Circular Transition for the Wind Energy Sector

A focus on Challenges and Obstacles when two transitions (Energy and Circular) intervene for the wind energy sector.

Master Thesis

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MSc Construction Management and Engineering

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Circular Transition For The Wind Energy Sector

A focus on challenges and obstacles when two transitions (Energy and Circular) intervene for the wind energy sector.

by

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Preface

It always seems impossible until it’s done, and I can’t believe I finally wrapped it up. Before you lie the master thesis report “Circular Transition for the Wind Energy Sector” written to attain a master’s degree in Construction Management & Engineering at Delft University of Technology.

I always had keen interest in environment and sustainable studies and lately developed an interest in circular economy and energy transition and wanted to focus my research on either of the topics. To get the best of both worlds, I decided to focus my research on both circular and energy transition. This master thesis particularly focused on identifying various challenges and obstacles when circular transition and energy transition intervene for the wind energy sector.

With the Pandemic in rise and a lot of uncertainty, this journey was nothing short of a roller coaster ride and I would like to express my heart felt gratitude to everyone who was a part of this journey.

First, I would like to thank my committee for guiding, supporting, and being an integral part of my thesis. I would like to thank my chair Thomas Hoppe, for helping and advising me with the research framework and for providing a constructive feedback throughout the research which was needed to improve the quality of my research. Next, I would like to thank my first supervisor Daan Schraven, for being supportive and helping me throughout the process. His constructive criticism compelled me to think out of the box. I admire his motivation and enthusiasm about circular economy and in general. I would also like to thank my second supervisor MingMing Hu, who provided an initial guidance to narrow the scope of my research and for being supportive throughout the process. Finally, a special thanks to my company supervisor Maarten Schäffner, for giving me the opportunity to do my research at Witteveen+Bos, for being a strong support and for guiding me throughout the process.

Second, I would like to thank Witteveen+Bos for giving me the opportunity to do my research. Special thanks to all the colleagues at Witteveen+Bos for being patient and supportive and helping me when necessary. I would also like to thank all the interviewees from various organizations who took out some time to help me with my research and for providing insightful information.

Finally, above all, I would like to thank my parents and my sister for being a constant support for the last two years. The love and affection I have for them is undisputable. Next, I would like to thank all my friends back home in India and all my friends here in the Netherlands for keeping me sane and for providing help and support when needed. It has been a wonderful journey.

Towards the end, thanks to you, reader. On the off chance that you are perusing this line after the others, you at least read one page of my thesis. Thank you.

Feel free to contact me if you want to know more about the topic.

Sai Nikhil Nadella
Delft, October 2020

Executive Summary

Converging and lasting global issues such as climate change, global warming, resource depletion, etc. have urged interest in science, technology and policy for systemic societal change. These aspects have led the policy makers in the Netherlands to gradually adopt a transition approach. Over the past few years there is an increase in the electricity production from renewable sources. Electricity produced from renewable sources amounted to 17 billion kilowatt-hours (kWh) in 2017, versus 15 billion kWh in 2016 with wind turbines being the largest contributors followed by biomass and solar energy. Electricity generation from wind power rose by 16% from 8.4 to 9.6 billion. Currently there are six offshore wind farms off the coast in the Netherlands and three more are expected to up by 2023. At the end of 2015 there were roughly at least 2525 onshore wind turbines generating 3000 megawatts (MW) of electricity. By 2020, Netherlands intended to have an onshore wind capacity of 6000 MW.

While a lot is already being done towards renewable energy transition, there still lacks focus on several aspects. Currently, in most of the sectors that are focusing on renewable energy transition particularly the wind energy systems, the focus is mostly on cost efficiency or conversion efficiency and there has been less attention to environmental impact due to extraction of resources. Thus, it is crucial to change the nature of these renewable energy transitions and resource consumption so that it becomes *circular*. Recycling of renewable energy systems like wind turbines is rising up the agendas of policymakers, researchers and industrialists. However, circular economy is more than just recycling. It focuses on the fundamental assessment of material, reusability, longer lifecycle, reduced materials impact and ease of disassembly for repair and replacement. This raises a question: What is hindering the transition towards a circular economy for the wind energy sector. Even though a lot of scholars focus on transition studies, currently it is unknown as to what are the challenges and obstacles that serve as a hindrance for circular transition alongside the ongoing energy transition for the wind energy sector. In order to address this research gap, the following research question was formulated:

"What challenges or obstacles hinder the transition towards circular economy alongside the ongoing energy transition for the wind energy sector in the Netherlands?"

Firstly, an elaborate literature review was conducted to understand the growth of the wind energy sector and the current state of energy transition, followed by the possibility of a circular transition for the wind energy as well. The circular aspects (circular construction) relevant for the development of a wind farm were also discussed. For the circular transition to befall, an elaborate literature review was conducted on transition studies, with a major focus on sustainable transitions. Based on the comparative analysis between various frameworks, particularly on multi-level perspective and innovation systems framework, and by combining the four main types of system failures, market failures and four additional types of transition failures, Weber & Rohracher obtained a comprehensive 'failures framework' that address both structural and transitional failure. Considering there does not exist a transition framework for a circular transition, the comprehensive 'failures framework' was considered the most feasible method to capture the challenges and obstacles for the circular transition alongside the ongoing energy transition for the wind energy sector.

Three cases, an onshore, an offshore and near the shore were selected from various parts of the Netherlands. Data was collected from each case on various challenges and obstacles for the circular transition for the wind energy sector. Data collection for these cases was primarily done by interviews. In order to conduct the interviews, an interview protocol was adopted to give a complete insight and guidance during the interview which can be found in APPENDIX A. The interview protocol basically consists of the introduction, interview questions and post interview analysis. A sample group of around 12 respondents (4 per case) were selected based on the respondent criteria, that consist of actors/stakeholders across all the life-cycle stages of a wind farm development. All the challenges and obstacles identified were categorized using the Weber & Rohracher's 'Failures Framework'. The collected data was then analyzed by a cross case analysis method. Firstly, the qualitative interview data

was evaluated by applying open and axial coding techniques using ATLAS.ti, a qualitative data analysis software, following that an individual case report was written. Based on the documented data and individual case reports, cross case conclusions were drawn.

Several challenges and obstacles hindering the circular transition for the wind energy sector were obtained for each phase of wind farm development.

Design & Development Phase: The challenges and obstacles obtained within the design and development phase have been categorized under all the three categories i.e. market failure, structural system failures and transitional failures as mentioned in Table 32. The most common challenges and obstacles that were noticed in all the three cases were categorized under all the four different types of market Failures. Within the structural system failures, even though only a few of the challenges and obstacles categorized under infrastructural failure and capabilities failure were noticed in all the three cases, overall, maximum number of challenges and obstacles were found under this category of failures. Within the transitional Failures, similar to the structural system failures, only a few challenges and obstacles categorized under directionality failure and demand articulation failure were noticed in all the three cases. Taking all the twelve types of failures into consideration, for the design and development phase, most number of challenges and obstacles were identified under directionality failure followed by institutional failure.

Construction Phase: The challenges and obstacles obtained within the construction phase have also been categorized under all the three categories i.e. market failure, structural system failures and transitional failures as mentioned in Table 34. The least number of challenges and obstacles identified were categorized under market Failures and within market failures, the challenges obtained were categorized under three of the four types of market failures. No challenge or obstacle was categorized under over exploitation of commons. Within the structural system failures, even though only a few of the challenges and obstacles categorized under capabilities failure and network and interaction failure were noticed in all the three cases, overall, maximum number of challenges and obstacles were found under this category of failures. Within the transitional failures, only one of the challenges or obstacles categorized under directionality failure was noticed in all the three cases. No challenge or obstacle was categorized under the reflexivity failure. Taking all the twelve types of failures into consideration, for the construction phase, most number of challenges and obstacles were identified under directionality failure followed by institutional failure.

Operation & Maintenance and Decommissioning Phase: None of the three chosen cases have been completely commissioned and haven't reached the operation and maintenance phase and decommissioning yet. Thus, the challenges and obstacles obtained in these two phases have been speculated to be a probable challenge or an obstacle by the practitioners working in these cases. A few market failures were noticed in both these phases. Other than that, a few challenges were identified under Infrastructural and Institutional failure (Structural system failures) for operation phase and a few challenges were identified under directionality failure (Transitional Failure) for decommissioning phase.

These broad lists of challenges identified in each phase of wind farm development show that although wind energy sector is outdoing in terms of energy transition and transformation towards a zero-carbon future, it is still at its infancy when it comes to circular transition. Energy transition was in discussion for decades and finally you can notice the transition. However, it took a lot of effort in corporate innovation, trial research, getting the regulations right etc. for this transition to befall. Perhaps it might be the same case for circular transition as well. Focusing a bit more in detail on the comprehensive list of identified challenges and obstacles, they are categorized under the twelve failures mentioned in the failure's framework distinctly for each phase of wind farm development which are categorized and listed below in Table A. The failures that are highlighted in orange were observed in all the three cases. And of all the challenges and obstacles identified majority of them were categorized under *directionality failure* followed by *institutional failure.* These failures have been highlighted underlined in blue.

Table A: Challenges hindering the transition towards circular economy alongside the ongoing energy transition for the wind energy sector in the Netherlands

	Market Failures	Structural System Failures	Transitional System Failures
Design & Development Phase	➢ **Information Asymmetries** ➢ **Knowledge Spill over** ➢ **Externalization of costs** ➢ **Over exploitation of commons**	➢ **Infrastructural Failure** ➢ **Institutional Failure** ➢ Interaction or Network Failure ➢ **Capabilities Failure**	➢ **Directionality Failure** ➢ **Demand Articulation Failure** ➢ Policy Coordination Failure
Construction Phase	➢ Information Asymmetries ➢ Knowledge Spill over ➢ Externalization of costs	➢ Infrastructural Failure ➢ **Institutional Failure** ➢ **Interaction or Network Failure** ➢ **Capabilities Failure**	➢ **Directionality Failure** ➢ Demand Articulation Failure ➢ Policy Coordination Failure
Operations & Maintenance Phase	➢ Information Asymmetries ➢ Externalization of costs	➢ Infrastructural Failure ➢ Institutional Failure	
Decommissioning Phase	➢ **Information Asymmetries**	➢ Infrastructural Failure	➢ Directionality Failure

Although, all the identified challenges and obstacles may not be applicable to every case but, the framework of failures obtained from this research definitely serves as a foundation or the starting point to understand why there is reluctance to adopt circular transition for the wind energy sector and what challenges are hindering this transition.

On the whole, this research gives an overview of challenges and obstacles hindering circular transition for each phase of wind farm development and for the wind energy sector in general. The research also highlights different circular aspects and their level of consideration during the construction of wind farms. Although the research does not focus on providing solutions to the identified challenges and obstacles hindering circular transition and focuses on just the wind energy sector, it definitely takes one step towards the nexus of energy transition and circular transition.

The government could work on coming up with strict regulations and change permit conditions making circular aspects a need and incentive for the wind energy sector. There is a need for new policies, new regulatory frameworks and even new financing tools for the management of a circular economy. On the whole, circular transition cannot be achieved for the wind energy sector only if one or few actors focus on circular economy. It is a joint development in the network of value chain.

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1. INTRODUCTION

1.1 Background

Climate change is not just a word anymore, it is currently the defining issue and the biggest threat to humanity. From increase in global temperatures to rise in sea levels, decrease in snow cover to shrinking of ice sheets, the impacts are global in scope and unparalleled in scale (Causes of climate change, 2017). Scientists attribute global warming and greenhouse effect to be the predominant cause of climate change, and we humans are solely responsible for it. Continuous human involvement with the nature particularly combustion of fossil fuels and release of large volumes of CO_2 into the atmosphere is responsible for 64% of man-made global warming (Causes of climate change, 2017) and this atmospheric CO_2 has increased drastically post industrial revolution, the graph below shows (Climate Change: Vital Signs of the Planet, 2020).

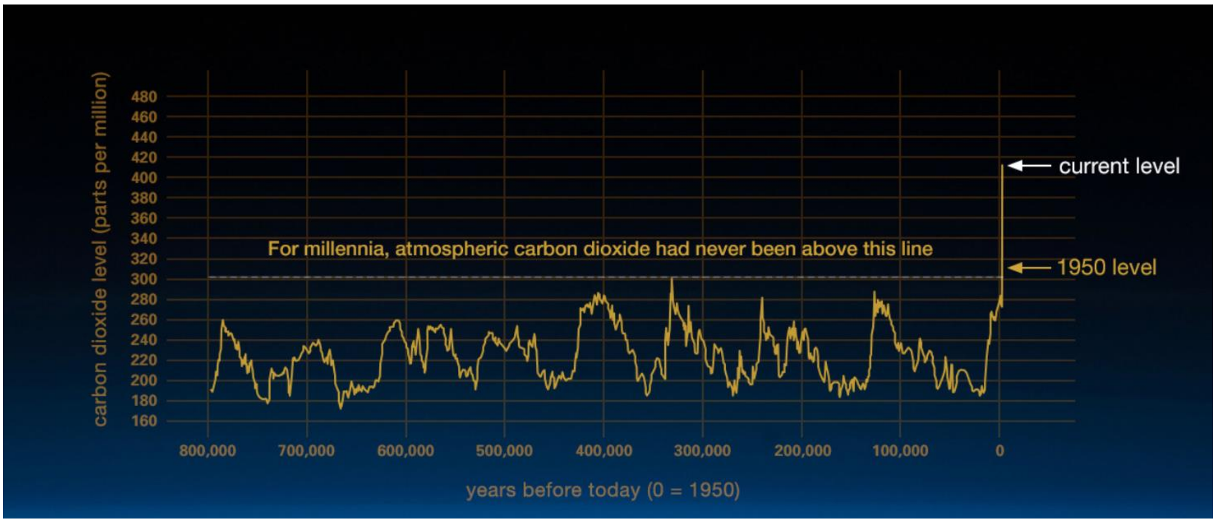

Figure 1: Comparison of atmospheric samples contained in ice cores and more recent direct measurements (Climate Change: Vital Signs of the Planet, 2020)

Long thought to be inexhaustible, the supply of fossil fuels is decreasing with every passing day. And considering the current rate, in the next 20 years we humans will consume 36% more energy than we do now (Netherlands Enterprise Agency, 2018). This calls for energy transition. Transition towards zero carbon emissions and renewable energy sources from fossil fuels could be the biggest measure for climate change and a lot of policies and agreements are being made to achieve the same.

In December 2015, parties to the UNFCCC reached an agreement known as the 'Paris Agreement' to strengthen the global response to the threat of climate change and to intensify the actions and investments to attain sustainable low carbon future. The agreement aims at keeping the global temperature rise well below 2 degrees Celsius above the pre-industrial levels and pursuing efforts to limit it to 1.5 degree Celsius. The EU and its Member States are among the close to 190 parties to the Paris Agreement (UNFCCC: The Paris Agreement, 2015)

Also, In 2018, the governments of Europe and the EU parliament implemented a set of EU laws for climate and energy policy in Europe and the aim is to have clean, affordable and reliable energy by 2030 (EU law on climate change, 2016).

1.1.1 Transitions

Converging and lasting global issues such as climate change, global warming, resource depletion, etc. have urged interest in science, technology and policy for systemic societal change. The subsequent calls for a 'transition' to echo the growing consensus that business as usual is no longer sufficient to address the global issues. 'Transition' is mostly used to define a process of shift from understanding and analyzing the problems to identifying the solutions for an environmental and societal change (Feola, 2014). Transitions are characterized by the development of new practices, structures and cultures in societal systems like energy, health, water, mobility, etc. as a result of co-evolution of economic, cultural, technological, ecological and institutional developments at different levels (Drift, 2020).

Energy Transition in the Netherlands

Several concerns regarding the climate change, depletion of fossil fuels and dependencies on the foreign material led the policy makers in the Netherlands to gradually adopt a transition approach. To combat climate change, the Dutch government aims to reduce 49% of greenhouse gas emissions by 2030 and 95% by 2050, compared to the 1990 levels (Dutch Climate policy, 2019). The Dutch government has formulated the Energy agenda: Taking steps towards sustainable energy, which set out a road map to 2050. It aims to achieve 14% sustainable energy by 2020, 16% sustainable energy by 2023, and almost 100% sustainable energy by 2050 (Dutch Energy Agenda, 2016). Despite these policies, Netherlands is near the bottom of the table on renewable energy usage in Europe according to Eurostat (2019). It is trailing behind the target to achieve 14% sustainability by 2020. According to the Eurostat (2019) only 7.6% of the gross final energy consumption in the Netherlands was renewable energy by February 2019. Even though far behind other EU countries on renewable energy goals, Netherlands is slowly picking up pace and energy efficiency continues to improve. Currently, the Dutch energy policies are working towards three main principles: 1) focus on CO_2 reduction 2) make the most of the economic opportunities that the energy transition offers and 3) integrate energy in spatial planning policy (Dutch Energy Report, 2016). To realize this transition, an analysis is conducted by distinguishing the way energy is used in the Netherlands in four energy functions: energy for space heating, energy for industrial process heat, energy for transport, and energy for power and light. In 2015, greenhouse gas emissions in the Netherlands amounted to 196 megaton CO_2 equivalents and the major part of it can be associated to the use of energy and can be roughly attributed to the four energy functionalities, the figure below shows, with the highest emissions being from power and light (Dutch Energy Agenda, 2016).

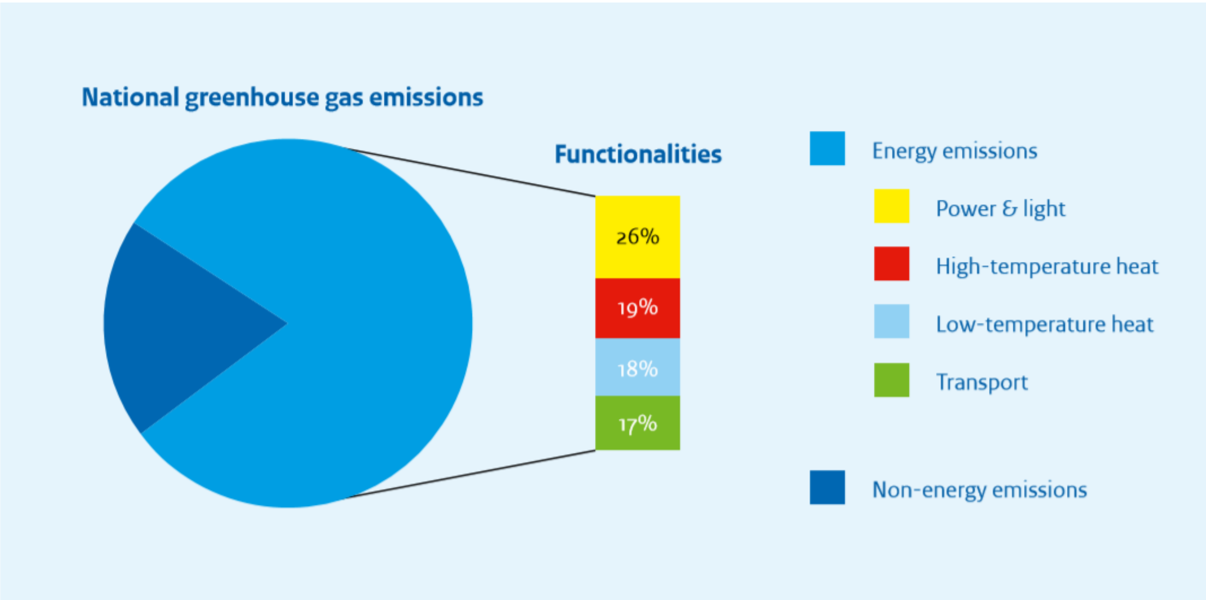

Figure 2: Dutch greenhouse gas emissions 2015 (Dutch Energy Agenda, 2016)

The demand for energy for power and light is met almost exclusively by electricity (Dutch Energy Agenda, 2016). Over the past few years there is an increase in the electricity production from renewable sources. Electricity produced from renewable sources amounted to 17 billion kilowatt-hours (kWh) in 2017, versus 15 billion kWh in 2016 with wind turbines being the largest contributors followed by biomass and solar energy (Statistics Netherlands, 2018). The figure (Statistics Netherlands, 2018) below shows.

