, it could be partially mitigated through scenario planning. As addressed in Section 2.8, the first step in scenario planning is constructing scenarios for

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\(^9\) Certain literature refers to this tool as Multi-Criteria Decision Analysis (MCDA).
evaluation of the repowering strategy. Scenarios limit uncertainty by sorting and grouping uncertain factors and through identification of key trends that could impact the company’s external environment.

An example of what scenarios in the wind power context could look like can be found in the research study commissioned by Crown Estate\(^\text{10}\) to identify the cost reduction opportunities for the offshore wind industry in the UK. The key aspects that varied across the four scenarios where the size of the offshore wind market in the UK and in the rest of Europe through to 2020 and beyond, the pace of technology development, and the maturity of offshore wind finance and supply chain (Crown Estate, 2012). Inherently, the research identified two key driving forces, technology and finance and supply chain, which are generally applicable to nearly every wind farm (see Figure 13). An important aspect of constructing scenarios is the timing, since there is a likely trade-off between how far ahead they are designed for and making the most out of their usage.

\[\text{Figure 13. UK Offshore “industry stories”.}\]


\(^{10}\) Crown Estate serves as the manager of the UK seabed out to 12 nautical miles.
4.4 Repowering Program – Strategy Implementation

Following the evaluation and selection of the optimal alternative of the repowering strategy, the strategy could advance to its implementation stage. As Pellegrini and Bowman (1994) argued, the strategy can be ‘operationalized’ by creating a framework for its implementation through program management. As explained in Section 2.7.3, the wind farm program would commence with the closure phase of the original wind farm construction project, which is also when the repowering strategy and the repowering project should be established. It was also argued that the initiation and planning phases of the repowering project would extend over the projected service life of the wind farm, and that the wind farm’s EOSL would mean the beginning of the execution phase of the repowering project. This phase would be completed when the repowering project reaches its closure phase, or operation of the new wind farm.

As means of improving the implementation of repowering strategy, or in other words ensuring a more seamless transition from the existing to the new wind farm, well-grounded strategic planning over the existing wind farm’s service life could enable the repowering project to capitalize on fast tracking. Fast tracking is the shortening of the project life cycle by overlapping project phases (Gardiner, 2005). In the repowering context, shortening of repowering project life cycle would imply an earlier beginning of operations for the new wind farm. In order to gain a better understanding of how this can be achieved, the focus will shift to the repowering project specifically.

4.5 Repowering Project

In general, repowering can be split into two main activities, the DfR of the old wind farm and construction of the new wind farm, where the former precedes the latter, and following similar logic, the repowering project has two main sub-projects. In concert with the general project life cycle, repowering project has four main phases, where each phase is a combination of sub-projects’ corresponding phase. Furthermore, while the project phases must follow each other, sub-project phases can overlap in order to shorten
the project life cycle, and this could be accomplished through having a repowering strategy.

Hypothetically speaking, if an owner did not have a repowering strategy in place and did not plan repowering accordingly, the worst case outcome that could happen is that the initiation phase of the DfR sub-project begins at EOSL, and that the construction sub-project begins after DfR’s closure. This way the time frame between the EOSL of the old farm and beginning of operations of the new farm would roughly take as much as the entire DfR sub-project life cycle plus the first three phases of the construction sub-project. On the other hand, with a well-planned repowering strategy, the EOSL of the old wind farm would immediately imply the beginning of the execution phase of the repowering project. The duration of the repowering execution phase can be regarded as the time frame between the beginning of DfR’s execution phase and the end of new construction’s execution phase. In practice, some overlap between the two execution phases might be possible, but that is hard to estimate without knowing site-specific details. In the case of a repowering strategy, the transition period between the existing and the new wind farm would roughly be the sum of the two execution phases. The two examples represent the worst and the best case outcome in terms of transition period between the existing and the new wind farm, but these are not the only potential outcomes. For example, an owner that might not have a repowering strategy, but substantial resources, could perform some of the DfR and new construction sub-projects’ activities in parallel and consequently shorten the repowering project life cycle. On the other hand, an owner that has a repowering strategy in place, but has regarded its strategic planning as an episodic ad hoc activity, will not be able to enjoy the benefits of the best case transition.