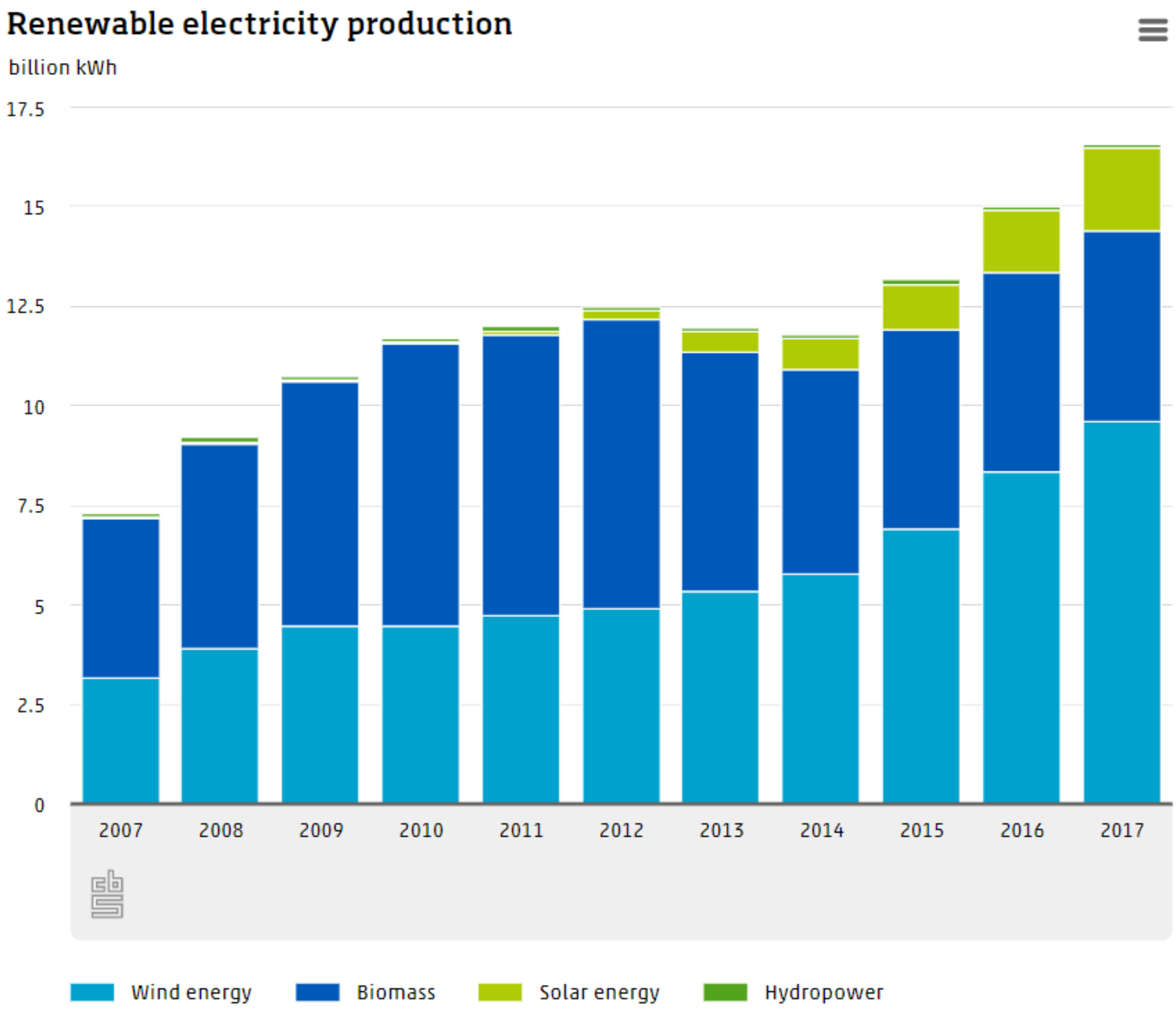

Figure 3: Renewable electricity production (Statistics Netherlands, 2018)

Electricity generation from wind power rose by 16% from 8.4 to 9.6 billion (Statistics Netherlands, 2018). With the current ongoing wind farm creation particularly in the North Sea, wind energy has seen the fastest growth in any renewable energy sector and is expected to increase in the coming years. Currently, there are six offshore wind farms off the coast in the Netherlands and three more are expected to come up by 2023 (Netherlands - Energy, 2019). At the end of 2015 there were roughly at least 2525 onshore wind turbines generating 3000 megawatts (MW) of electricity. By 2020, Netherlands intended to have an onshore wind capacity of 6000 MW. An average wind turbine has a capacity of 2 to 3 MW, so the Netherlands needs roughly 1000 to 1500 new onshore wind turbines by the end of 2020 (Ministerie van Algemene Zaken, 2017).

Circular Transition in the Netherlands

Besides becoming climate neutral, the Netherlands aims to become circular. The goal is for the Netherlands to have a completely circular economy by 2050 (Waterstaat, 2020). Although it is challenging to find a clear measure for 'circularity', the government aims to reduce 50% of primary raw material usage and materials to be reused as far as possible by 2030 (Waterstaat, 2020). As main priorities it has: Biomass and food, plastics, the manufacturing industry, construction sector and consumer goods (European Circular Economy Stakeholder Platform, 2016). The government has set out three main goals to accelerate transition towards a circular economy as soon as possible: 1) Ensure efficient use of raw materials for production processes. 2) Use sustainably produced renewable and widely available raw materials instead. 3) Develop new production methods and design new products to be circular. This transition presents economic opportunities to the Netherlands. It will make Netherlands less dependent on the critical materials and will contribute to a cleaner environment (A circular economy in the Netherlands by 2050, 2016)

1.2 Problem Description

While a lot is already being done towards renewable energy transition and transition towards a circular economy, we are still not doing all we could. Currently, in most of the sectors that are focusing on renewable energy transition particularly the wind energy systems, the focus is mostly on cost efficiency or conversion efficiency, there has been less attention to environmental impact due to extraction of resources (Watari, et al., 2019). Studies have shown that the decarbonization of various sectors could potentially be restricted due to mineral availability in the long term (Watari, et al., 2019). This can have severe implications to the environment and a threat to local and national economies. Wind energy systems are also completely dependent on rare earth metals. But, the current global supply of several rare earth metals is insufficient to transition to a renewable energy system (Metabolic, 2018). The Netherlands is particularly at risk, because its economy is intensively dependent on energy and materials and will continue to be dependent on primary raw materials for a long time to come. Thus, it is crucial to change the nature of these renewable energy transitions and resource consumption so that it becomes *circular*. The principle of the circular economy is about achieving the most efficient use of resources. Implementation of circular economy in the renewable energy systems may lower the global use of materials. The Dutch government considers circular economy as an important instrument to limit global climate change and to have a completely circular economy by 2050 (Waterstaat, 2020).

Many initiatives have been developed under the term 'circular economy', such as complete recycling or total carbon neutral (EM Foundation, 2013). Particularly for the researchers, industrialists and policymakers, recycling of renewable energy systems like wind turbines is climbing up the priority list. Recently, several studies regarding the environmental impact of wind turbines and turbine recycling, especially for blades have been carried out. Targets for recyclability have also been set by few manufacturers for their wind turbines (Andersen, et al., 2014). However, they fail to address the actual problem and address only a part of it. Recycling is just one of the several different 'R-strategies' (Reike et al., 2018). Recycling can lead to higher energy costs by shifting the problems to a different product chain and lead to a delay in reaching the maximum limit of the available raw materials. However, circular economy is more than just recycling (Kalchenko, et al., 2019). It focuses on the fundamental assessment of material, reusability, longer lifecycle, reduced materials impact and ease of disassembly for repair and replacement (Kalchenko, et al., 2019).

1.2.1 Problem Statement

Transition to a low carbon future is essential for realizing sustainable development and it has been in progress for quite a few years. However, renewable energy systems have certain tradeoffs with regards to resource flows and environmental impacts associated with resource extraction and end-of-life waste generation (Watari, et al., 2019). Thus, it is necessary to change the nature of renewable energy transition and resource consumption towards a circular transition. While a lot of concepts have emerged in Circular Economy in the 21st century, very little discussion has been established regarding the circular transition for the energy systems (Chen & Kim, 2019) and only limited research has been conducted on transition towards a circular economy for the wind energy systems; focus lies mainly on recycling rather than high-quality re-using of materials (Ghisellini et al., 2016).

This raises a question: What is hindering the transition towards a circular economy for the wind energy sector. Even though a lot of scholars focus on transition studies, currently it is unknown as to what are the challenges and obstacles that serve as a hindrance for circular transition alongside the ongoing energy transition for the wind energy sector.

1.3 Research Objective

Circular economy is moving from buzz to business. Currently, it is still at its nascent stage and not all the industries focus on it. The principle of circular economy is about attaining efficient use of resources and reducing waste generation, and the solution to attain sustainable energy transition for the renewable energy systems in terms of materials used could be 'circular economy' for the renewable energy transition (Kalchenko, et al., 2019). However, only limited research has been done regarding this transition towards circular economy for the wind energy sector.

Therefore, the main objective of this research project is to identify the potential challenges or obstacles that are hindering the transition towards circular economy alongside the ongoing energy transition of the wind energy sector in the Netherlands.

1.4 Research Questions

Main research question:

In order to achieve the research objective, the following research question has been formulated.

"What challenges or obstacles hinder the transition towards circular economy alongside the ongoing energy transition for the wind energy sector in the Netherlands?"

Sub research Questions:

To answer the main research question, several sub-research questions have been formulated.

I. *What transition approach describes best and is able to capture the challenges of a circular transition alongside the ongoing energy transition for the wind energy sector?*

II. *How to capture the challenges for adopting circular transition along with the ongoing energy transition for the wind energy sector in the Netherlands?*

III. *What are the challenges or obstacles identified when a circular transition intervenes with the ongoing energy transition for the wind energy sector in the Netherlands?*

IV. *What are the implications of these challenges or obstacles when two transitions (Circular economy and Energy transition) for the wind energy sector intervene?*

1.6 Research Scope

The major focus of the research is to capture the *challenges and obstacles* that hinder the *circular transition* alongside the ongoing *energy transition* of the wind energy sector in the Netherlands. The energy transition, away from fossil fuels and towards Renewable energy is gaining momentum. Renewable energy and energy efficiency measures can play a major role in reducing the carbon emissions. However, the lesser known fact is the environmental impact caused due to decarbonization of various sectors particularly associated with resource extraction and end-of-life waste generation (Watari, et al., 2019). Thus, it is necessary to change the nature of renewable energy transition and resource consumption towards a circular transition. In order to address this, first and foremost, the research will focus on the ongoing energy transition of the *wind energy sector in the Netherlands.* The focus will be on the offshore, onshore and near the shore wind farms in the Netherlands particularly on the construction, installation, operation and decommissioning of the wind turbines.

Secondly, Circular Economy has seen a significant increase in interest in the past few years and is steadily gaining momentum. With the surge in popularity, circular economy has many definitions, principles and practices. For the scope of this research, primary focus will be on circular construction. Several circular aspects throughout the lifecycle of construction will be considered for the circular transition alongside the ongoing energy transition for the wind energy sector. Finally, in order to capture the challenges for circular transition, a suitable transition framework will be adopted. The research mainly aims to provide a framework that highlights the challenges and obstacles of a circular transition and does not aim to provide solutions to the various challenges encountered for the circular transition.

1.7 Research Relevance

1.7.1 Scientific Relevance

In the past decade, wind energy has become one of the world's fastest growing sector and debatably reduced CO_2 emissions more than any other technology (Building a Sustainable Wind Industry For The Energy Transition, 2019). Unprecedented progress has been made to reduce the cost and improve the efficiency through innovation. However, the focus is just on the cost efficiency or conversion efficiency and not on the aspects of circularity (Watari, et al., 2019). The amount of scientific literature on circular economy has been increasing rapidly. Yet, there seems to be a gap between the theoretical concept of circular economy and its implementation, particularly when it comes to wind energy sector. Several studies regarding the environmental impact of wind turbines have been carried out recently, along with technological development projects related to the recyclability of wind turbines (Andersen, et al., 2014). However, circular economy is more than just recycling. Although a lot of scholar focus on transition studies, studies that focus on circular transition alongside the ongoing energy transition for the wind energy sector is still at its initial stage. There has been little or no academic attention as well. This study particularly focuses on rather unknown challenges when circular transition intervenes with the ongoing energy transition for the wind energy sector in the Netherlands making a modest yet essential contribution in the field of circular economy and energy transition for the wind energy sector.

1.7.2 Practical Relevance

Over the past few years implementation of circular economy has gained increasing attention in few sectors. However, there has been very little attention regarding circular transition when it comes to the wind energy sector. Thus, as a preparatory step in the transition towards circular economy for the wind energy sector along with the forecasted energy transition, this study will focus on identifying challenges and obstacles for a circular transition and create/use a comprehensive framework to capture these challenges. The identified challenges will give a complete overview for the practitioners and the stakeholders involved during the complete life-cycle stages of a wind farm, regarding the major challenges hindering circular transition alongside the ongoing energy transition for the wind energy sector in the Netherlands. The developed framework can also be used to obtain solutions based on the identified challenges. On the whole, by sharing the attained knowledge and information regarding the challenges for a circular transition alongside the ongoing energy transition for the wind energy sector, this research makes a modest yet essential contribution in the field of circular economy and energy transition for the wind energy sector.

1.8 Research Design

In order to obtain answer to the research questions, the research is designed into several chapters. The research structure of the main body of this research in relation to the several chapters is visualized in Figure 4. In Chapter 2, a brief literature review is conducted on Energy transition for the wind energy sector along with the concept of Circular economy and circular construction. This is followed by review on various transition approaches to obtain a suitable framework to capture the challenges and obstacles for Circular transition alongside the ongoing Energy transition for the wind energy sector in the Netherlands. In Chapter 3, a research methodology is chosen explaining how it will be used for data collection and data analysis. Chapter 4 presents results about the different challenges and obstacles experienced when two transitions (circular transition and energy transition) intervene for the Dutch wind energy sector. This is followed by Chapter 5 which includes discussion and expert validation. The final Chapter of the research draws conclusion regarding the final results including the answer to the main research question followed by research limitations. From these, recommendations for practice and further research follow.

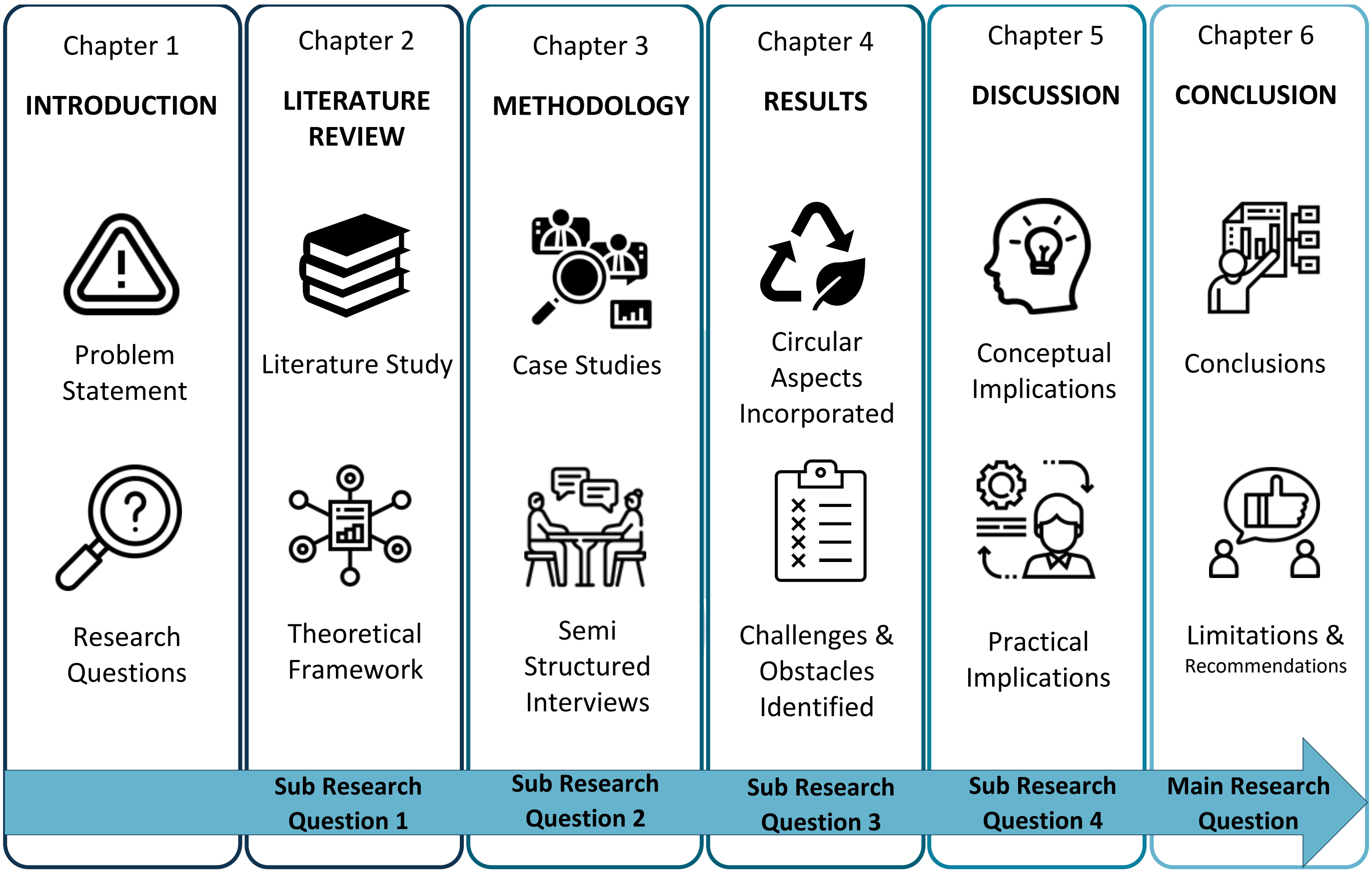

Figure 4: Research Design (Own Illustration)

2. LITERATURE REVIEW

The focus of this research is to identify the challenges and obstacles when circular transition intervenes with the ongoing energy transition for the wind energy sector in the Netherlands. This chapter provides theoretically available knowledge to address this knowledge gap and to define a theoretical framework. First, the wind energy sector is explained. The ongoing energy transition and the possibility of circular transition for the wind energy sector is discussed in section 2.1. In section 2.2 the concept of circular economy and circular construction is elaborated. In section 2.3, literature review will be conducted on transition studies to identify and elaborate on various transitions frameworks that are available. Finally, in section 2.4, a comprehensive transition framework is adopted and elaborated in detail as theoretical framework for the research followed by summary in section 2.5.

2.1 Energy Transition And Circular Transition For The Wind Energy Sector

2.1.1 Wind energy sector

Wind energy is one of the fastest growing renewable energy technologies accounting for nearly 16% of electricity generated by the renewables as per 2016 (IRENA, 2020). Wind turbines emerged more than a century ago and the first modern wind power is considered to have been developed in Denmark in 1891 which began operation in 1897 (IRENA, 2020). Primarily there are three main types of wind energy;

i. *Distributed Wind:* Single small wind turbines under 100 kilowatts and are not connected to the grid. They are utilized to straight away power a home, farm or small business (AWEA, 2020).

ii. *Utility-scale wind:* Wind turbines that range in size from 100 kilowatts to several megawatts. Electricity is usually delivered to the power grid and distributed to the end user by electric utilities or power system operators (AWEA, 2020).

iii. *Offshore wind:* Wind turbines that are established in large bodies of water, usually on the continental shelf. Offshore wind turbines are larger than onshore turbines and can generate more power (AWEA, 2020).

Often, when a large number of wind turbines are built close together, it is referred to as a wind farm or a wind project. A wind farm functions as a single power plant and sends electricity to the grid. Both distributed wind and utility-scale wind can be categorized as onshore or near the shore wind farms (AWEA, 2020).

Phases of construction and Implementing sectors involved for a typical Wind Farm

Development of wind farms is highly complicated process that involves various organizations with a variety of knowledge, technology and diverse background. The process of construction of wind farms varies from project to project and depends on various factors such as the type of contract the client has chosen. It involves several steps from surveys, planning processes, production, services for installation, etc. All these can be categorized into four phases which are defined by Weig & Schultz-Zehden, (2019) as follows;

Figure 5: Phases of wind farm construction (own illustration)

Design and Development Phase

This is the first phase of the project that primarily involves objective for the project, feasibility, identification of major deliverables, presentation of contract, tender type, overall timeframe for the project, survey and design studies, and approval of design. Firstly, several survey and studies are carried out to obtain the approval status. Based on the type of project, offshore or onshore, environmental, met stations, geophysical, geotechnical and costal surveys are conducted. This is followed by Front end engineering and design studies to address technical uncertainties, design and develop the concept of wind farm tailored to local conditions. Human impact studies assess the impact of the proposed wind farm on local communities. Tender is also placed either before, after, or in the middle of the design phase, depending on what type of contract the client prefers. This phase ends, at best, with the approval of the wind farm (Weig & Schultz-Zehden, 2019).

The most important actor that are involved in this phase is the wind farm owner/developer. Firstly, economic, environmental and technical consultancies are contracted to conduct the necessary surveys and gather relevant information for approval. Project management/engineering consultant team is formed during this phase to carry out the entire project. Several investment companies get involved to procure the funds for the project. Insurances are contracted to minimize the risk and legal consultancies are used to solve conflicts if any between various contracting partners. Technical components and installations are certified by the certifiers before use. Several logistic services are contracted based on the type of the project, offshore or onshore. Also, research plays a key role for new insights in offshore and onshore wind farms (Weig & Schultz-Zehden, 2019).

Construction Phase

Construction phase mostly involves installation and commissioning of several services from cable lying, to installations of foundations, turbines and substations for wind. Many components have to be assembled and put together. Starting with one of the most important components *nacelle,* which typically includes nacelle bedplate and cover, the main bearing and the shaft, the gearbox, a generator, the power take-off and a control system. Another important component is the *rotor,* that typically consists of blades, blade bearings, a pitch system to adjust the pitch angle of the blades, a spinner, a rotor auxiliary system, a hub casting, steel components and structural composite materials. The third important component is the *tower,* basically made of steel. It includes personnel access and survival equipment, a tuned damper, an electrical system and tower internal lightning. Another important component is the turbine *foundation* consisting of a foundation structure, a transition piece to connect foundation and turbine, a crew access system and a J-tube to route the array cable. Finally, several substations are built, and cables produced connecting wind turbines and substations which includes an electrical system along with services to support the operation and maintenance of the whole wind farm (Weig, pg.37, 2017).

For a wind farm construction, be it offshore or onshore, construction phase is the most demanding phase. The overall requirements can be divided in the following fields: raw materials, civil engineering, electrical engineering, drive technology, sensor technology, network connection, production of various tools and other components. In order to operate and maintain the turbines, IT-solutions are developed and installed. Several coatings and lubricants are used for protection against corrosion and to ensure smooth running of the machines. Safety precautions are installed along with lightning protection measurements. Different forms of logistics and access is required for installation of the wind farms. Most of all, a comprehensive health and safety management is required to prevent accidents and aid help in cases of emergency (Weig & Schultz-Zehden, 2019).

Operation & Maintenance Phase

The operation phase of a wind farm is usually limited to 20-25 years. During this phase the overall performance of wind farms are monitored, scheduled maintenance is planned, and customer-supplier interaction is managed. Primarily observation, maintenance and repair are the tasks to be done. In case of damages, components are replaced.

In the operation phase, comparatively, only a few sectors/actors are involved who primarily focus on monitoring, maintenance and repairing the wind farms. Besides technical, environmental monitoring is equally necessary during the whole lifecycle of the wind farm. Logistics are still needed, legal consultants, insurances and research team go on with their work. Lubricants and coatings are usually renewed, IT-service providers monitor and improve their system regularly. The owner/developer and investment firms intend to recoup their money during this phase. Overall, project management/consultant is responsible for smooth functioning of the system (Weig & Schultz-Zehden, 2019).

Decommissioning Phase

When a windfarm reaches the end of its useful life it will be deconstructed and removed from the site. It primarily involves dismantling and removing of wind turbines and the electrical and civil infrastructure. At this stage, most of the wind turbine components still have a commercial value along with recycling potential. Another option could be to repower the project which involve removing old turbines and placing the new and efficient turbines at the same time. This allows some of the existing civil and electrical to be retained and reused, with associated environmental and economic benefits. Repowering brings the project back to the start of the life cycle process.

The decommissioning phase is not as experienced considering the first wind farm operation in the Netherlands began operation in 2000 (World wind energy association, 2018). However, for decommissioning of wind farms primarily for transportation and recycling of different components a variety of actors/enterprises are required much similar to the construction phase including recycling agencies.

2.1.2 Energy Transition: Current state for the wind energy sector

Wind energy sector has emerged as a pioneering renewable technology in the recent decades. As of 2018, with more than half a terawatt installed globally, wind power is leading in terms of total installed capacity after hydropower (IRENA, 2019). Wind energy sector will emerge and remain as the key renewable energy option in the coming decades with increase in both onshore and offshore sectors. By the end of 2020, in most of the regions, onshore wind sector is set to offer consistently a less source of new electricity than the least-cost fossil fuel alternative (IRENA, 2019).

The evolution of the wind energy sector worldwide, has been quite significant. Several milestones in terms of installation, technological innovations and cost reductions have been achieved in the last four decades as shown in Figure 6.

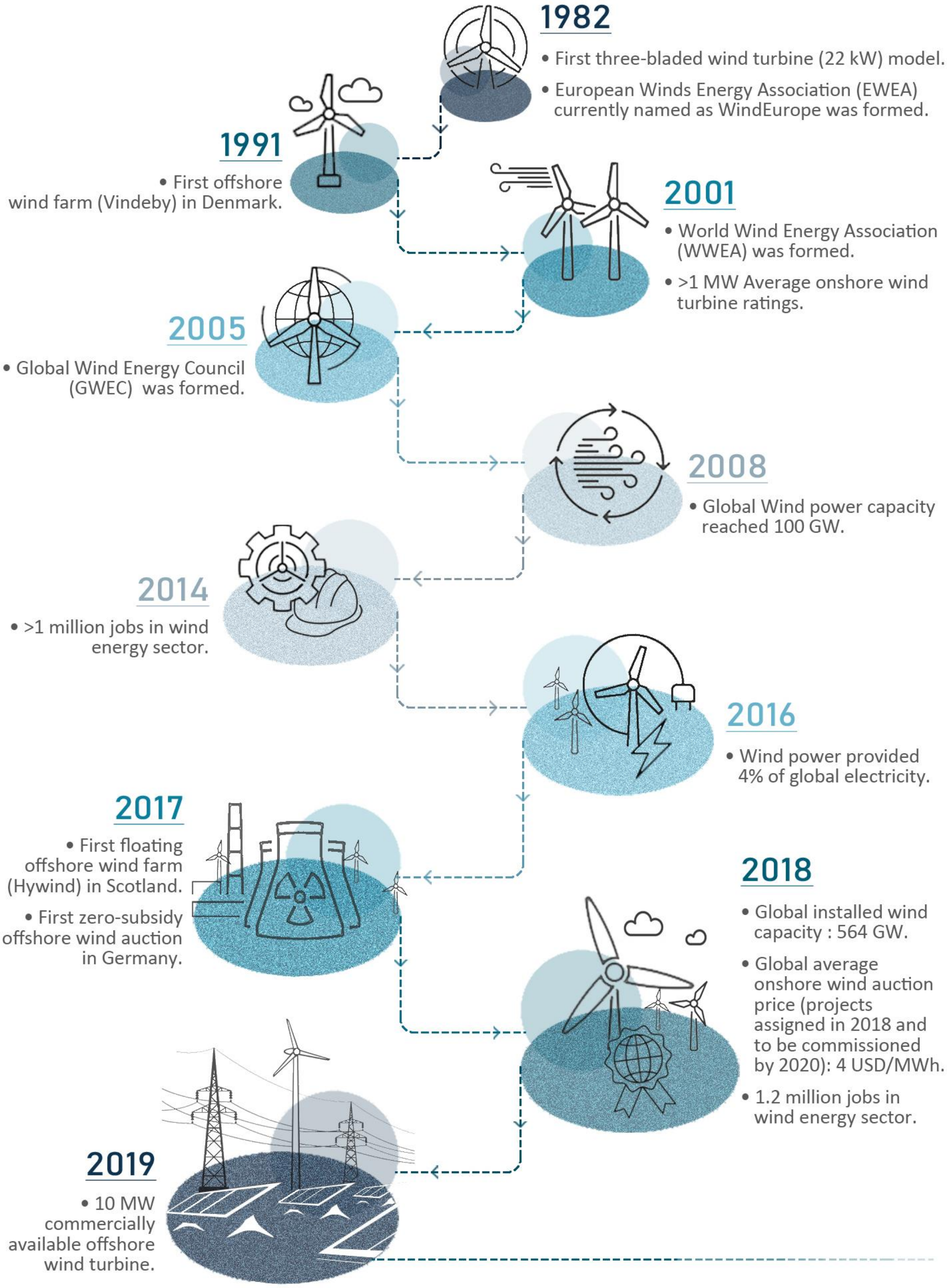

Figure 6: Key milestone in Wind Energy Sector

In the Netherlands, wind energy has been in use since the inception of the country. Windmills have been used to drain the wetlands, saw logs for building, grind grain for food, and many other industrial purposes (Ogg, 2018). Soon the modern wind turbines took over making wind energy one of the largest contributors of renewable energy technologies in the Netherlands with a focus on both onshore and offshore projects. As of 2018 there are around 2000 onshore wind turbines, providing around 4% of the total Dutch electricity requirement (Ogg, 2018). And by the end of 2020, the Dutch target 6000 megawatts installed power capacity from onshore wind turbines. In case of offshore wind, currently there are six offshore wind farms off the coast in the Netherlands and three more are expected to up by 2023 increasing the capacity to 4500 megawatts (Netherlands - Energy, 2019). Several long-term visions dating to 2050 have been drafted for both onshore and offshore wind sector.

2.1.3 Circular Transition: Current state for the wind energy sector

Wind energy sector in itself is a part of transition towards circular economy for many reasons, mainly for producing clean and renewable energy. A genuine circular economy would be powered in its entirety by renewable energy, creating a restorative and regenerative economic model (Wind Europe, 2017). Although wind energy is considered as the one of the supreme renewable energy sources, lately, attention is turning to reduce the possible environmental impacts of this sector. Recently, several studies regarding the environmental impact of wind turbines and turbine recycling, especially for blades have been carried out. Targets for recyclability have also been set by few manufacturers for their wind turbines (Andersen, et al., 2014). Hao, et al., (2020) reason that wind energy would not be 'green' if anthropogenic materials used for the construction of wind turbines are not considered in a responsible manner. Using the concept of circular economy, Hao, et al., (2020) recommend recycle of the anthropogenic materials in the form of extracted carbon fibers to close the circular economy loop. However, they fail to address the actual problem and address only a part of it. Circular economy is much more than just recycling. It focuses on the fundamental assessment of material; reusability, longer lifecycle, reduced materials impact and ease of disassembly for repair and replacement (Kalchenko, et al., 2019)

Nonetheless, Circular transition for the wind energy sector is still at its nascent stage and currently, it is unknown as to how this transition would affect the ongoing energy transition for the wind energy sector, and what could be the potential challenges.

2.2 Circular Economy (CE)

2.2.1 Definition and Concept

Circular economy is proposed as an approach to economic growth corresponding to sustainable environment (EM Foundation, 2013). The current traditional linear take-make-dispose economic model has several implications on the materials used and the environment making it unsustainable. Circular economy, however, provides a cyclic flow model of materials and energy for the economic system (Korhonen, et al., 2018). It is currently a popular concept being endorsed by most of the countries including the Netherlands, as well as several businesses and communities around the world. There are various possibilities for defining circular economy and no commonly accepted definition (Kirchherr, et al., 2017). Generally accepted and often cited definition of circular economy is by the Ellen MacArthur Foundation, (2015) *"Circular economy is restorative and regenerative by design and aims to decouple economic growth from the consumption of finite resources and build economic, natural, and social capital"* based on three principles; Design out waste and pollution, Keep products and materials in use, Regenerate natural systems. Based on Ellen MacArthur Foundation several other definitions were extended or adopted. Taking into consideration the current academic, policy and industry consensus and from the perspective of production-consumption systems and sustainable societal development, Korhonen et al., (pg.39, 2018) defined circular economy as *"sustainable development initiative with the objective of reducing the societal production-consumption system, material and energy throughput flows by applying materials cycles, renewable and cascade-type energy flows to the linear system".* Circular Economy supports high value material cycles along with traditional recycling and develops systems approaches to the cooperation of producers, consumers and other societal actors in sustainable development work (Korhonen et al., 2018).

There are quite a few advantages of defining circular economy from a production-consumption perspective. First, the definition considers the system boundary challenge by highlighting production-consumption systems and their integrated flows. Second, the definition also recognizes the governance and management limitations of the physical flows by emphasizing on inter-sectoral and inter-organizational management and governance models (Korhonen et al., 2018). In short, it can only maximize the service produced by linear flow and focus not only on production but also on environmental, social and economic impacts throughout the entire lifecycle for sustainable development.

2.2.2 Circular Economy in Construction

Construction industry is one of the largest users of energy, water and material resources and contributes to a large proportion of all types of waste. The demand for raw materials in the construction sector is increasing over time putting an enormous amount of pressure on the resources and the living environment. Globally, construction material resources may be abundant. However, at regional level, construction material shortage is already a huge concern, and transporting these materials from larger distances can have several environmental implications. Given the concern regarding the material shortage and environmental impacts, circular economy for the construction sector can be a way to tackle these problems (Adams, et al., 2017).

The circular economy thinking in construction is at its infancy and is mainly limited to recycling and construction waste minimization with a little attention on the reuse of products (Adams, et al., 2017). Circular construction considers all the phases of lifecycle of a structure starting from the design phase. The architect should have a knowledge on how the demolition contractor works, the contractor must ensure that the manager/owner of the structure is well informed regarding the information concerning the materials being used, and the manager/owner must ensure that the demolition contractor can also have access to the information, sometimes more than a hundred years later. And the recycling firms must have a knowledge on the technical requirements the circular constructor places on the materials that he uses, to adapt suitable recycling technology. Accordingly, when circular construction is at first a design and technical task, it swiftly proceeds to cooperation, knowledge sharing and transparency (Rijkswaterstaat, 2015).

2.2.3 Circular economy aspects in each phase of construction

Like mentioned above, there has been a limited application of circular economy principles in the construction sector within the whole systems perspective. Currently, the focus is majorly on solutions to manage waste generation which may have led to an overall improvement in construction and demolition waste. However, most of this waste is downcycled reducing the quality and functionality of the original product (Adams, et al., 2017). In order to make a complete transition towards circular economy, key circular aspects need to be applied in all the phases of construction throughout the life cycle of the building or a product. Adams, et al., (2017) have identified several key aspects of circular economy that can be applied throughout the complete lifecycle for a circular construction. Table 1 has an overview of circular economy aspects for circular construction. These circular aspects, however, lack complete adoption and are often applied in separation within a particular project or sector, with minimal consideration for the economic aspects across the life cycle for a particular construction project. The circular aspects mentioned below in Table 1 can be of consideration for the construction of wind farms.

Table 1:Circular economy aspects for circular construction (Adams, et al., pg. 3, 2017)

Phase of wind farm construction	Life-cycle stage	Circular Economy Aspect
1. Design & Development Phase	Design	Design for deconstruction
		Design for adaptability and flexibility
		Design for standardization
		Design out waste
		Design in modularity
		Specify reclaimed materials
		Specify recycled materials
	Manufacture and Supply	Eco design principles
		Use less materials/optimize material use
		Use less hazardous material
		Increase the life span
		Design for product disassembly
		Design for product standardization
		Use secondary materials
		Take back schemes
		Reverse Logistics
2. Construction Phase	Construction	Minimize Waste
		Procure reused materials
		Procure recycled materials
		Off-site construction
3. Operation & Maintenance Phase	In use and Refurbishment	Minimize waste
		Minimal Maintenance
		Easy Repair and upgrade
		Adaptability & Flexibility
4. Decommissioning Phase	End of life	Deconstruction
		Selective Demolition
		Reuse of components/products
		Closed loop recycling
		Open loop recycling

2.3 Defining Transition and Transformation

Transition and Transformation are used interchangeably merely as a metaphor to refer to fundamental and structural pathways for desirable societal and environmental change (Feola, 2014). Multiple research approaches have surfaced to understand and analyze the societal and environmental transitions and transformations. In these approaches, 'Transition' is particularly used by the sustainable transition research community to represent social, technical, economical and fundamental change from one societal regime to another. Whereas, research approaches concerned with global environmental change have adopted 'Transformation' to refer to fundamental human and environmental interactions (Hölscher, et al., 2018). Few scholars have used transformation to portray transition. Geels & Schot, (2007) used transformation as one of the possible transition pathways, while other scholars differentiate transformation as more fundamental, large scale and long-term changes like environmental and societal transformations (Stirling, 2014).

While both transition and transformation refer to a change in complex adaptive systems, they are often used by the scholar for different system foci (Hölscher, et al., 2018). Considering the entomological origin, transition is a change from one form to another or the process by which this happens (Cambridge Dictionary, 2016). Transition concept has been applied to explain how the non-linear shift from one state to another is supported or stalled (Silva & Stocker, 2018). Entomologically, transformation means change in the appearance or the character of something or someone (Cambridge Dictionary, 2016) and this concept has been applied to analyze 'what' it is that changes and what are the results at a systemic level (Hölscher, et al., 2018). Both transition and transformation depend on various perceptions and values, from change in normative notions to sustainable societal systems. Actors also play a key role in transitions and transformations through agencies and governance. Both transition and transformation provide a perception on how to describe, analyze, and assist fundamental and non-linear societal changes. However, they are not mutually exclusive. Their differences partially originate from their entomological definition but mostly from different scholars and research communities concerned with transition and transformation. An overview comparing their applications (Hölscher, et al., 2018) is shown in Table 2.

Table 2: Transition vs Transformation: Comparing applications (Hölscher, et al., 2018, pg. 2)

Dimensions of System Change	Transition	Transformation
System Focus *(Focus on complex adaptive systems)*	Includes Social, institutional and technological change in societal sub-systems (e.g. energy, mobility, cities)	Includes Large-scale societal change processes involving social-ecological interactions (e.g. global, regional, local etc.)
Dynamics and processes	*'How'* non-linear change occurs focusing on interactions between support and hindrances.	*'What'* are emergent patterns of change and how do these affect outcomes
Normativity *(System change is contested and can be desirable and undesirable)*	Outcome focus is on shift of system from unsustainable to sustainable.	Outcome focus is on creating safe and just operating spaces to avoid undesirable system change
Agency and governance *(Multi-actor processes enabling innovation, learning, collaboration and knowledge integration)*	Developing disruptive interventions to support sustainability transitions	Respond to the implications of change (e.g. risks, vulnerabilities); individual motives and values supporting transformations

Based on the review the research will focus on circular 'Transition' of the Dutch wind energy sectors as the research is more likely to be focused on social, institutional and technological challenges rather than large-scale societal changes involving social-ecological interactions. The research focuses on how to make the wind energy sectors more sustainable rather than creating safe and just operating spaces to avoid undesirable system changes. And finally, the research neither focusses on responding to the implications of change nor on individual motives, rather focuses on supporting sustainability transitions.