The best and worst case transition periods, as well as a few other speculative outcomes, can be seen in Figure 14. It is important to note that this is an illustrative graph and that the sub-project phases are not necessarily as proportional as represented. Moreover, potential time savings demonstrate the entire range of time savings between the best and worst case outcome. As it can be noted, the graph does not have a time
scale, however, some of the phases can be in the order of weeks and months, potentially years.

4.6 Repowering Project and Wind Farm Program Timeline

In order for an owner to achieve the best case transition period, the initiation and planning phases need to be carried out during the existing wind farm’s service life and the proposed timeline that is in concert with the proposed RSPM framework can be seen in Figure 15\(^{11}\). The timeline suggests six milestones in the repowering project life cycle, which were chosen because of their importance in the existing wind farm’s operational (service) life and in the repowering project life cycle.

\(^{11}\) I, P, E, C are abbreviations of the four project phases. Grey project – construction of existing WF, Yellow – DfR sub-project, Dark Blue – new construction sub-project.
4.6.1 Milestone 1

Milestone 1 is probably the most important date in a wind farm program because it marks the following:

- Beginning of the wind farm program
- Closure phase of the original construction project, implying the beginning of the existing wind farm’s service life
- Beginning of the repowering project

Even though the owner might not even know if he is interested in repowering at the beginning of wind farm’s operational life, the repowering project should be initiated at this point. The beginning of the initiation phase implies a modest up-front investment in terms of time and resources, but could mean a better transition between the existing wind farm and the new wind farm in the long run. At this point in time, the owner can set up a mission statement of continuing production and repowering the wind farm. Furthermore, an initial strategy analysis could be performed as well. Assuming that the owner performed a SWOT analysis prior to the construction of the existing wind farm, there is a good basis for drafting an updated version based on the original and any changes that might have occurred as a result of additional experience. Based on the geo-
political environment and the development of renewable energy sources, the owner might want to rank the external factors by importance and establish additional checkpoints for their monitoring.

Moreover, the owner should have completed a stakeholder analysis as part of the old project which can be used for setting up the stakeholder profile. As explained earlier in the paper, based on the location of the wind farm, some of the stakeholder groups might change and thus conducting any in-depth analysis of the stakeholders at this stage would not be necessary. Another very useful activity that needs to be included is database creation with the necessary information regarding the suppliers, turbine manufacturers, governing authority contacts etc. The presumed TDD from the original project should serve as a good starting point for this task, and this is something that should be updated on an annual or bi-annual basis. Lastly, a general identification of repowering strategy alternatives should be completed at this point, merely in order to establish a framework to follow.

4.6.2 Milestone 2

Milestone 2 is the date when the O&M warranty expires, which is typically between two and five years since the beginning of operations (Brown, 2010). When this happens, the owner needs to decide how to treat O&M in the future. The owner has three choices: continue using the original equipment manufacturer’s services, hire a third-party, or do it in-house (Dvorak, 2012). The decision making process for selecting the optimal option is not easy, since the cheapest option does not have to be the best option (Jones, 2010). Given the complexity of this decision, the owner should have gathered enough experience to make the optimal decision for the wind farm, in other words, he should have a good understanding of the characteristics and challenges regarding the wind farm. Another thing to keep in mind here is that some manufacturers include retrofitting into their packages, and this could impact the decision making process regarding the type of repowering in the long run.
4.6.3 Milestone 3

Milestone 3 is the halfway point of the existing wind farm operations, which can be after 10-12 years of operation, assuming a 20 to 25-year service life time. By this point, the owner should have an in-depth understanding of the wind resource and the financial performance of the wind farm, which should provide some information regarding whether repowering could be plausible. In preparation for this stage, the stakeholder profile should have been updated if there were changes and all of the alternatives should be identified and prepared for evaluation. As mentioned earlier, the evaluation could be performed using a CBA, MCA, or any other type of analysis that the owner prefers.