2.3.1 Sustainability Transitions

Sustainability transitions are fundamental, multi-dimensional and long-term transition processes where established socio-technical systems shift to a more sustainable modes of production and consumption (Markard, et al., 2012). Sectors like energy supply, water supply or transportation and in this case wind energy sector can be conceptualized as socio-technical systems. These socio-technical systems consist of network of actors and institutions along with knowledge and material artifacts which are tightly interrelated and dependent on each other to deliver explicit services for society

(Markard, et al., 2012). Socio-technical transitions involve a set of processes that steer a fundamental shift in socio-technical systems (Geels & Schot, 2010). Socio-technical transitions differ from technological transitions in that they include institutional, organizational, consumer practices and non-technical innovations in addition to technological aspects (Geels & Schot, 2010; Markard, et al., 2012). A broad range of theoretical approaches have been used to analyze and explain the characteristics of transitions. Markard, et al., (2012) reviewed various theories including general theories, such as evolutionary economic theory, actor network theory, as well as theories with a specific focus on technology. However, so far, in theoretical terms four particular frameworks have gained quite some importance in transition researches. These include the strategic niche management, multi-level perspective on socio-technical transitions, transition management and technological innovation systems (Markard, et al., 2012). Each of these conceptual approaches will be briefly explained.

Strategic Niche Management: (SNM)

Strategic niche management comprises of insights from constructivist science and technology studies into evolutionary economics, which was initially developed by Nelson, Winter and Dosi (1982) and further improved by Rip (1995) and Schot (1998) (Schot & Geels, 2008). The SNM approach could help stimulate a socio-technical transition towards a more sustainable development. It was designed to facilitate the introduction of new sustainable technologies in fields such as wind energy, biogas, transport systems, and eco-friendly food production (Caniëls & Romijn, 2008). SNM approach indicates that this journey can be facilitated by creating technological niches (Schot & Geels, 2008). Niches have been theorized as protected spaces that permits fundamental innovations with the co-evolution of technology, user practices, and regulatory structures without being subject to the selection pressure of the existing regime (Markard, et al., 2012).

Multi-level perspective on socio-technical transitions: (MLP)

The multi-level perspective is a prominent transition framework which was first developed by Arie Rip and Rene Kemp, and further improved by Frank Geels and Johan Schot (Bilali, 2019). MLP framework combines concepts from evolutionary economics, science and technology studies, structuration theory and neo-institutional theory (Geels, 2011). MLP theorizes that transition processes result from the interaction of three analytical levels: niches, regimes and socio-technical landscapes (Geels, 2011). Regimes are of primary significance as transitions are usually defined as shift from one regime to another (Geels, 2011). Regimes comprise of institutions, actors and technology (Bilali, 2019). Whereas the niches and landscape levels can be perceived as derived concepts as they are identified in relation to the regime particularly as practices that sustainably alter the existing regime (Geels, 2011).

Transition Management: (TM)

Transition management was introduced into the science, technology and policy discussions regarding complex societal issues and sustainable development in 2001 (Loorbach, et al., 2015). Transition management itself is still in development (Loorbach, 2010). According to (Loorbach, 2010) TM is a governance approach based on insights from both governance and complex systems theory as much as practical experience. TM framework is built to analyze and manage current governance processes in society (Loorbach, 2010) and this framework is considered innovative for two reasons: Firstly, it offers a fundamental approach towards governance which serves as a basis for functioning policy models, and secondly, it serves as a normative model taking sustainable development as long-term goal (Loorbach, 2010). Recently, it is observed that there is an increase in attention for TM on regional and local levels (Markard, et al., 2012)

Technological Innovation Systems: (TIS)

Technological innovation systems approach involves analysis of innovations with technological core. The TIS framework is generally used to study emerging and new technological systems in and beyond sustainability transition frameworks (Markard, et al., 2015). TIS has to do with the development of novel technologies and the institutional and organizational changes that have to go hand in hand with technology development (Markard, et al., 2012). Previously, TIS studies had a focus on generic technologies at the core of the analysis, while the recent TIS studies have developed a much stronger focus on specific technologies for fundamental sociotechnical transitions (Markard, et al., 2012). One of the key roles of the TIS approach is that it replaced the concept of market failure with a broad set of system failures (Markard, et al., 2012). Currently, TIS framework is well recognized and holds a strong position in research on sustainability transitions.

These aforementioned frameworks hold elements that can serve as foundation to capture the challenges of circular transition for the Dutch wind energy systems. Firstly, although the Technological innovation systems approach focus on improving the overall performance of TIS, its major focus is on the technology-specific systemic change and not on the challenges of strategic transition of comprehensive systems of production and consumption (Weber & Rohracher, 2012). Secondly, strategic and long-term transition processes are at the center of interest of the other three transition frameworks namely; Strategic Niche Management, Multi-Level Perspective Approach and Transition Management (Weber & Rohracher, 2012). However, many authors critique that Transition Management is in a hypothetical stage. Although a lot of studies have been conducted on the TM, its value still needs to be proven by a sufficient number of empirical case studies (Loorbach, 2007). Loorbach (2007) indicates that it might take around two decades before the concept of TM can be fully validated and is effective. Lastly, although strategic niche management and Multi-level perspective approaches aim at goal-oriented system transitions, Weber & Rohracher (2012) believe that the theoretical foundation and actual implementation of transition could be considerably improved by combining the strengths of these theoretical frameworks. And particularly, in order to capture the challenges of transition, the strengths of structurally oriented innovation systems approach along with systems failure can be combined with the transformation-oriented multi-level perspective approach (Weber & Rohracher, 2012).

Innovation systems and Multi-level perspective approaches are believed to complement each other. Innovation systems approach has a major focus on the internal functioning of the system which includes the functions and interactions of different types of actors for knowledge creation and transmission, and the institutions that assist and confine their behavior. Complementary to this, the MLP approach highlights stability and dynamics of need-oriented external socio-technical structures that accomplish particular societal needs. It focuses on the interlinks of institutions, technologies and social practices. Studies conducted by Weber & Rohracher (2012) also present various arguments which shows that the Innovations system approach can offer essential components to describe transition changes, but it needs to be complimented by the components from the MLP. Based on the comparative analysis between MLP and Innovation Systems framework, Weber & Rohracher (2012) proposed an integrated 'framework of failures' which support policies for transformative change. This framework of failures is an enriched version of the conventional market and systems failure which was conceptualized to counter the arguments from the multi-level perspective that have been identified as inhibiting processes of transition change in a social and political environment. By combining the four main types of system failures introduced by Woolthuis et al. (2005), market failures and four additional types of transition failures, Weber & Rohracher (2012) obtained a comprehensive 'failures framework' that address both structural and transitional failure. These 12 failures comprising the failures framework can be used to develop a policy approach as well as capture the challenges to foster the required transition change to address major societal challenges particularly in areas such as energy, but also in other fields like transportation or green production (Weber & Rohracher, 2012).

2.4 Failures Framework

Integrated Failures Framework has been developed on the basis of the prevailing literature on multi-level perspective and innovation systems research, particularly for policy interventions for transition change. This framework has been developed by Weber & Rohracher (2012) by re-framing few significant perceptions from transition studies in terms of failures and linking them with market failures and structural innovation systems failures. This integrated failures framework comprises of 12 failures that include four traditional market failures namely; Information asymmetries, Knowledge spill-over, Externalization of costs and Over-exploitation of commons combined with four main types of systemic failures as introduced by Woolthuis et al. (2005), which include; infrastructural failure, institutional failure, interaction or network failure and capabilities failure and finally Weber & Rohracher (2012) complimented this framework by introducing four additional transitional failures namely; Directionality failure, Demand articulation failure, Policy coordination failure and Reflexivity failure. Each of these failures are explained in brief.

2.4.1 Market Failures

Information Asymmetries

Information asymmetries is related to the decisions in transactions where certain actors have more or better information than the others. This asymmetric distribution of information can be categorized as pre-contractual of the transaction or post-contractual of the transaction, that will influence economic behavior and operation of the market (Stiglitz, 1993). This type of market failure happens when the information in the market is not efficient. Adverse selection and moral hazard are the two main forms of asymmetric information which pertain to hidden information and hidden action respectively (Stiglitz, 1993). In terms of research and innovation, it can be lack of funding for the research due to the uncertainty of private investors.

Knowledge Spill-over

In general, knowledge spillover refers to exchange of ideas among individuals/actors. Usually, for firms with underdeveloped technology, this knowledge-borrowing process becomes essential for their further development (Trachuk & Linder, 2019). Knowledge spillover occurs when recipient firms exploit knowledge that has been developed by the originating firm by combining the knowledge of the originating firm with other knowledge to create their own unique innovations (Yang & Steensma, 2014). This knowledge spillover can have various effects in terms of its nature and direction. Considering the process of innovation and technology, the knowledge spillover has these following effects, 1) knowledge spillover beyond the defined range or boundary of individuals or institutions, 2) diffusion of technologies in an uncontrolled fashion without any payment for technology (Trachuk & Linder, 2019). Several researches were conducted to study the relationships between spillover effects and innovations. However, the importance of what the knowledge has on innovation is unfortunately unmeasurable and hard to reach (Trachuk & Linder, 2019)

Externalization of Costs

In general, externalization of costs is an economic activity that imposes negatives effect on an unrelated actor or third party. It can occur either during production or consumption of goods. In terms of technology and transitions, externalization of costs can lead to innovations that can have a negative impact on the environment or another social institution (Weber & Rohracher, 2012).

Over Exploitation of Commons

Over exploitation of commons also known as the tragedy of commons refers to the overuse of resources due to incentives created by common ownership which can lead to overexploitation and underinvestment. The tragedy of commons framework is widely used to explain the social origins of environmental resource depletion (Longo & Clausen, 2011).

2.4.2 Structural System Failures

Infrastructural Failure

Infrastructural failures are particularly concerned with the issues regarding the physical infrastructure that is necessary to assist the innovation activities. However, these infrastructural failures have received comparatively limited attention by the innovation scholars. But, for organizations and companies to succeed, they require dependable infrastructure to support their day-to-day operations and long-term developments. Woolthuis et al. (2005) suggest a higher emphasis on the knowledge infrastructure and high-quality ICT infrastructure along with emphasis on additional infrastructure such as accommodation and transport.

Institutional Failures

Compared to the infrastructural failures, the institutional failures were distinguished by most of the authors. The institutional failures are most commonly distinguished as hard and soft failures. Hard institutional failures refer to the formal institutional mechanisms that hinder innovation pertaining to technical standards, laws and legislation, regulations, risk management rules, etc. Whereas, soft failures refer to more informal institutional failures pertaining to social norms and values, political and economic cultures and the willingness to share resources with other actors. Together, these institutions serve as the selection environment where knowledge institutions, firms and the government are embedded (Woolthuis, et al., 2005)

Interaction or Network Failure

Interaction or Network failures can be classified as strong and weak network failures. Strong network failures are the one in which the interactions between network of actors lead to a wrong direction which hinders knowledge transfer and novel insights. This is mainly caused due to 1) Internal orientation of an organization leading to myopia (group think causing insufficient attention to outside development), 2) Lack of weak ties with other actors and. 3) Strong dependence on dominant actors to lock-in phenomena (Woolthuis, et al., 2005). Whereas, the weak network failures occur when interactive learning and innovations are limited due to weak connectivity between various actors and technology which might hinder research.

Capabilities Failure

Capabilities failure refer to the lack of certain competences, capacity, or even resources to adapt to the new and changing environments or paradigm. This type of failure can also occur because firms or organizations always concentrate on products and technologies that they have knowledge and skills on or what they know the best. This might lead to lock-in into existing technologies/paradigm which might hinder the firm's development

2.3.3 Transition System Failures

Directionality Failure

Directionality failure highlights that it is not just necessary to produce innovations as effectively and efficiently possible, but also to focus on a certain direction of the transformative change. For instance, this direction can be outlined by identifying major societal problems or disputes that requires development of solutions with the help of research and innovation. Directionality failure can sometimes be mixed with the anticipatory myopia; however, the latter is used only to rationalize investment in research and innovation but without a view to a specific direction of change. Directionality failure can be overcome by 1) absorbing the requirements external to the innovation systems and 2) By interpreting and negotiating with the intension of providing orientation for the different actors, which was also recognized by the transition scholars (Weber & Rohracher, 2012).

Demand Articulation Failure

Demand articulation failure address the issues pertaining to the production and consumption. Both the market failures and systems failures fail to address this. These failures do not consider novelties once they have moved beyond the innovation stage. The shortcomings of these two systems is addressed by demand articulation failure with a prime focus on innovations by users and user needs. The most effective way to overcome this demand articulation failure is by integrating consumers and producers in innovation processes and innovation models (Weber & Rohracher, 2012).

Policy Coordination Failure

Although system failures highlight the coordination failure in research and innovation, it refers to only coordination failures pertaining to research actors and not to coordination problems at policy levels. Policy coordination failure can be categorized as horizontal and vertical coordination failure. Horizontal coordination failure refers to the need for rational policy impulses from diverse policy sections, actions and initiatives to ensure that the required transformative change addressing major societal challenges can be achieved. Whereas the vertical coordination failure is between different levels of the government (regional, national, European). In addition to these, the policy coordination failure also applies to the private sector institutions and their policies. Policy coordination failure also consists of time-based mismatches pertaining to the interventions by different actors (Weber & Rohracher, 2012).

Reflexivity Failure

Reflexivity failure addresses the insufficient ability of the system to monitor, anticipate and involve actors in the process of self-governance. Reflexivity failure highlights the lack of reflexive arrangement to connect different broad domains which is important for directionality, demand articulation and institutional coordination but also at societal level to prepare for and frame the other three specific levels of reflexivity. Bringing reflexivity into the equation transcends a strictly evolutionary approach to transitions (Weber & Rohracher, pg. 1044, 2012). Table 3 has an overview of all the 12 failures that makes the integrated 'failures framework'

Table 3: Overview of failures Framework (Weber & Rohracher, 2012)

CATEGORIES OF FAILURE	TYPES OF FAILURE	
1. Market Failures	I.	Information Asymmetries
	II.	Knowledge Spill over
	III.	Externalization of costs
	IV.	Over exploitation of commons
2. Structural System Failures	I.	Infrastructural Failure
	II.	Institutional Failure
	III.	Interaction or Network Failure
	IV.	Capabilities Failure
3. Transitional System Failures	I.	Directionality Failure
	II.	Demand Articulation Failure
	III.	Policy coordination failure
	IV.	Reflexivity Failure

2.5 Summary: Sub-Research Question 1

The main objective of this chapter was to provide an answer to the sub research question 1;

What transition approach describes best and is able to capture the challenges of a circular transition alongside the ongoing energy transition for the wind energy sector?

Firstly, an elaborate literature review was conducted to understand the growth of the wind energy sector and the current state of energy transition, followed by the possibility of a circular transition for the wind energy as well. The circular aspects (circular construction) relevant for the development of a wind farm are also discussed. For this transition to befall, an elaborate literature review was conducted on transition studies, with a major focus on sustainable transitions like SNM, MLP, TM, TIS. Building on the analysis of complementarities between these frameworks, particularly on MLP and Innovation Systems framework, and by combining the four main types of system failures introduced by Woolthuis et al. (2005), market failures and four additional types of transition failures, Weber & Rohracher (2012) obtained a *comprehensive 'failures framework'* that address both structural and transitional failure. Considering, there does not exist a transition framework for a circular transition, the comprehensive 'failures framework' was considered the most feasible method to capture the challenges and obstacles for the circular transition alongside the ongoing energy transition for the wind energy sector.

3. METHODOLOGY

In this chapter, the research methodology is determined, specifically to formulate an answer to the second sub-research question “*How to capture the challenges for adopting circular transition along with the ongoing energy transition of the wind energy sector in the Netherlands?”* Section 3.1 will describe the overall methodology that the research will follow, and section 3.2 will discuss the research strategy chosen for the research in detail, section 3.3 will highlight and discuss the data collection methods suitable for this research, followed by section 3.4 which discuss data analysis. Finally, section 3.5 concludes the methodology chapter.

3.1 Research Strategy

The research method intended to be used for this research is qualitative research. It is imperative to choose an appropriate qualitative research strategy to obtain results for this research. According to Yin (2003), research strategy should be chosen as a function of the type of research question, the control over behavioral elements and the degree of focus on historic and contemporary events. And each strategy has its own method of collecting and analyzing research data. Table 4 portrays the outcome of interactions based on the identified functions and most common research strategies.

Table 4: Interaction between research strategies and various functions (Yin, 2003, pg. 09)

Research Strategy	Type of Research Question	Requires Control Over Behavioral Events?	Focuses on Contemporary Events?
1. Experiment	How, Why	Yes	Yes
2. Survey	What, Who, Where, How many, How much	No	Yes
3. Archival Analysis	How, Why	No	Yes/No
4. History	How, Why	No	No
5. Case Study	How, Why	No	Yes

Considering the explorative nature of the research with a focus on examining the contemporary events and to address the question on ‘How’ to capture the challenges for adopting circular transition along with the ongoing energy transition of the wind energy sector in the Netherlands, the ‘Case Study’ research strategy can be considered as an appropriate research strategy for this research. The case study research method can be used for exploratory, explanatory, or descriptive study (Yin, 2003). According to Yin (2003), a case study can be defined as an empirical study that investigates a contemporary phenomenon in-depth in the real-world context especially when the boundaries between the phenomenon and context are hard to define.

3.2 Case Study Selection

While using cases to study a specific phenomenon, one could use a single or multiple case studies and numerous levels of analysis for gathered data and information (Eisenhardt, 2010). In a single case study only one case is thoroughly examined, and it requires a comprehensive description of the context and several other factors pertaining to the phenomena. Since the findings are case specific, it is quite hard to apply the findings to other situations (Verschuren & Doorewaard, 2010). This uncertainty can be reduced by using a minimum of two cases, and analytic conclusions from multiple case studies will be more prevailing than those from a single case study (Yin, 2003). The advantage of using multiple case studies for the research is that it is relatively easier to generalize the findings and verify the findings using cross case reference. Another way of conducting multiple case studies for the research is comparative case study, where several interrelated cases are compared instead of just one. Thus, for the research multiple cases are selected and compared. Several sub variants of comparative case study can be identified, of which the two most important are *hierarchic method* and the *sequential method*. In *hierarchic method*, the research is carried out in two stages. Firstly, the separate cases are studied independently from each other. Secondly, the results from the first case can be used as an input for a comparative analysis to find similarities and differences between the various cases. Whereas in the *sequential method,* an individual case is examined meticulously, and a second case is selected by using the results and based on the conclusion of the first one. And on the basis of conclusions from the first two cases, a third case is selected, and so forth (Verschuren & Doorewaard, 2010). Considering the exploratory nature of the research, the *hierarchic method* will be followed where each case will be examined and studied independently. When analyzing the cases and describing the results, the output from various cases can be used for a comparative analysis.

The cases that have been selected are based in the Netherlands. As per Eurostat 2018, Netherlands is far behind most other EU countries in the production of energy from renewable sources and thus plans to increase the renewable energy sources in the coming years. Netherlands aims to achieve 14% renewable energy by 2020 and a minimum of 27% in 2030, and wind energy serves as an important form of renewable energy to attain these goals. Currently, and in the coming years, several onshore and offshore wind turbines are being set up in the Netherlands. By the end of 2020, Netherlands plans to have an onshore wind capacity of 6,000 MW (Ministerie van Algemene Zaken, 2017). In 2019, offshore wind turbines generated approximately 1 gigawatt (GW) of power in total, and with the current plan and policies, offshore windfarms are expected to generate approximately 11GW by 2030 (Ministerie van Algemene Zaken, 2020). Thus, there will be an increase in market demand in the Netherlands, in the coming years.

3.2.1 Case Selection Criteria

One of the foremost aspects of conducting case study research is selection of suitable cases (Eisenhardt, 2010). Cases for this research are selected based on certain criteria and requirements. Firstly, since the main aim of the project is to find the challenges and obstacles of circular transition for the wind energy sector, circularity should be one of the aspects taken into consideration at some level of the project. A second criterion is that the researcher should be granted permission and should be able to get access to the available project information, project documents and the researcher should be allowed to investigate the project. Also, information concerning the project should be available on the internet. Besides access to the information, access to the actors involved in the project is crucial. Actors need to be accessible and available in order to conduct interviews for data collection. The research cannot be accomplished without being able to interview the relevant actors involved. A third criterion for the case study selection is that the project should be conducted within the same country, in this case, Netherlands. Projects from different countries are usually harder to compare because of differences in various conditions and aspects like nature of working, culture, institutions, policies, laws and permits, etc. making it unsuitable for this research. Netherlands is chosen mainly because of increase in both onshore and offshore projects in the coming years and also because of easy access to the actors and data within the country of research. As mentioned in the literature review, considering the type of wind energy, the research will majorly focus on utility-scale wind comprising of onshore and near the shore wind farms, and offshore wind in order to get a broad overview of the wind energy sector. Within the Netherlands, the cases are located in the regions of Friesland (near the shore case), North Holland (onshore case) and Zeeland (offshore case).

3.2.2 Cases

A brief introduction describing the general characteristics of all the chosen cases is explained in this section.

Wind Plan Blauw

Wind Plan Blauw is a new near the shore windfarm being developed in the northwest corner of Flevoland, in the municipalities of Dronten and Lelystad. Currently there are 74 windmills in the project area which will be replaced by 61 larger turbines with more power. Total power is approximately 250MW. Vattenfall and SwifterwinT are responsible for both realization of the new turbines and remediation of the current mills. The current mills are expected to be demolished no later than six months after the start of use of the new wind farm.

Wind farm Borssele 1 & 2

Wind farm Borssele 1 & 2 is an offshore windfarm being developed about 23 km from Westkapelle, in the Dutch part of the North Sea, off the coast of Zeeland. When realized, Borssele 1 & 2 with 94 wind turbines, will be the largest offshore wind farm in the Netherlands. It has a capacity of 752MW. Orsted is the owner and developer of Borssele 1 & 2. Orsted won the tender in 2016 and the wind farm will be built in 2020.

Wind Park Wieringermeer

Wind park Wieringermeer is an onshore wind farm which is an initiative of ECN Wind Energy Facilities BV and Vattenfall. It is located in the polder Wieringermeer, in the province of North Holland. The Wieringermeer windfarm has 99 wind turbines making it the largest onshore wind farm in the Netherlands with a capacity of around 300MW. 82 wind turbines belong to Vattenfall and partners, and the other turbines belong to the ECN wind energy facilities. Construction of the wind farm started in 2018 and the wind farm will be completely realized at the end of 2020.

3.3 Data Collection

Considering the exploratory nature of this research, the primary source of data collection for this research will be interviews. For this study, key actors from the selected case will be interviewed.

3.3.1 Interviews

Interviewing is considered as one of the most common format of data collection method in a qualitative research. The key purpose of research interview is to survey the views, opinions, beliefs and experience of individuals on particular matters. Interviews are considered to provide profound understanding of a particular phenomenon which would be otherwise not possible from purely quantitative methods, such as questionnaires (Gill, et al., 2008). There are three fundamental types of qualitative research interviews: Structured, Semi-structured and Unstructured interviews (Gill, et al., 2008 & Jamshed, 2014). For this research, a Semi-structured interview will be used to survey the respondent's opinions, obtain relevant information and explore precise topics.

Semi-Structured Interviews

Semi-structured interviews are those in-depth interviews that consist of several key open-ended questions that help to outline the subjects to be explored, but also allows the interviewee and/or interviewer to deviate in order to follow an idea or response in more detail. It usually combines the insights of both structured and unstructured interviews (Jamshed, 2014). This type of interviews are conducted only once with an individual or sometimes with a group. The flexibility of this type of interviewing, particularly compared to structured interviews is that it allows for the discovery of information which may not have previously been thought of as relevant by the interviewer (Gill, et al., 2008). Semi-structured interviews will be more favorable for this research as it does not limit the answers to the lines of expectations of the researcher. Rather, stipulates an opportunity to seek information based on practitioner's experience along with different perspectives contributing to a comprehensive and holistic understanding of the problem.

3.3.2 Respondent Criteria and Selection

After establishing semi-structured interviews as an appropriate data collection tool for this research, the following step requires selecting suitable respondents/interviewees for the interviews. The process of selection follows a certain criterion.

i. Firstly, a mixture of actors following a stakeholder analysis working in various stages of a wind farm project life-cycle will be chosen as respondents for the interview as it is assumed that each of them will have different views and opinions on the system, and each of them might face different challenges and obstacles resulting in different types of failures.
ii. Secondly, the mixture of respondents chosen should be equally balanced and not focusing on a particular actor/stakeholder type and each respondent should belong to different phase of wind farm development.
iii. Finally, the respondents chosen should be familiar with the concept of circular economy and energy transition and must be willing to actively take part in the interview process.

Throughout the complete life cycle of wind farm development several actors are involved. According to Hertenberger (2016) the major identified stakeholders for a wind farm project include the owners/developers, engineering and consultancy firms, construction companies and suppliers, landowners, banks and investors, the public, authorities and environmental considerations and neighbors of the wind farms. For the scope of this research, in order to get an overview of the four development phases mentioned in the literature review, the owners/developers, engineering and consultancy firms, construction companies, suppliers and authorities will be considered as potential respondents for the interviews. Table 5 presents a short description of type of respondents that would be chosen for the semi-structured interview based on different phases of wind farm development. The phases that are highlighted in blue show the current state of the project development.

Table 5: Description of stakeholder type chosen for the interviews for different phases of wind farm development (own illustration)

SL.NO	Cases	Phases Of Wind Farm Development	Actors/Stakeholders
1	Wind Plan Blauw	Design & Development Phase	• Owner/Developer • Engineering and consultancy firms • Suppliers & Manufacturers
		Construction phase	• Construction Company/ Contractor
		Operation & Maintenance Phase	• Owner/Developer
		Decommissioning Phase	• Owners/Developers • Construction Company/ Contractor
2	Borssele 1 & 2	Design & Development Phase	• Owner/Developer • Engineering and consultancy firms • Suppliers & Manufacturers
		Construction phase	• Construction Company/ Contractor
		Operation & Maintenance Phase	• Owner/Developer
		Decommissioning Phase	• Owners/Developers • Construction Company/ Contractor
3	Wieringermeer	Design & Development Phase	• Owner/Developer

			• Engineering and consultancy firms • Suppliers & Manufacturers
		Construction phase	• Construction Company/ Contractor
		Operation & Maintenance Phase	• Owner/Developer
		Decommissioning Phase	• Owners/Developers • Construction Company/ Contractor

In addition to the criteria and selection of respondent type for the semi-structured interviews, it is also necessary to determine an adequate sample size. For an explorative and phenomenological studies such as this research, Creswell (1998) recommends that a range of 5 to 25 interviews and Morse (1994) suggests a minimum of six interviews would generally suffice to obtain enough data to describe the phenomenon of interest and address the research questions. Ultimately quality is more important than quantity and the required number of participants should generally depend on when saturation is reached. Considering four different stakeholder types as respondents for the interview, the aim of the research is to conduct four interviews for each case, making it approximately 12 interviews overall.

3.3.3 Interview Protocol

After defining the suitable qualitative interview type and respondent criteria, the next step is to formulate appropriate and effective interview questions. For a semi-structured interview, interviewers follow a guide called the interview protocol. The interview protocol is shown in APPENDIX A. The interview protocol mainly consists of three sections which are defined below (Wilson, 2014).

I. *Introduction:* The interview begins with a brief introductory segment, where both the interviewer and the interviewee introduce themselves. In this part of the interview, the interviewee will also be explained the aim of the research, the purpose of the interview and the confidentiality agreement.
II. *Interview Questions:* The second part of the interview consists of the interview questions. In order to obtain effective and unbiased answers during the interview, the questions asked will be open ended and will not steer the respondents in a particular direction. The interview questions are divided into three different parts. Firstly, general questions regarding the topic and circular economy are asked. Secondly, questions regarding the circular aspects during the life-cycle stages of windfarm developments are asked. Finally, the respondents will be asked if they can recognize different challenges and obstacles based on the categories identified in the theoretical framework.
III. *Interview closure and Post Interview:* The final part involves a general discussion and answers to the questions that were not a part of the interview protocol followed by the end of the interview where the respondent is thanked for his time and patience. Post interview, the interviews are transcribed and sent back to the respondents for verification before analyzing the data.

A few mock interviews were conducted before the actual interviews to check and monitor the structure of the interview protocol and the interview questions. The interview questions were modified based on the results obtained during the mock interviews to obtain appropriate data for the research.

3.3.4 Document Analysis

Interviews will be used as primary source of data collection as far as possible. Along with the interviews, several project documents will also be analyzed to gather relevant data for the research. The received documents will most likely be used to compare the data gathered from the interviews.

More or less, document analysis will be used for the triangulation of data. Triangulation provides stronger substantiation of constructs (Eisenhardt, 2010). If no documents are available, data triangulation is done by the interviews alone, with multiple interviewees for each case.

3.4 Data Analysis: Cross Case Analysis

The collected data will be analyzed by a cross case analysis method. This method can be applied if the separate cases have been studied independently from each other (Yin, 2003) and is suitable for a comparative case study method. Figure 7 depicts several steps that will be followed. After selecting the cases and designing data collection protocol, individual case studies are done. Interviews are conducted, transcribed and verified before documenting them using the failures framework for each case. Further, an individual case report is written. Based on the documented data and individual case reports a cross case analysis will be performed to mobilize the knowledge from individual case studies. The results obtained from individual case studies will be presented in tables in the form of a unified framework for cross case comparison. The overall arrangement of gathered data and patterns obtained within the table will lead to conclusions. These new relations obtained across cases augment existing knowledge and experience and produce new knowledge. The conclusions are further used to determine if the original framework needs to be modified. Consequently, the cross-case report is documented.

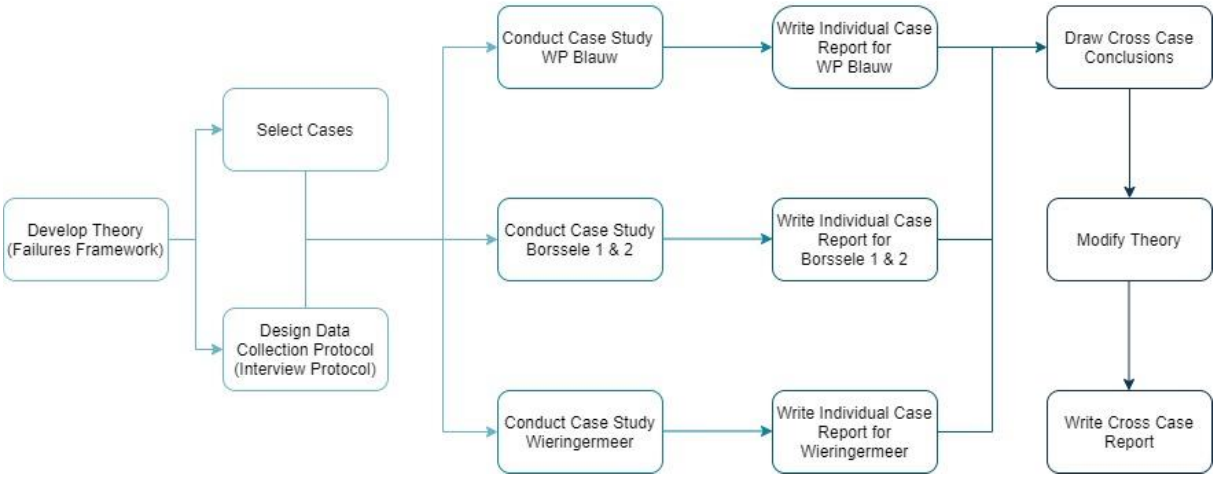

Figure 7: Case Study Procedure (Yin, 2003, pg. 60)

Before drafting the individual case reports, the qualitative analysis of interview data is evaluated by applying different ways of coding. Coding is a process of conceptual abstraction by assigning codes to singular incidences in the data. This concept is obtained from the work approach of Corbin & Strauss (2008) and was opted, as it allows methodological configuration of bulky qualitative data into manageable units (codes) (Corbin & Strauss,2008). Corbin & Strauss (2008) distinguish three kinds of coding procedures: open, axial, and selective coding. These procedures do not easily define phases that chronologically come one after the other. Each procedure has a different way of working with the data and may or may not be combined with each other based on the preference of the researcher (Mey and Mruck, 2011). For this research, open coding and axial coding are used. Although the three different procedures do not follow a strict chronology, open coding is usually the first approach, more often that the others and the same will be followed for this research. In this step the raw data from the transcripts will be analyzed to identify and label (code) relevant words, phrases, or sentences which result in a list of open codes. Open coding is generally followed by axial coding. This process intends to look into the open codes to identify common characteristics within the open codes and suggest categories to cluster them to decrease the complexity of the data. It is primarily the concept of relating codes to each other to create categories and formulate second set of codes (Corbin & Strauss, 2008).

The coding of the qualitative interview data was done using ATLAS.ti, (ATLAS.ti 8 Windows) a computer program used for qualitative data analysis.

3.5 SUMMARY: Sub-Research Question 2

The main objective of this chapter was to provide an answer to the sub research question 2;

''How to capture the challenges for adopting circular transition along with the ongoing energy transition of the wind energy sector in the Netherlands?''

Considering the explorative nature of the research with a focus on examining the contemporary events and to address the question on 'How' to capture the challenges for adopting circular transition along with the ongoing energy transition of the wind energy sector in the Netherlands, the 'Case Study' research strategy is chosen as the most suitable methodology to conduct this research. Three cases, an onshore- Wind farm Wieringermeer, an offshore- Borssele 1 & 2, and a near the shore- Wind Plan Blauw, cases are selected from various parts of the Netherlands. Data is collected from each case on various challenges and obstacles for the circular transition for the wind energy sector. Data collection for these cases is primarily done by interviews. In order to conduct the interviews, an interview protocol is adopted to give a complete insight and guidance during the interview which can be found in APPENDIX A.

The interview protocol basically consists of the introduction, interview questions and post interview analysis. A sample group of around 12 respondents (4 per case) are selected based on the respondent criteria, that consist of actors/stakeholders across all the life-cycle stages of a wind farm development in order to get a complete overview of challenges and obstacles for a circular transition for the wind energy sector in the Netherlands. Post interview, the transcribed documents are sent back to the respondents for verification. The collected data will be analyzed by a cross case analysis method. Firstly, the qualitative interview data is evaluated by applying open and axial coding techniques, following that an individual case report is written. Based on the documented data and individual case reports, cross case conclusions are drawn.

4. RESULTS

In the following chapter, the answer to the third sub-research question will be answered: *What are the challenges and obstacles identified when a circular transition intervenes with the ongoing energy transition for the wind energy sector in the Netherlands?* Three cases were studied by means of semi-structured interviews. A comprehensive insight and perspective regarding various challenges and obstacles for the circular transition for the wind energy sector was obtained from all the actors involved throughout the life cycle of wind farm development. The owners/developers, engineering and consultancy firms, construction companies and suppliers in particular.

This chapter starts with a description and analysis of results for each case which can be seen in section 4.1, 4.2 and 4.3, followed by a cross case analysis in section 4.4. The chapter ends with section 4.5 which concludes the results chapter.

Firstly, the transcribed interviews were verified by the interviewees. The verified data was analyzed by coding distinctly for each case. Finally, a cross-case analysis was done to compare the findings of each case. For each case, the collected data was analyzed on different levels and on different aspects. The data was analyzed for;

I. Specific challenges and obstacles for the circular transition per case.
II. Specific types of challenges and obstacles faced by practitioners in each phase of wind farm development.
III. Circular aspects that are being/not being incorporated in each phase of wind farm development.

Following the analysis per case, a cross case analysis is done, and cross case conclusions are drawn. The conclusions are then validated by experts working within the wind energy sector. The conclusions are further used to determine if the original framework can capture all the challenges hindering circular transition for the wind energy sector or if the framework needs to be modified. Consequently, the cross-case report is documented.

4.1 Case: Wind Plan Blauw

4.1.1 Introduction

The 'SwifterwinT' association together with Vattenfall came to an agreement and took an initiative together for the realization of the Wind plan Blauw wind farm. The association was founded on July 7, 2016 from a combination of the members of the former Vereniging Wind park Rivierduin, the Vereniging Natuur Stroom Groep and the Vereniging Initiatiefgroep wind park Ketelmeerzoom (Wind Plan Blauw, 2020). The project facts and numbers are listed in Table 6.

Table 6: Facts and Numbers (Wind Plan Blauw, 2020)

SL NO:	Description	Facts and Numbers
1	Project Type	Near the shore wind farm
2	Owner & Developer	Vattenfall & SwifterwinT
3	Location	Flevoland
4	Number of Wind Turbines to be built	61
5	Number of wind turbines to be removed	74
6	Turbine Type	Provisional 4MW
7	Total MW	250
8	Avoided Emissions	340,000 tons of CO_2

Currently, the wind plan Blauw is at the pre-construction phase. Choice of turbines for land and in water are being made. The construction of the wind farm is set to begin in the first quarter of 2021 and the wind farm will be complete and running during the first quarter of 2022. Mentioned below are few project specifications.

Location

The wind plan Blauw is located in the north west corner of Flevoland (Municipalities of Dronten and Lelystad). The Figure 8 shows the exact location of the wind turbines. The wind plan Blauw was developed based on the preconditions of the Flevoland Wind Energy Region Plan and an environmental impact assessment was conducted to explore whether there was a need to deviate from these conditions. The assessment concluded that there was no reason to deviate from the placement zones established in the regional plan and high wind turbines have less environmental impact and better economic feasibility than lower turbines (Wind plan Blauw, 2020).

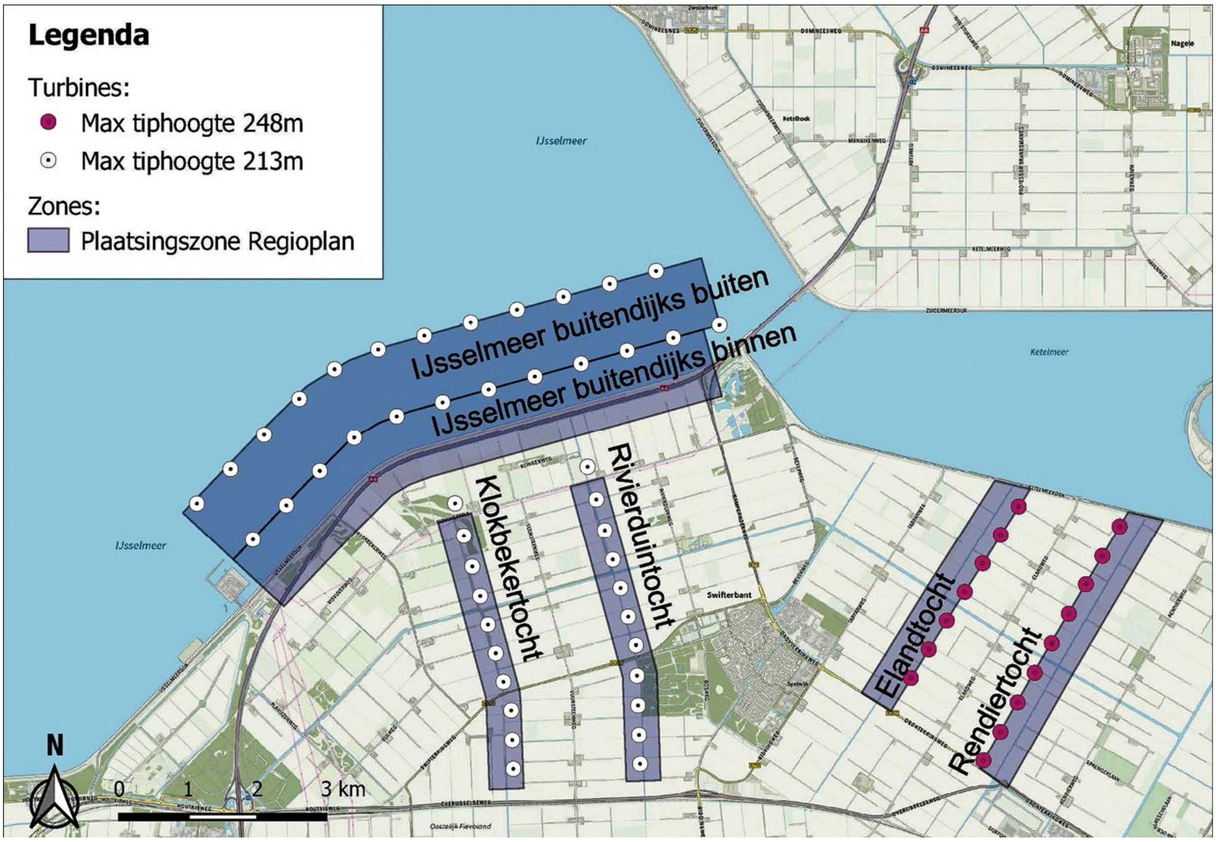

Figure 8: Wind Plan Blauw, wind turbines location, (Ministerie van Economische Zaken en Klimaat, 2019)

Actors/Stakeholders Involved

Wind plan Blauw is primarily developed by SwifterwinT and Vattenfall. SwifterwinT originated from three wind associations; Association Initiative Wind farm Ketelmeerzoom, association Natuur Stroom group and association wind park Rivierduinggebied. For the development of wind farm Blauw, not only the three members of the association were involved but also the stakeholders, residents and turbine owners from the project area were also involved. Since the wind plan Blauw is more than 100MW in size, the ministries of Economic affairs and Climate and of Interior and Kingdom relations are the competent authorities for the development of this wind farm. Within the project, the initiators also work closely with the municipality of Dronten, municipality of Lelystad, the province of Flevoland, the Ministry of Infrastructure and the Environment, the Ministry of Economic affairs and the Energy projects office.