Furthermore, in order to mitigate some of the uncertainty, the halfway point presents itself as the appropriate time for constructing scenarios, as the owner has enough experience and the scenario time frame should be acceptable for getting a better idea of how the repowering strategy will be implemented. Having constructed scenarios while taking into account any present or potential changes in the external environment, the owner could evaluate the alternatives and see which alternative fairs the best for each scenario. After this point, the owner should start engaging some of the stakeholders, primarily the supply chain, governing authority, and grid operator, in order to get a better understanding of the necessary conditions and constraints underlying repowering execution, after which he should have enough information to perform a feasibility study.

4.6.4 Milestone 4

Milestone 4 marks the end of the initiation phase and the beginning of the planning phase of the repowering project. By this point, the owner should have engaged the main stakeholders, conducted a feasibility study, and chosen an optimal repowering strategy. The best timing of this date is hard to estimate, since it is most likely site-specific. However, assuming that the owner can make a reasonable estimate on the date of EOSL, the time spacing between these two dates should be approximately the same as the planning phase of the original construction project. Based on the additional project
complexity, stakeholder attitude, and effects of the external environment, this date could shift one way or another. Having completed all of the above, the owner can engage in the planning and permission process in anticipation of the EOSL.

4.6.5 Milestone 5

Milestone 5 marks the EOSL. If the repowering strategy has been diligently implemented throughout the existing wind farm’s operational life, the owner should be able to proceed with the execution phase of the DfR sub-project. It is important that even though the timeline in Figure 14 suggests that the initiation and planning phases of this sub-project occurred between Milestone 4 and Milestone 5, this is likely not the case, since each phase is part of its corresponding phase of the repowering project. After the DfR execution phase has been completed, the execution phase of new construction could commence.

4.6.6 Milestone 6

Milestone 6 implies that the repowering project has reached its closure phase, and thus the new wind farm could begin operating. The wind farm program would continue running, and if the proper conditions are in place, a new repowering project could begin with a similar process to the one that had just finished.

4.7 Conclusion

Chapter 4 expanded on the theoretical foundation from Chapter 2 by following the framework established in Chapter 3. After the literature review confirmed the applicability of strategic and project management concepts on repowering, this chapter proposed a way of using these concepts in practice. It was demonstrated that having a repowering strategy established early can help the owner make a more coherent transition between the existing wind farm and the new wind farm.
5 DISCUSSION AND ANALYSIS

Besides being a topic of theoretical nature, many of the concepts covered in this thesis can be considered to be conditional. The research attempted to create a general picture of what a repowering strategy and its corresponding repowering project would look like and how they would be implemented. However, due to the conditional nature of the research, nearly every step of the RSPM framework left some room for unforeseen circumstances, and this section will try to answer some of these hypothetical situations and any additional implications.

5.1 Policy Implications

Given that the renewable energy sources have historically relied on financial incentives, a question arises on how much this would differ for a repowering project. Historically, there are examples of additional incentives for repowering projects, as in Germany and Denmark, but also a lack thereof in California (Lantz et al., 2013). Meanwhile, having a decommissioning strategy during the initial project development has become mandatory in certain countries, as demonstrated by the literature search, which brings up another question. What if having a repowering strategy during the initial project development was also governed by regulations and policies as means of incentivizing the owner to deliberately plan for the EOSL? While the ideal goal of a repowering strategy would be to continue production, refuting the option of repowering might be just as valuable for the owner.

In addition, according to the articles 5.37 and 5.38 of the UK Energy Act of 2004, “Government will be seeking to ensure that decommissioning of installations, or redundant parts of them, will be carried out as soon as reasonably practicable…it is recognised that disused facilities may represent important infrastructure and provide the means for welcome future development…Government will expect the removal, repowering…not to be delayed” (DECC, 2011). After analyzing this statement, the potential for a repowering strategy policy can be recognized since the strategy could shorten the transition period between wind farms. This way, a policy on having a
repowering strategy can work as a two-way stream. On one hand, the governing authority could use it to control the owner and make sure that the transition will be carried out in the most practical way, and on the other, the owner would have an incentive to diligently develop the repowering strategy instead of regarding it as an episodic task. Both sides would be working towards the same goal – finding the optimal EOSL solution.