Actors Interviewed For This case

A total of four actors were interviewed for this case. Each actor was involved with different/multiple phases of the wind farm development.

Table 7: Actors Interviewed for the case wind plan Blauw

Interview Number	Roles	Organization
1	Director of Environment & Sustainability	Owners/Developers
2	Team Manager-Energy Planning	Engineering & Consultancy Company
3	Partner & Senior Consultant	Contractor
4	Sales & Supply Manager	Supplier & Manufacturer

Project Schedule

The project wind plan Blauw was initiated by SwifterwinT and Vattenfall on the 7th of July 2016. Currently, wind plan Blauw is preparing for construction. For smooth construction roads are being improved and few roads are being newly built. In order to ensure safe supply of power to the grid and to people's homes, wind plan Blauw is currently in discussion with parties that can carry out the earthworks, purchase the power from the new wind turbines and supply the new wind turbines. By the end of this year it will be clear which parties will work together with wind plan Blauw and the construction can start in 2021 (Wind Plan Blauw, 2020). The Wind plan Blauw schedule (Wind plan Blauw, 2020) in APPENDIX C shows the complete schedule and planning of the wind plan Blauw.

Project Goals

The project wind farm Blauw is being developed to generate sustainable energy and plays an important role in achieving the objective in the energy agreement. According to the energy agreement, by 2023 16% of the energy must be generated sustainably (Ministerie van Algemene Zaken, 2017). For the province of Flevoland this means an objective of 1390.5MW. Wind plan Blauw being a 250MW project, contributes about 18% to this initiative. Which is enough to provide 5% of Dutch household with electricity. The 74 current dispersed mills make way to 61 larger turbines in neat lines which will generate four times more energy than all the current turbines combined (Wind Plan Blauw, 2020).

4.1.2 Case Study Results

Through interviews, data was collected for various challenges and obstacles experienced by the practitioners for the circular transition for the case wind plan Blauw and also different circular aspects being/not being incorporated for the case. The data collected was analyzed and categorized for different phases of development. Particularly for this case, the owners/developers, consultants, suppliers/manufacturers and the contractors were interviewed concerning their role and involvement within the project. They were questioned regarding the circular aspects based on the phase of the project they were involved in followed by questions on various challenges and obstacles for the circular transition within the project in general. The challenges identified during the interview were given codes after transcribing and verifying the interview data. The codes given were based on the terms and phrases used by the respondents. APPENDIX D consists of the excerpts from the transcribed interview with allotted codes.

For each phase of development circular aspects that were incorporated/not incorporate along with the challenges identified are explained in detail below. After each phase, the challenges identified were categorized based on different types of failures as mentioned in the 'Overview of failures Framework (Weber & Rohracher, 2012)

1. Design & Development Phase

Design

Circular Aspects

Circular economy is still at the nascent stage when it comes to the wind energy sector. The developers believe that if you need to attain full circular economy, wind energy sector is one of the paths which also needs to become circular. Currently, they are involved with a lot of research projects regarding the decommissioned blade waste and how they can be recycled and reused. However, for most of them it is still unclear what circular economy indicates or stands for. Below is an excerpt from one of the interviews which indicates that there lacks a common understanding about circular economy.

> *"Circular economy is a buzz word like sustainability, and there is a need to shed clarity on what do we mean by circular economy and what the industry as a whole should do when it comes to circular economy''. - Director of Environment & Sustainability unit BA Wind.*

The consultants are also involved during the design and development phase of the project. They mainly advised the developers during the planning phase of wind plan Blauw. The consultants believe that in terms of 'Circular Economy', even though they had intensions, they haven't done much about it. Currently, they believe it is not one of the major aspects being considered for the project, at least not as particularly as the other aspects, primarily because there is no specific need or requirement for it. Working for the developers, the consultants mainly focused on how to optimize the business case and how to create local benefit because for the wind plan Blauw project about 200 local farmers have joined together in the corporation with the developers for the development of the wind farm. The consultants also did not receive enough funding to incorporate the circular aspects for the project. And it is not just the funding, the believe that the entire planning phase is a busy process and it makes it hard to prioritize something extra as circular economy with business as usual.

For the case wind plan Blauw, Circular economy is one of the aspects that was taken into consideration during the design and development phase. However, the aspects considered were not particularly labeled or categorized as circular aspects majorly because the term 'sustainability' is often used interchangeably with circular economy. Thus, in order to get a clear understanding of which activities incorporated were considered circular, the respondents were briefed about the concept of circular economy and circular construction and were later asked which phase of construction were they involved with and which particular circular aspects from Table 1 were considered during the development of a wind farm. Although the developers are indirectly involved with all the phases of wind farm development, the were particularly responsible for the design and development phase and the operation phase. Within the design and development phase, most of the circular aspects either lack incorporation or lack complete adoption. Few of the aspects are still under consideration while few of them have not been given any thought or regard.

Taking the circular aspects from Table 1 for the wind plan Blauw, currently, they are looking into using *less materials* and *less hazardous materials* and to optimize material use. Aspects like *design for deconstruction* and *use of secondary materials* have been partially incorporated. Reused/secondary materials have been used for the construction of roads. *Design for standardization* and design for modularity are few of the aspects that are taken into consideration while designing a wind turbine. Although all the wind farms are *designed for deconstruction*, when it comes to the aspect of circularity, it is not completely incorporated. During the turbine design, for most of the wind farms the composites are glued to the steel especially for the turbine blades which makes it evident that they are not *designed for deconstruction* or is partially done. Developers also worked together with the suppliers to discuss and understand whether they can reuse materials for cement and cement production. The other circular aspects like *design out waste, specify recycled materials and take back schemes* are under discussion with the suppliers and also within the industry forums such as sustainability working group in wind Europe. These are the aspects that the clients are aiming for and want to consider for their future projects. However, for wind plan Blauw, the developers cannot claim to have worked with the suppliers or implemented any of these aspects for the project.

Challenges and Obstacles Identified

At the moment the focus is on phasing out fossil fuels and bringing in renewable energy so there is a lot of effort needed in finding out how can we make energy transition possible. The respondents believe that once we come really far into the aspect of energy transition, maybe then there will be a bigger focus on how we are producing the green energy in a circular way. Below is an excerpt from one of the interviews which indicates the same.

> *"Circular economy and renewable energy are two parallel transitions. Energy Transition is mainly focused on producing renewable energy and not at minimizing material usage along the processes. The development is mostly focused on the production side and how do we get bigger and better wind turbines but there is no focus on use of materials" - Team Manager-Energy Planning (Respondent)*

Several challenges and obstacles hindering the circular transition for the project wind plan Blauw during the design phase were experienced and anticipated by the respondent which are explained in detail below.

Cost Incentive

For developers, one of the major concerns is costs. It is one of the major factors that is hindering the circular transition for the wind industry sector. The developers believe that the sustainable and circular solutions are always more expensive, and they are not willing to spend that kind of amount on it. For example, in case of logistics they did consider using only electrified vehicles or trucks for example during construction, however, that is costlier than using normal or standard vehicles. They also believe a lot of effort and understanding is required for incorporating circular aspects, to work along suppliers to find out what is necessary and also maybe invest in research. But for all of these costs is a big factor. The respondent believes time is money, and it is difficult to prioritize this topic unless there is cost incentive to it. Also, when we consider the use of recycled materials like the green steel or other material with increased amount of recycled content, it might be costlier than the normal steel. Also, in case of blades, the virgin carbon and glass fibers that are used for blade manufacturing are cheaper than the recycled fibers, which is definitely not an incentive for blade manufacturers to use the recycled fibers. The respondent believes that there is a general understanding that if you want to be more sustainable it is more costly in respect to time, resources, knowledge base and technology and that is why it is sometimes harder to trigger the business to really take it forward.

Lack of Knowledge and Information

Lack of knowledge and appropriate information is one of the obstacles hindering the circular transition. It is quite unclear on how to measure and asses circularity. Life cycle analysis is method which is not commonly used by a lot of suppliers which makes it difficult to assess circularity. Also, there is no information available that pinpoints at areas of improvement particularly for circularity. The respondent also believes that the project can attain circularity with the current infrastructure. However, knowledge is the key and a lot can be achieved if there is enough knowledge and right understanding. You can also notice lack of inclusion of new ideas within the closed networks in terms of circularity majorly due to lack of clear understanding.

Lack of Awareness

One of the formeost obstacles hindering circular transition is a lack of awareness. Not every government is aware about the materials being used for the wind turbine construction. During the phase of contracting, there is little or no involvement by the government and considering the infrastructure business, governments don't have a development or building departments regarding renewable energy and there is no expertise as well. The respondent aslo acknowledges that he is not really sure regarding the materials and standards used by the wind turbine producers/manufacturers because it is not a part of the design and planning phase.

Involvement of Suppliers

How circular can the wind farm be mainly depends on how well the developers are involved with the suppliers during the design phase. Because the developers are just responsible for the planning and development and operation, but the construction, the type of materials used, etc. is all dependent on the suppliers and without them attaining circular transition isn't possible. And currently, the developers are not as involved as they should be with the suppliers. They are not involved during the decisions made regarding the type of materials used for the wind turbines. The respondent finds it very interesting to notice that during the design and planning phase the turbine suppliers were not directly involved within the process. The wind turbine supplier is usually contracted after the design and planning phase.

Liberal Approach and Lack of Appropriate Policies

Although being ranked at the bottom of the table for renewable energy in Europe, the respondent believes that the Dutch are much more of a front runner than a lot of other countries when it comes to sustainable and circular activities. For example, to calculate the carbon footprint for construction industry the Netherlands developed a tool called Milieukostenindicator (MKI), so that's a calculation methodology to calculate the carbon footprint for construction projects and that is quite unique compared to other European countries. The respondent believes that the Dutch are quite proud and content with their innovations and technology which might be one the reason why the circular aspect is being overshadowed and not getting the required attention especially when it comes to the wind industry.

Also, The repondent deems that both the government and the developers have a very liberal approch towards circularity. It is seen that they have a very liberal approach like reducing costs in subsides and not stating any quality aspects in rewarding subsidies. Even the climate subsides, and the policies are currently focused on reducing the costs of production installations and none in particular to circularity. Currently, circularity completely depends on the willingness of the developers and the government.

Flexibility over Circularity

The respondent believes that the wind turbine industry is still a bit like the car industry before the onset of electric cars. They are just looking at using less materials and using less fuels to make it more efficient instead of going to a system with new source of power. Now, the whole car industry is going electrical and going through electrical transition. However, for wind energy I don't think we are at that point. All the things I read about innovation is mostly about building the wind turbine faster or making it modular. These are few aspects you could call circular but that is the main reason they are doing it.

Also, the developers prefer maximum flexibility to get the project done on time. For instance, in wind farms there are a lot of things like roads and slab of concrete that is beneath the crane which is quite big (30mX60m). This can be reduced easily. However, in such cases the developers would prefer maximum flexibility over circularity.

Innovations not directed towards circularity

Along with minimizing costs, the whole of the wind industry's current major focus is still about optimizing wind production. All the current innovations in case of wind turbines are mainly directed towards making the wind turbines lager and making sure it does not break under high wind velocity so that it can be certified. So, in a way it is forcing the hand of the turbine developer to make a strong, large turbine and are very efficient with the use of materials but on the other hand it is not promoting the innovation of recycling or upcycling afterwards.

Lack of Need and Incentive

The owners and developers do not have an incentive or are not challenged enough to think about the circular aspects. Particularly in the development phase, none of the parties involved are asking or demanding for the circular aspects which gives no incentives for the developers to incorporate them The respondents acknowledge that it circular aspects are something very important to consider and incorporate and believes it is the right thing to do but it is not something they need to do.

Uncertainty in Quality

Another major aspect that is hindering the circular transition for this particular project and the wind industry in general is the uncertainty in quality. The respondent deems that the recycled materials lack quality that is necessary for the construction of wind turbines. In order to construct long lasting windfarms, the recycled materials are not suitable.

Technology Availability

Although the project has enough infrastructure to attain certain level of circularity, the respondent believes that they lack suitable technology to incorporate circularity. Considering steel for example, steel produced with low carbon emissions, is not yet available in quantity and quality which is needed for the wind farm construction. Also, there are a lot of recycling and reusing ideas which are being tested at the moment, but it is unknown when these technologies will be brought to market scale.

Lack of Shared Vision

Circular economy is still at its initial stages particularly when it comes to the wind energy sector. There are very few people within the project or within the industry for that matter who understand the relevance of circular transition. Thus, there lacks a shared vision to attain circular transition which is one of the obstacles hindering it. Also, when it comes to circularity, the focus is directly on recycling. They are definitely considering on how to recycle these wind turbines at the end of life. But the question is not just recycling, which is basically downcycling, but also input during construction. How circular is the entire process of construction is debatable.

Lack of Resources and Competencies

The topic of circularity is not gaining traction mainly due to lack of resources (people and expertise) to specifically focus on that topic. The respondent believes that the circular transition can speed up if there were experts working particularly on that topic. There is also lack of expertise from the government side considering the infrastructure business. Governments don't have a development or building departments regarding renewable energy and there is no expertise as well.

Manufacture & Supply

Circular Aspects

The respondents are mostly responsible for the design and development phase and particularly involved in the manufacture and supply. They are usually involved in the construction and operation phase as well but that depends on the client. Considering the aspects from Table 1 within the manufacture and supply phase;

Eco-design Principles is something that is taken into consideration. As a company they believe they have been the sole promotor of actively excited generator technology which means that they use electromagnets in the turbines in order to prevent the rare earth materials in electricity generation. This is an impactful decision. It changes the way you design the turbines and how you operate. What we see now is that it is quite an expensive choice and as the generators get bigger and bigger it is more efficient to use permanent magnets for your generator.

Use less materials and optimize material use is also something that is taken into consideration. For example considering the tower design, if you look at the previous design they used to build these very strong and rigid tower that used a lot of material but what you see now is they started to work with modular steel segmented tower which consists of standard container units with metal sheets which can be constructed into a tower segments. These sheets are a lot thinner and can be transported very easily. *Use of less hazardous material is* actually one of the advantages of direct drive turbines. They neither have gear boxes nor do they require large amount of lubricants or oils. That's basically been the design decision from the beginning.

Increase in life span is an interesting one. About 10 years ago, they believe that they were the first to deliver a turbine that has a suitable life span of 30 years. But what we see now in the market is that the business models dictate the lifetime of the turbines and technical and economic lifetime isn't the driver anymore. Since this is the case what you see happening now is manufacturers optimize their technical lifetime to match the economic lifetime better in order to have a competitive offer. This was a big game changer as the clients preferred a less durable turbine that is cheaper and fits the business case rather than having a turbine with longer lifetime.

In case of Design for disassembly usually the wind turbine can be disassembled the same way, the turbine is assembled. But it depends on the tower type again. *Take back schemes and reverse logistics* is something they are trying to take into consideration. *Use of secondary materials* is something that they are really not sure about or not taken into consideration at the moment.

Challenges and Obstacles Identified

Dependent on Certain Type of Materials

The respondent believes that one of the biggest challenges to attain circularity for the wind energy sector will be the dependence on certain types of materials and material concern. For example, within the wind industry the biggest issue at the moment is rotor blades. You are completely dependent on certain type of materials for them. The material that is currently used to make this rotor blades are epoxy resins and glass fibers and it is a difficult material to reuse but it is easily available. This material automatically comes with a downside as it is really hard to reprocess. Another issue is the dependent on permanent magnets. You are completely dependent of these kinds of material and you don't really have other options.

Cost Incentive

Within the wind energy sector, you see an immense cost pressure in general. You see companies going bankrupt and incurring huge losses and this particularly relates to the turbine price. Currently, all the design decisions are focused on highest output in terms of electricity of the machine and the lowest cost in terms of design and the entire process. What we currently see in the market is that the customers/clients usually prefer lowest cost per kwh. Even when it comes to designing the wind turbines for longer life span. What we see now in the market is that the business models dictate the lifetime of the turbines and technical and economic lifetime isn't the driver anymore.

Lack of Focus

One of the major obstacles for circular transition is lack of focus on circularity. The respondent believes that if they were to focus on circular design, they could hire the required experts and they could achieve it. But what is difficult to achieve at the moment is that there is an increase in pace to market.

You can notice new prototypes being deployed almost every two years. So, what is the focus, is to improve the design based on these principles or is to improve the technology and value towards customer? Where does the value lie? Is this value in circularity or is it in the price of the turbine? Do utilities get discount if they have proven machines that can be reused? That value can be difficult to price in. So currently, the focus of the manufactures is on the cost of energy.

Easy Access to Resources

All the actors in the wind industry have really large companies with large procuring departments and currently, the focus is on obtaining resources easily and cost effectively. The respondent deems that easy access to resources is one of the major reasons for the same.

Lack of Need or Incentive

Currently, what you see happening is that the customer/clients are not very keen or particular when it comes to the aspect of circularity. They do not ask any questions regarding circularity because they are not obliged to do so. If the customers/clients are more particular or see the need to incorporate circularity, the manufactures are also obliged to these circular aspects.

Lack of Appropriate Policies

The current policies for the wind energy sector just focus on high level energy but not so much on circularity or circular waste. And this is majorly due to lack of focus by the government. Currently, the government just focuses on producing green energy. If the turbines provide green electricity, then no further questions are asked by the government.

Types of Failures

Challenges and obstacles identified so far were analyzed based on open codes done by qualitative interpretation of texts using the qualitative data analysis software ATLAS.ti. These codes are now clustered into categories using axial codes based on occurrence of particular 'failures' according to Webber and Rohracher classification (theoretical framework adopted for this research).

Table 8: Types of Failure For the Design & Development Phase (Wind plan Blauw)

Type of Failure	Failures Identified for the Design & Development Phase
Information Asymmetries	*Lack of Awareness* • There is lack of awareness regarding the aspect of circularity for the case wind plan Blauw. Not all the actors that are a part of wind plan Blauw development including the government are aware about the concept of circularity and are also unaware about the negative consequences of the wind farm development and the materials used. *Lack of Information* • Lack of appropriate information is one of the obstacles hindering the circular transition. It is quite unclear on how to measure and asses circularity.
Knowledge Spill over	*Lack of Knowledge* • There's a huge knowledge gap and poor knowledge transfer regarding the aspect of circularity. There is lack of knowledge regarding the circular practices, the materials being used for the wind turbines, the recycle and reuse technologies and practices, and also regarding the areas of optimization of circularity for the wind farms. The respondents believe that knowledge is the key and

	a lot can be achieved if there is enough knowledge and right understanding.
Externalization of costs	*Cost Incentive* • As developers one of the major concerns is the cost. It is one of the major factors that is hindering the circular transition for the wind industry sector. The developers believe that the sustainable and circular solutions are always more expensive. • For example, in case of logistics they did consider using only electrified vehicles or trucks for example during construction, however that is much more costly than using normal or standard vehicles • Also, steel or other material with increased amount of recycled content might be costlier. And in case of the blades, the current carbon and glass fibers which are used for blade manufacturing are still cheaper than the recycled. • Even when it comes to designing the wind turbines for longer life span, the clients prefer a less durable turbine that is cheaper and fits the business case rather than having a turbine with longer lifetime.
Over exploitation of commons	*Easy Access to Resources* • All the actors in the wind industry have really large companies with large procuring departments and currently, the focus is on obtaining resources easily and cost effectively. The respondent deems that easy access to resources is one of the major reasons for the same. *Dependent on Certain Type of Materials* • Within the wind industry the biggest issue at the moment is rotor blades. You are completely dependent on certain type of materials for them. The material that is currently used to make this rotor blades are epoxy resins and glass fibers and it is a difficult material to reuse but it is easily available. This material automatically comes with a downside as it is really hard to reprocess. Another issue is the dependent on permanent magnets.
Infrastructural Failure	*Technology Availability* • Although the project has enough infrastructure to attain certain level of circularity, the respondent believes that they lack suitable technology to incorporate circularity. Considering steel for example, steel produced with low carbon emissions, is not yet available in quantity and quality which is needed for the wind farm construction. • Also, there are lot of recycling and reusing ideas which are being tested at the moment but when will these technologies be brought to market scale is still unknown. • The governments don't have a development or a building departments or infrastructure regarding renewable energy. *Lack of Knowledge* • Lack of knowledge infrastructure is one of the major obstacles for circular transition. How to optimize circularity, what is the base line to step up from, what is the methodology to follow, etc. is currently unknown. *Uncertainty in Quality* • The respondent deems that the recycled materials lack quality that is necessary for the construction of wind turbines. In order to

	construct long lasting windfarms, the recycled materials are not suitable. Currently, there lacks knowledge and technology to make sure that the recycled materials have similar quality as the virgin materials.
Institutional Failure	*Innovations not directed towards circularity* • Currently, in order to get the wind turbine certified, you need to assure that the turbines are large and suitable for the location and don’t break under high wind velocities. Thus, the innovations are directed towards making them resilient. *Liberal Approach* • The repondent deems that both the government and the developers have a very liberal approch towards circularity like reducing costs in subsides and not stating any quality aspects in rewarding subsidies. Even the climate subsides, and the policies are currently focused on reducing the costs of production installations and none in particular to circularity. • The respondent also believes that the Dutch are quite proud and content with their innovations and technology which might be one the reason why the circular aspect is being overshadowed and not getting the required attention especially when it comes to the wind industry.
Capabilities Failure	*Lack of Resources and Competencies* • The topic of circularity is not gaining traction mainly due to lack of resources (people and expertise) to specifically focus on that topic. The respondent believes that the circular transition can speed up if there were experts working particularly on that topic. There is also lack of expertise from the government side considering the infrastructure business.
Directionality Failure	*Lack of Need or Incentive* • The owners and developers do not have an incentive or are not challenged enough to think about the circular aspects. Particularly in the development phase, none of the parties involved are asking or demanding for the circular aspects which gives no incentives for the developers or the manufacturers to incorporate the circular aspects. The respondents acknowledge that circular aspects are something very important to consider and incorporate and believes it is the right thing to do but it is not something they need to do. • All the innovations that were taken into consideration for this project are mostly about building the wind turbine faster or making it modular. These are few aspects you could call circular, but the incentive wasn’t to become circular. *Flexibility over Circularity* • The developers prefer maximum flexibility to get the project done on time. For instance, in wind farms there are a lot of things like roads and slab of concrete that is beneath the crane which is quite big (30mX60m). This can be reduced easily. *Lack of Shared Vision* • There are very few people within the project or within the industry for that matter who understand the relevance of circular transition. Thus, there lacks a shared vision to attain circular transition which is one of the obstacles hindering it. Also, when it comes to

	circularity, the focus is directly recycling but how circular is the entire process of construction is debatable. *Lack of Focus* • The respondent believes that if they were to focus on circular design, they could achieve it. But what is difficult to achieve at the moment is that there is an increase in pace to market. You see new prototypes being deployed almost every two years. So currently, the focus of the manufactures is on the cost of energy and not on circularity.
Demand Articulation Failure	*Involvement of Suppliers* • The manufactures/suppliers are not directly involved during the design and planning phase of the project. They are usually contracted after the planning phase of the project which prevents the government and the developer to go into much details regarding the circular aspects as it is not possible to become circular without the suppliers.
Policy coordination failure	*Lack of Appropriate Policies* • The climate subsides and the policies are currently focused on reducing the costs of production installations and none in particular to circularity • There are no policies to involve suppliers early into the process and have the technical competencies early into the process. • Currently, the government just focuses on producing green energy and If the turbines provide green electricity then no further questions asked.

2. Construction Phase

Circular Aspects

The respondent acknowledges the fact that there is a problem with the wind energy sector regarding sustainability, with major concern being the type of materials used for the wind turbines. Taking tower as an example, the majority of the towers are made of steel. But how sustainable is the production of steel is debatable. An alternative to steel is concrete. Both the materials are considered good for recycling, but the respondent believes that both the materials have a significant impact with no other alternative at the moment. And these are just two components, if we consider all the oils, lubricants, the materials for blades, fibers and other fabrics, etc. there are multiple concerns at the moment. Although it is definitely getting better with years, the respondent believes that the wind industry is in need for a solution. The respondent was then asked what his idea of circular economy is and was then briefed about the concept of circular economy and circular construction and was later asked which of the circular aspects from Table 1 were taken into consideration for the construction of wind plan Blauw.

For the case wind plan Blauw in particular, the aspects *Procuring reused materials, and Procuring recycled materials* is something that isn't noticed or taken into consideration for construction. There have been few attempts of *Procuring reused materials*, but most often the decision is fundamentally based on price by the suppliers. The suppliers have the freedom within the contract to decide where and what to purchase. And there was an attempt to procure recycled materials probably 10 years ago and that wasn't successful, thus the contractors usually don't prefer using the recycled materials. The aspects that are considered to an extent is *minimize waste* and *offsite construction*. In terms of offsite construction, all the parts of a wind turbine from cables, towers, blades, wings, etc. are constructed off site and are installed and assembled onsite. But not everything can be done offsite.

Challenges and Obstacles Identified

Circular economy is a topic where you will come across a lot of contradictory opinions, especially when it is in relation to the wind energy sector. A lot of contractors working in the wind energy sector believe that they are already working for a better future and a fossil free living. However, the major issue is circular transition being overshadowed by energy transition. Several challenges and obstacles hindering the circular transition for the project wind plan Blauw were experienced and anticipated by the respondent which are explained in detail below.

Lack of Need or Incentive

One of the major obstacles for not incorporating circular aspects and preventing circular transition is lack of need and an incentive to do so. For the project Blauw, it wasn't an obligation to follow the EU tender regulations or as they say in Dutch, it is not aanbestedingsplic. When it is not an obligation to do so, the clients do not consider it. However, the circular aspect was used for the selecting process in the tender but unfortunately was not given enough value in the evaluation process. At the moment circularity is given similar importance as health and safety. It is considered important, but the priority is given to the business case.

Lack of Awareness, Knowledge and Information

One of the major reasons that affects the circular transition is the lack of awareness. Most of the practitioners working within the wind industry are unfamiliar with the concept of circular economy. Most of them fail to understand that there is a limitation or scarcity of materials. A lot of practitioners involved within the case lack knowledge and not all of them have the same understanding when it comes to circular economy. There is a huge knowledge gap and poor knowledge transfer. The respondent believes that lack of knowledge and lack of awareness are the biggest challenges that hinders circular transition for the wind energy sector. It is not just lack of knowledge and awareness that hinders circular transition but also lack of appropriate information. In terms of circular economy, not every party has the same information and there is lack of efficient information in the market as a whole which is hindering the circular transition.

Lack of Communication and Interaction

Lack of communication and interaction within the actors involved is one of the major reasons for lack of awareness, knowledge and information. You can notice something similar happening right now in the province of Flevoland where Blauw is situated where there also have many other projects nearby with the same contractors for the grid or for the foundations and maybe also the same clients and turbine suppliers. Yet there is no communication or interaction. A lot can be done there to minimize material usage or spare parts. And sometimes due to lack of communication and interaction you can also notice lack of inclusion of new ideas or lack of incorporation of new concepts such as circularity.

Lack of Shared Vision

Another major reason that is currently hindering the circular transition considering this case is the lack of shared vision. And the main reason for that is they lack common understanding and common agenda. For example, currently, energy transition is a common agenda. So, there is a shared goal and targets to meet that creates a shared or combined agenda. But it isn't the case for circular transition. One of the main reasons for this can also be the lack of need or urgency to do so.

Liberal approach and Lack of Appropriate Policies

Currently, there are no regulation and policies regarding the incorporation of circularity. It also mostly depends on the motivation of the client/developer. If the aspect of circularity is not in the employer's requirement then it is really hard to incorporate it because it is intended that the client/developer does not want to spend money on it. The only way it can be incorporate is to make it an obligation through permits and regulation, which are currently lacking. The respondent also believes that the socio-economic element plays a major role. The Dutch are a bit lazy when it comes to the topic of circularity or sustainability when compared to the Nordic countries. Countries like Sweden, Denmark or Norway are much more aware when it comes to the environment and how to contribute to it.

Lack of Resources and Competencies

It is less to do with turbines but a bit more to do with electrical infrastructure. All the cables, transformers, switch gears and all the other hardware components are not reused and used only once. They try to standardize these components a little, but it is quite hard to do so. For example, every big windfarm has two transformers. They don't need two transformers it can be done with one. But the risk of this transformer failing is the only reason they install two as the it takes almost 18 months to deliver a new one. You can try and standardize the project and make sure every project has a same step-up transformer. But there is a lack of skill and competency to do so. And this is just one such example. But in order to achieve circular transition, currently, we lack resources and competencies, says the respondent.

Uncertainty in Quality

Although there are advanced techniques for recycling steel and concrete the practitioners involved within the case and in general struggle to believe that reused material are good as the new ones and doubt the quality of the materials despite the fact that the recycling companies are able to show certificates of the material. Thus, lack of quality is also one of the major reasons hindering circular transition.

Cost Incentive

The respondent believes that majority of the clients are cost focused and driven by cost reductions and this often is an hindrence to innovative ideas and serves as an obstacle for incorporating circular aspects. The respondent also deems that the clients are scared to be more innovative and stick to traditional methods to avoid increase in costs.

Lack of Urgency

One of the major reasons for not incorporating the aspects of circularity is because there lacks a sense of urgency at the moment. Currently, the focus is just to phase out the use of fossil fuels and attain energy transition.

Types of Failures

All the challenges and obstacles identified in the construction phase are categorized based on Webber and Rohracher 'failures' framework.

Table 9: Types of Failures For the Construction Phase (wind plan Blauw)

Type of Failure	Failures Identified for the Construction Phase
Information Asymmetries	*Lack of Awareness* • Most of the practitioners working within the case or wind industry for that matter are unfamiliar with the concept of circular economy. Most of them fail to understand that there is a limitation or scarcity of materials. The respondent believes lack of awareness is one of the biggest challenges that hinders circular transition for the wind energy sector. *Lack of Information*

	• It is not just lack of awareness that hinders circular transition but also lack of appropriate information. In terms of circular economy, not every party has the same information and there is lack of efficient information in the market as a whole which is hindering the circular transition
Knowledge Spill over	*Lack of Knowledge* • A lot of practitioners involved within the case lack knowledge and not all of them have the same understanding when it comes to circular economy. There is a huge knowledge gap and poor knowledge transfer within the wind industry.
Externalization of Costs	*Cost Incentive* • The respondent believes that majority of the clients are cost focused and driven by cost reductions and this often is an hindrence to innovative ideas and serves as an obstacle for incorporating circular aspects. The respondent also deems that the clients are scared to be more innovative and stick to traditional methods to avoid increase in costs.
Infrastructural Failure	*Uncertainty in Quality* • Although there are advanced techniques for recycling steel and concrete lately, the practitioners involved within the case and in general struggle to believe that reused material are good as the new ones and doubt the quality of the materials despite the fact that the recycling companies are able to show certificates of the material.
Institutional Failure	*Liberal Approach* • The respondent also believes that the socio-economic element plays a major role. The Dutch are a bit lazy when it comes to the topic of circularity or sustainability when compared to the Nordic countries. Countries like Sweden, Denmark or Norway are much more aware when it comes to the environment and how to contribute to it particularly when it comes to the renewables such as the wind industry.
Interaction or Network Failure	*Lack of Communication & Interaction* • Lack of communication and interaction within the actors involved is one of the major reasons for lack of awareness, knowledge and information. You can notice something similar happening right now in the province of Flevoland where Blauw is situated where there also have many other projects nearby with the same contractors for the grid or for the foundations and maybe also the same clients and turbine suppliers. Yet there is no communication or interaction. • And sometimes due to lack of communication and interaction you can also notice lack of inclusion of new ideas or lack of incorporation of new concepts such as circularity.
Capabilities Failure	*Lack of Resources and Competencies* • Every big windfarm including Blauw has two transformers. They don't need two transformers it can be done with one. But the risk of this transformer failing is the only reason they install two as the it takes almost 18 months to deliver a new one. We can try and standardize the project and make sure every project has a same step-up transformer. But there is a lack of skill and competency to do so. And this is just one such example.
	Lack of Need or Incentive • For the project Blauw, it wasn't an obligation to follow the EU tender regulations or as they say in Dutch, it is not

Directionality Failure	aanbestedingsplic. When it is not an obligation to do so, the clients do not consider it. • Although it is one of the aspects to be considered but at the end of the day the selection is made on another criteria. At the moment circularity is given similar importance as health and safety. It is considered important, but the priority is given to the business case. Currently, due to lack of need or incentives, circularity is not the priority. *Lack of Shared Vision* • The main reason for lack of shared vision is they lack common understanding and common agenda. Currently, energy transition is a common agenda. So, there is a shared goal and targets to meet that creates a shared or combined agenda. But it isn't the case for circular transition and currently it is at the bottom of the agenda. *Lack of Urgency* • One of the major reasons for not incorporating the aspects of circularity is because there lacks a sense of urgency at the moment. Currently, the focus is just to phase out the use of fossil fuels and attain energy transition
Policy Coordination Failure	*Lack of Appropriate Policies* • One of the promising ways to incorporate the aspect of circularity would be to have appropriate policies and regulations. Currently, there are no regulation and policies regarding the incorporation of circularity. If the aspect of circularity is not in the employer's requirement then it is really hard to incorporate it because it is intended that the client/developer do not want to spend money on it. The only way it can be incorporate is to make it an obligation through permits and regulation, which are currently lacking.

3. Operation & Maintenance Phase

Circular Aspects & Challenges and Obstacles Identified

Wind plan Blauw is currently in the pre-construction phase. The construction is set to being early 2021 and the wind fam will be completely ready and commissioned in 2022. The operation phase of the wind farm will fall after the year 2022 and thus the respondent couldn't answer much of the questions regarding the operation phase. The respondent was asked which of the circular aspects from Table 1 would be considered during the operation phase. The respondent seemed a bit uncertain. However, the respondent anticipated a few aspects that could be considered. Firstly, *minimal maintenance* is something that is taken into consideration. They design their turbines to be robust but what you notice is if you have maintenance you also have downtime on your turbines which is not favorable. They design the turbines in such a way that they are serviced just once a year. *Minimize waste* is also something that is definitely taken into consideration. They experience very limited wear and tear on our machines due to design. It is a design decision that has a huge impact in the operation phase. Easy Repair, adaptability and flexibility are also the aspects that are definitely taken into consideration.

No particular challenges were mentioned during this phase of wind farm development. This is majorly due to lack of awareness and information. The respondent seemed unsure about the aspect of circularity being incorporated during the operation phase and almost all of his/her answers were particularly specified for the design and development phase as the respondent deems design and development phase is where the aspects of circularity can make a difference. All the circular aspects mentioned in this phase are incorporated taking cost efficiency into consideration and not particularly the aspect of circularity.

Types of Failures

All the challenges and obstacles identified in the Operations & Maintenance phase are categorized based on Webber and Rohracher 'failures' framework.

Table 10: Types of Failures For the Operations & Maintenance Phase (wind plan Blauw)

Type of Failure	Failures Identified for the Operations & Maintenance Phase
Information Asymmetries	*Lack of Awareness and Information* • The respondent seemed unsure about the aspect of circularity being incorporated during the operation phase and almost all of his/her answers were particularly specified for the design and development phase as the respondent deems design and development phase is where the aspects of circularity can make a difference. All the circular aspects mentioned earlier are incorporated taking cost efficiency into consideration and not particularly the aspect of circularity.

4. Decommissioning Phase

Circular Aspects

The respondent involved with the construction phase was also questioned regarding the decommissioning phase and was asked which of the aspects from Table 1 were taken into consideration for the decommissioning of the existing wind turbines.

Decommissioning is definitely taken into consideration. It's an obligation to design all the wind turbines for deconstruction. All the 74 existing wind turbines are decommissioned. *Reuse of components and products* depends on where the used parts go after decommissioning. The respondent deems that a bit of refurbishing of the turbines is done. If you refurbish them in a right way and have a lot of spare parts then there is a market for it. But if the brand doesn't exist anymore and spare parts are limited then you see the turbines being scrapped. You can notice 28 such turbines in the windfarm with no interest for it other than scrap yards. *Open loop recycling* is something that can be incorporated. For example, if the repowering of the turbines is done at the same spot as the old turbines, what's interesting is if you have a new contractor coming in and there's foundations in the ground, what would be ideal is to have them in the ground for the new contractor to take out rather than you taking it out and leaving holes in the ground or back filling it with unkoown material, because then you run into a contractual risk. *Closed loop recycling* is something that's not been considered yet for this project.

Challenges and Obstacles Identified

Cost Incentive

Most of the decisions taken during the entire process of development of wind farms are money driven. Even if the activity was considered circular, that particular activity was undertaken because of cost incentive and not because it was circular. For example, in case of wind plan Blauw, since few old turbines were being replaced by the new ones, holes are left in the ground and new holes are dug out for the new turbines. The soil dug out for the new turbines is used to fill in the old holes in order to avoid import and export of soil as you will have to pay to do so. This is completely a money driven decision and not a decision made due to circularity or sustainability. Also, a lot of decision makers believe that circular economy is complex and costing a lot of money. Thus, if it is not mentioned in the contract or if it is not an employer's requirement, they would rather avoid it.

Lack of Awareness, Knowledge and Information

Most of the contractors are not aware about what is being done to the decommissioned turbines, how are they being refurbished, where is it being done, are the products sent for recycling or not? etc., and are aslo unawre if the turbine components can be reused. Secondly, the contractors responsble for deconstructing the old turbines are not the ones reponsible for its construction 25 years ago. Thus, there is lack of information regarding certain specific details.

Maintenance of several brands of turbines is difficult due to the lack of knowledge and information regarding these turbines. Construction wise, blades are difficult for re-use as construction is more or less a secret. Therefor it is difficult to use blades in other projects. Finally, there lacks a knowledge on how efficiently the old turbine components can be recycled and reused. Although there exists a technique to recycle steel and coccrete, but it is not being done efficiently. And in case of turbine blades and composites, there is still a lack of knowledge and technology on how efficiently they can be recycled.