5.2 Transition between wind farms

Given that Figure 13 was mainly an illustration of different transition periods without set time boundaries, the worst and best case outcome require some additional discussion. The worst case was set up in a way that when the closure of DfR sub-project is completed, the construction sub-project is initiated, and that the initiation of DfR begins at the EOSL. This presumed case does not take into consideration that the initiation of the construction sub-project does not begin exactly after the DfR closure. This case was not regarded since DfR can only be executed if the intent is to repower the wind farm, and as such the construction would have to immediately follow. If this is not the case, the wind farm would just be decommissioned and restored, and thus the project would probably not have the status of a repowering project. Also, assuming that having a decommissioning strategy is mandatory, it could be argued that EOSL does not mean the beginning of DfR’s initiation phase, but rather later point of the phase. On the other hand, the presumed best case scenario could be even shorter because of the reversal idea of installation and decommissioning of wind turbines, as mentioned in Section 2.7.3. In this case, the sub-projects’ execution phases would overlap, thus causing the execution phase of the repowering project to shorten.

5.3 Repowering Project Timeline

The presented repowering project timeline is a general proposal aimed to fit a wide array of wind farms. However, since it is hard to generalize wind farms, the process could vary significantly based on the type and location of the wind farm, and the
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timeline should be expanded to fit the site-specific characteristics. Alongside the six milestones, any referendums, elections, or policies that can have an effect the repowering outcome need to be taken into consideration. For example, the latest elections in the UK have jeopardized the future of onshore wind power as the Conservative Party, an opponent of onshore wind, was set to form a majority in the House of Commons (Quitte, 2015). Moreover, one of the reasons for the early initiation of the repowering project is that it can serve as a risk planning tool and ensure that the owner is better prepared in case of an unforeseen event. Lastly, another important factor to keep in mind is how the decommissioning funds are accrued. If the decommissioning funds are accumulated over the course of the entire projected service life, any unforeseen events could cause the owner to lose money and consequently impact the repowering outcome.

5.4 Repowering Considerations

For the purposes of this paper, four broad groups of considerations were identified and regarded as having two main options to choose from. Seeing as though that the decision making process is highly complex, splitting the considerations into four main groups might not be sufficient. Also, depending on the type of wind farm, namely if it is onshore or offshore, certain considerations might not be applicable. For example, Crown Estate gives a lease of 40-50 to offshore wind farm sites in the UK (LWFL, 2010; RWE Innogy, 2012). With this being the case, the site area considerations could potentially be less complex, since the owner would have a secured lease for essentially another operational life time.

Another option that was not considered was the option of decreasing the wind farm capacity. This option was overlooked because it was presumed that the production from renewable energy source was supported and encouraged. Even with this being true, another renewable energy source, or even a different wind farm, could cause the owner to decrease the installed capacity.
6 CONCLUSIONS

6.1 Introduction

This chapter will provide conclusions regarding the research questions, list research limitations and provide recommendations for future research. Lastly, the paper will conclude with some final thoughts regarding the research.

6.2 Conclusions regarding the research questions

As established in Section 1.2, a review of literature demonstrated a lack of wind farm repowering discussion in project management context. With this in mind, three research questions were defined with the aim of demonstrating the applicability of fundamental strategic and project management concepts on wind farm repowering.

➢ Can repowering be analyzed from a strategic management perspective?

In order to answer this question, it can be helpful to reflect on the definition of strategic management. According to Jemison (1981), “strategic management is the process by which general managers of complex organizations develop and use a strategy to coaligning their organization’s competences and the opportunities and constraints in the environment” (Jemison, 1981, cited in Nag et al., 2007).

In short, the answer to the first research question is yes. It was demonstrated that by following the strategic management process, the owner can use his competencies, which are the available information he has regarding the wind farm and the modest up-front investment that the repowering strategy entails, to successfully shorten the execution phase of the repowering project and select and implement the optimal alternative of the repowering strategy. Furthermore, the links between key concepts were presented in order to demonstrate how different concepts can be combined in order to ensure an optimal strategy implementation.
What tools and concepts can the fields of strategic management and project management offer to the wind power industry, specifically to repowering?

The first concept used was that of strategic intent, whose hierarchy demonstrated the relationship between different hierarchical levels of strategy. This served as basis for the repowering strategic management process which analyzed the strategy and identified the repowering alternatives. Proceeding to the strategy implementation stage was facilitated through the wind farm program that governed the repowering project life cycle. Implementation of scenario planning was recommended at the halfway point of the existing wind farm’s service life as means of strategy evaluation and risk assessment. Finally, with an established program timeline, the potential time savings in transition between the existing and the new wind farm were represented.

Besides the theoretical links and implications, can these tools be utilized in practice?

Due to the time constraints and scope of the thesis, this question was only partially answered, since verifying some of the postulate would require a real-life case. Nevertheless, through the demonstration of applicability of different concepts and the creation of the RSPM framework, these concepts have demonstrated that they should be utilized in practice.

6.3 Limitations of the research

As Section 1.7 has previously established the limitations of the research used to define the scope of the project, this section discusses the limitations that became apparent during the progress of the research.

Firstly, as mentioned in Section 2.6, strategic management has three main paradigms and this paper used the rational approach. Certain van Heijden’s (1996) assumptions of this approach, such as “predictability, with no outside interference” and “implementation follows formulation, while independent of action” reveal some of its
limitations. While this approach seemed most suited for this kind of research, the author acknowledges that using another paradigm might have led to different conclusions.

In addition, the broad groups of considerations might have some impact on the outcome since the problem was simplified to fit the profile of a generic wind farm. Transportation, installation methods, and contracting, are examples of underlying activities following the repowering decision making process. Each one of these subsections implies its own decision making process, and expanding on this could have affected the outcome and brought up more considerations that need to be addressed. Moreover, the only approach to the program operationalizing repowering strategy has been the forward looking and somewhat conservative approach that only regarded the situation if the repowering project started at the same as the wind farm program. Further research is needed for situations when the repowering project does not start at Milestone 1 to see how this affects the repowering strategy.

Finally, the biggest limitation lies in the fact that the framework is conceptual and has not been tested in a real-life wind farm. Due to its theoretical nature, it is possible that the rational approach could not account for some difficulties that could happen along the way. Attempting to estimate any of these difficulties would eventually lead to guessing and thus affect the credibility of the research.

### 6.4 Recommendations

The first recommendation, of course, is to test this framework for an existing wind farm, preferably two wind farms, with one being onshore and the other offshore to compare the differences in strategy development and implementation. Ideally, the framework should be tested on numerous wind farms in order to understand which, and if any of the postulates can fit the characteristics of any kind of wind farm.

Due to the time constraints during the study, strategy evaluation methods such as CBA, MCA, and scenario planning have not been tested. While it may be more meaningful to evaluate a strategy using real data, some of these methods could be applied as a theoretical exercise. Given that the paper has focused on the decision
making process, a simple and useful tool to use during evaluation could be the decision tree (see Gardiner 2005; Halpin, 2010).

Some of the construction issues, such as the difference between decommissioning and DfR and the possibility of upgrading foundations have been brought up during this paper and both represent highly interesting topics that could provide value for both the academic world and the wind power industry. Lastly, a further analysis into the timing aspect of the repowering strategy would be a terrific continuation of this research, as the proposed milestones could be evaluated and updated with any missing knowledge.

6.5 Concluding Remarks

The study’s distinct contribution to the body knowledge lies in identifying the potential of viewing wind farm repowering from a strategic and project management perspective rather than a solely engineering one. Repowering as an activity has the potential to double the operational life of a wind farm and the results of this study indicate that a deliberate, contingency planning approach to the development of the repowering strategy is necessary to achieve this in the most effective manner.
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