Lack of Urgency

One of the major reasons for not incorporating the aspects of circularity is because there lacks a sense of urgency at the moment. Currently, the focus is just to phase out the use of fossil fuels and attain energy transition.

Types of Failures

All the challenges and obstacles identified in the Decommissioning phase are categorized based on Webber and Rohracher 'failures' framework.

Table 11: Types of Failures For the Deconstruction Phase (wind plan Blauw)

<table>
<tr><th>Type of Failure</th><th>Failures Identified for the Decommissioning Phase</th></tr>
<tr><td>Information Asymmetries</td><td>Lack of Awareness
Most of the contractors are unaware about what is being done to the decommissioned turbines, how are they refurbishing, where is it being done, are the products sent for recycling and are aslo unawre if the turbine components can be reused.
Lack of Information
The contractors responsble for deconstructing the old turbines are not the ones reponsible for its construction 25 years ago. Thus, there is lack of information regarding certain specific details.
Maintenance of several brands of turbines is difficult due to the lack of information regarding these turbines. Construction wise, blades are difficult for re-use as the construction is more or less secret. Therefor it is difficult to use blades in other constructions like buildings or waterworks.</td></tr>
<tr><td>Infrastructural Failure</td><td>Lack of Knowledge
There lacks a knowledge on how efficiently the old turbine components can be recycled and reused. Although there exists a technique to recycle steel and concrete it is not being done efficiently. And in case of turbine blades and composites, there is still a lack of knowledge and technology on how efficiently they can be recycled.</td></tr>
<tr><td>Directionality Failure</td><td>Lack of Urgency
One of the major reasons for not incorporating the aspects of circularity is because there lacks a sense of urgency at the moment. Currently, the focus is just to phase out the use of fossil fuels and attain energy transition.</td></tr>
</table>

4.1.3 Case Summary

The circular aspects and the failures identified for the case wind plan Blauw are summarized in tables below.

Circular Aspects

In order to summarize all the circular aspects that were incorporated/not incorporated for the case wind plan Blauw, the circular aspects were scored using five-point scales ranging from **- -** for not being taken into consideration at all and **+ +** for completely being incorporated within the project. For all the five values (+ +, +, + / -, -, - -) qualitative description is given in Table 12 and Table 13 summarizes all the circular aspects for the case wind plan Blauw by assigning the five point scale.

Table 12: Qualitative description for five-point scale

SL NO:	Five Point Scale	(Qualitative) Score
1	Completely Incorporated	**+ +**
2	Partially Incorporated	**+**
3	May/May not be incorporated (Under Consideration)	**+ / -**
4	Not Incorporated (Under consideration for Future Projects)	**-**
5	Not Under Consideration	**- -**
6	Not Applicable	**NA**

Table 13: Circular aspects being considered/not considered for Wind Plan Blauw

Phase of wind farm construction	Life-cycle stage	Circular Economy Aspect	Five Point Score
1. Design & Development Phase	Design	Design for deconstruction	**+**
		Design for adaptability and flexibility	**+**
		Design for standardization	**+**
		Design out waste	**-**
		Design in modularity	**+**
		Specify reclaimed materials	**-**
		Specify recycled materials	**-**
	Manufacture and Supply	Eco design principles	**+**
		Use less materials/optimize material use	**+**
		Use less hazardous material	**+ +**
		Increase the life span	**+ / -**
		Design for product disassembly	**+**
		Design for product standardization	**+ +**
		Use secondary materials	**- -**
		Take back schemes	**+ / -**
		Reverse Logistics	**+ / -**
2. Construction Phase	Construction	Minimize Waste	**+**
		Procure reused materials	**-**
		Procure recycled materials	**- -**
		Off-site construction	**+**
3. Operation Phase	In use and Refurbishment	Minimize waste	**+**
		Minimal Maintenance	**+**
		Easy Repair and upgrade	**+**

		Adaptability & Flexibility	+
4. Decommissioning Phase	End of life	Deconstruction	+ +
		Selective Demolition	+
		Reuse of components/products	+ / -
		Closed loop recycling	- -
		Open loop recycling	-

Types of Failures Identified For Each Phase of Wind Farm development.

All the types of challenges and obstacles identified in each phase of wind farm development for the case Wind Plan Blauw based on the 'failures' framework is summarized below in Table 14.

Table 14: Failures Identified For Each Phase of Wind Farm development (Wind Plan Blauw)

	Market Failures	Structural System Failures	Transitional System Failures
Design & Development Phase	➢ Information Asymmetries ➢ Knowledge Spill over ➢ Externalization of costs ➢ Over exploitation of commons	➢ Infrastructural Failure ➢ Institutional Failure ➢ Capabilities Failure	➢ Directionality Failure ➢ Demand Articulation Failure ➢ Policy coordination failure
Construction Phase	➢ Information Asymmetries ➢ Knowledge Spill over ➢ Externalization of costs	➢ Infrastructural Failure ➢ Institutional Failure ➢ Interaction or Network Failure ➢ Capabilities Failure	➢ Directionality Failure ➢ Policy coordination failure
Operations & Maintenance Phase	➢ Information Asymmetries		
Decommissioning Phase	➢ Information Asymmetries	➢ Infrastructural Failure	➢ Directionality Failure

4.2 Case: Borssele 1 & 2

4.2.1 Introduction

Orsted is the owner and developer of Borssele 1 & 2. Orsted is a Danish multinational power company based in Denmark and they stand for a world that runs on green energy. Borssele 1 & 2 off the coast of Zeeland, is their first offshore windfarm construction in the Netherlands. Borssele 1 & 2 which have a combined capacity of 752MW, are a part of the Borssele windfarm zone, which comprises the development of five projects. When realized, Borssele 1 & 2 will be the largest offshore wind farm in the Netherlands (Orsted-Borssele 1&2, 2020). The project facts and figures are listed below in Table 15

Table 15: Facts and Numbers (Borssele 1 & 2, 2020)

SL NO:	Description	Facts and Numbers
1	Project Type	Offshore wind farm
2	Owner & Developer	Orsted
3	Location	About 23 km from Westkapelle
4	Timeline	2020 with a flexibility of 1 year
5	Number of Wind Turbines to be built	94
6	Turbine Type	Provisional 8MW
7	Total MW	752
8	Foundation	Monopiles

Construction of Borssele 1 & 2 started in January 2020 with the installation of the first foundation. In April 2020, Borssele 1 & 2 has delivered first power to the Dutch grid. The first wind turbine is now supplying electricity. Currently, the construction is on schedule and the wind farm is set to be complete by the end of this year (Orsted-Borssele 1&2, 2020).

Location

Borssele 1 & 2 is located about 23km from Westkapelle, in the Dutch part of the North Sea, off the coast of the Dutch province of Zeeland at water depths ranging from 14 to 39.7 meters. The Figure 9 shows the exact location of the wind farms. The location was designated by the Dutch government. The maintenance of the wind farms take place from the maintenance location at Vlissingen.

Figure 9: Location of Borssele 1 & 2 (Nexans: Borssele 1 and 2 wind farms off the Netherlands coast, 2020)

Actors/Stakeholders Involved

On July 2017, subsidy and permits for the Borssele wind farm sites 1 & 2 were awarded to Orsted. They are responsible for the ownership and development of the wind farm. In November 2017, Orsted announced that the wind farm turbines will be equipped with Siemens Gamesa. They are 8MW turbines with a rotor of 167 meters. The Sif group, Bladt, EEW SPC, EEW OSB, have been awarded the contract for the delivery of the monopile foundations. Both the turbines and the foundations will be installed by DEME Offshore. Nexans was awarded the contract by Orsted to supply 66kV submarine inter-array cables. The installation of cables is done by Van Oord.

Actors Interviewed For This case

A total of four actors were interviewed for this case. Each actor was involved with different phases of the wind farm development.

Table 16: Actors interviewed for the case Borssele 1 & 2

Interview Number	Roles	Organization
1	Senior Environmental Advisor	Owners/Developers
2	Team Manager: Wind Energy and High Voltage	Engineering & Consultancy Company
3	Project Manager	Contractor
4	Wind Turbine Package Manager	Supplier & Manufacturer

Project Schedule

Borssele 1 & 2 is currently in the last stages of construction and installations of wind turbines. In the first weeks of July 2020, 25 of the 94 turbines and all the 94 cables were installed. And Orsted has revealed that by October 2020 all the turbines will be installed, and the wind farm will be fully commissioned. The Figure 13 in APPENDIX C shows the complete schedule and planning of the wind farm Borssele 1 & 2.

Project Goals

In 2013, the government of Netherlands commenced an Energy Agreement for sustainable growth and set a target of meeting 16% of the nation's electricity needs through renewable energy sources by 2023 and planned to develop 3500MW offshore wind projects. Overall, 40 organizations agreed to develop the offshore wind farms as a result of which three offshore windfarm zones were proposed to be built namely Borssele (1,400MW), South Holland coast (1,400MW), and North Holland coast (700MW). Borssele 1 & 2 (752MW) is a part of Borssele zone. The developers also have the vision to run a world completely on green energy. The amount of green electricity generated corresponds to the consumption of one million households in the Netherlands.

4.2.2 Case Study Results

Similar to the first case study, data was collected via interviews for various challenges and obstacles experienced by the practitioners hindering circular transition for the case Borssele 1 & 2 and also different circular aspects being/not being incorporated. The challenges identified during the interview were given codes after transcribing and verifying the interview data. The codes given were based on the terms and phrases used by the respondents. APPENDIX D consists of the excerpts from the transcribed interview with allotted codes. Similarly the data was categorized based on different phases of wind farm development where the perspective of the owners/developers, consultants, suppliers/manufacturers and the contractors were taken into consideration, listed and then categorized based on the types of failures from the 'Overview of failures Framework (Weber & Rohracher, 2012).

1. Design & Development Phase

Design

Circular Aspects

From the respondent's perspective, circular economy is a complex subject and for it to be successfully implemented a lot of aspects need to align together and that will take some time. Moving away from the linear economy and the current way of business will definitely be a huge task. Perhaps you can see a similar transition going on with the renewable energy and energy transition and moving away from the fossil fuels. It was something in discussion for decades and finally a lot is happening now but that has taken a lot of effort in corporate innovation, trial research, getting the regulations right etc. Perhaps it might be the same case for circular economy as well. It is a concept that has to be matured and then be incorporated in all of these aspects. On a societal level, there is definitely an increased focus on circular economy aspects.

For the case Borssele 1 & 2, during the design and development phase circularity is an aspect taken into consideration also in the company's sustainable strategy. They also understand the need to recycle materials and avoid landfilling of waste. However, it is difficult to point out to a particular activity related to the Borssele wind farm. Considering the circular aspects from Table 1 for all the windfarms there is a decommissioning plan made while designing the windfarms, so they are considered for *design for deconstruction*. For a wind farm, it is one of the conditions for the permit as well. The wind turbine always needs to be designed to be removed so it is a legal requirement and thus an incentive for the developers to do it. There is some *modularity* to the wind turbines as well. You can change individual parts of the wind turbine during the turbine lifecycle. But it is also a question of interpretation when it comes to what aspects are included for the wind farm development. But in general*, design for deconstruction, design for modularity* and *design for standardization* are taken into consideration. In terms of design for *flexibility and adaptability*, the foundation (monopoles) is designed based on the location and based on the strength of the waves etc. *Specifying reclaimed and recycled materials* and *design out waste* is something that is not taken into consideration at least for this particular project.

Challenges and Obstacles Identified

Several challenges and obstacles for circular transition for the project Borssele 1 & 2 were experienced and anticipated by the respondent during the design phase which are explained in detail below.

Blade waste and Composites

Currently, the biggest challenge when it comes to the wind turbines is at the end of their economic life. For this case and at a corporate level, the main issue when it comes to the circular economy is the blade waste of the wind turbines and the composite fiber glass. A lot of materials can be recycled as they are, but not the turbine blades and the fiber glass composite. The issue of fiber glass composites waste is not something unique to the wind industry alone. There have been other sectors with similar issues like the aviation industry, marine boats etc. The respondent deems that recycling technologies for these fiber glass composites are not yet available. This is something they are working on within the company and also with a lot of other actors in the wind industry. Also, another issue is that in several southern European countries it is very cheap to get rid of the fiber glass and blade waste and as long as that is the case the business case for recycling and circular economy is more difficult.

Lack of Need or Incentive

The respondent reckons that often a lot of decisions taken during the design and development phase in terms of circular economy if any, is for the benefit of other stakeholders or other departments or for a later point of time. It is not necessarily to the benefit of the decision maker in the design phase. For instance, looking at glass fiber composites used for wind turbine blades, currently, it is a very effective and cheap material to use and even though it cannot be effectively recycled at the end of life it is still used abundantly and that is because there are no proper incentives to ensure that this should not be happening. There aren't many economic incentives to recycle materials.

The respondent also advised the Borssele for some environmental and technical aspects in relation to the tender of Borssele, but they did not advise them regarding circularity. This is mainly because Borssele is the first large offshore wind farm in the coast of the Netherlands and in that moment of time in 2015, the tender was only about the lowest price for wind energy so there wasn't any incentive for the client to look broader.

Lack of Knowledge & Information

For practitioners generally involved in the decision-making process, circular economy is considered as a complex phenomenon. The respondent believes that for people involved within the case or for wind industry in general, circular economy is a complex concept and there is still room for improvement in understanding the concept of circular economy and believes it is still theoretical in nature.

Even when it comes to recycling and reusing of old materials, the respondent believes that they lack knowledge and a smart approach to do so. It is not just knowledge, they also lack information and standardized approach on how they can reuse the materials, particularly the wind turbines.

Cost Incentive

One of the biggest obstacles hindering circular transition for the wind energy sector is the financial incentives. For the Borssele case the tender was focused only on the lowest price for wind energy. Offshore wind, until recently has been a niche industry and there has been a massive focus on bringing down the cost of the technology and compete with fossil fuels and the first priority is to have a healthy business case and then you look at all the other aspects and probably invest in circularity. The respondent also deems that all the initiatives they could do will be weighed against the financial costs. Also, when it comes to reusing and recycling of materials, there lacks a smart approach to do so. By smart it means cost effective approach. Currently, it is cheaper to dump the materials in the graveyard than to reuse the materials which might hinder the circular transition.

Innovations not directed towards circularity

Most of the aspects taken into consideration like minimizing waste generation and minimal maintenance, etc. is due to company policies. However, the respondent believes that these aspects are strictly considered for economic reasons and has nothing to do with becoming circular. The respondent also deems that almost all the companies have their own policies and ambitions but are unaware of an any existing central vision for circularity. The evolution of the majority of the sector from the beginning was always focused on optimizing wind energy and cost effectiveness.

Lack of Regulations & Appropriate Policies

One of the biggest shortcomings is lack of regulations and policies. It is interesting to point towards regulations on blade waste in particular. Because in some European countries, landfilling of blade waste is illegal by national law, which means that the business case for decommissioning and recycling is different than in countries where you can landfill blades at a lower cost. It is also interesting to note that when it comes to circular economy aspects the wind industry is not as regulated when compared to other sectors.

Need for Research

The challenge like lack of knowledge and lack of information can be addressed if there is enough research and development activities. A lot could be achieved in terms of circularity by incentivizing research and development activities and recycling technologies. Currently, there isn't a lot of research and development activities focused on the circular aspects for the wind energy sector particularly for recycling of fiber glass composites, and also research for alternate use of wind turbine blades.

Lack of Resources & Expertise

In general, for the wind energy sector there is still room for improvement in the understanding of the circular economy aspects. There needs to be a good professional understanding of the issues in order to provide solutions for the issues. However currently, there is lack of resources and expertise within the project who can guide and work on the circular aspects.

Involvement of Suppliers

The respondent believes that they have a strong tradition within the wind energy sector for cross collaboration across the value chain. But isn't very sure about how well the customers and designers collaborate on circular economy aspects. Because some of the decisions regarding circular economy are made during product development phase at the suppliers where developers are not involved. Most of the important decisions are made in the design phase by the developers where the actors throughout rest of the value chain are not involved.

Easy access to Resources

Another major reason to avoid reusing the materials or use the recycled material is due to easy access to material resources. Steel is always easily available, and concrete is also easily available for the foundation and it does not encourage the developers to use reused materials.

Lack of Shared Vision

The respondent believes that there does not exist a shared vision within the company or within the wind industry in general. Almost all the companies have their own policies and ambitions and none of them have an existing central vision for circularity.

Manufacture & Supply

Circular Aspects

The respondent was mostly involved with the design and development phase particularly with manufacture and supply and also with the construction phase for the installation of the turbines. Thus, the respondent was asked which of the circular aspects from Table 1 were taken into consideration during the manufacture and supply.

Eco design principles is something that is taken into consideration when it comes to the type of materials or the types of chemicals used. *Using less materials and optimizing material use* is also something that is taken into consideration but mostly due to economic incentives. Being circular and cost conscious comes hand in hand for such aspects and thus these aspects are definitely taken into consideration. Considering the environmental perspective, *Using less hazardous materials* is also taken into consideration. When it comes to *increase in life span* the aim is not just increase it but to optimize the use of the turbines. So, it is hard to make a generic statement. Because all the components of a wind turbine from the blades, tower, foundation, etc. have different life spans and merely trying to increase everything will not be sensible to do because the other parts will not last that long. You can make the tower last forever, but the other components don't. So, it is difficult to say in general for a wind farm. *Design for disassembly* is something that is feasible to do but not sure if all the disassembled parts could be used again. *Design for standardization* is definitely taken into consideration, you could easily use these products in different projects as well. In terms *of use of secondary materials*, *take back schemes and reverse logistics* the respondent is unsure.

Challenges and Obstacles Identified

Cost Incentive

The respondent states that the biggest obstacle for circular transition would be costs. Within the project or as an industry as a whole they are mainly focused on price. Every tender you can see a new record in terms of cost and especially in the Netherlands you see subsidy free schemes, and everything needs to be cheaper. The respondent believes that as long as there are no policies that link CO_2 emissions and costs or costs and circularity, circular transition would not be a goal to achieve.

Lack of Information

The respondent states that he is not quite sure about the type of information everybody has within the project particularly in terms circular economy. This shows that there is lack of sufficient information about circular economy which might serve as an obstacle for circular transition.

Lack of Technology

When it comes to the use of secondary materials and use of certain type of material and for circular design solutions, the respondent deems that they are not completely aware of the available technologies. Particularly in terms of blade waste, there is no available technology at the moment to reuse the blades.

Uncertainty in Quality

One of the major reasons for not using the reused material is due to uncertainty in quality and strength of the reused material.

Lack of Need or Incentive & Lack of Appropriate Policies

The respondent states that currently, he is not aware of any such policies that focus on attaining or incorporating circular aspects and the main reason being lack of need or incentive. The respondent believes that if there is an incentive and a need to do so, the aspects of circularity will be incorporated, and this should come from the policy makers.

Types of Failures

Similar to the first case, all the challenges and obstacles identified in the design and development phase were analyzed based on open codes done by qualitative interpretation of texts using the qualitative data analysis software ATLAS.ti. see APPENDIX D. These codes are now clustered into categories using axial codes based on occurrence of particular 'failures' according to Webber and Rohracher classification (theoretical framework adopted for this research).

Table 17: Types of Failure For the Design & Development Phase (Borssele 1 & 2)

Type of Failure	Failures Identified for the Design & Development Phase
Information Asymmetries	*Lack of Information* • The respondent believes that for people involved within the case or for wind industry in general, circular economy is a complex concept and there is room for improvement in understanding of the circular concepts. • They also lack information and standardized approach on how you can reuse the materials, particularly the turbines.
Knowledge Spill over	*Lack of Knowledge* • When it comes to recycling and reusing of old materials, the respondent believes that they lack knowledge and a smart approach to do so. The respondents believe that knowledge is the key aspect to achieve circular transition.

Externalization of costs	*Cost Incentive* • For the Borssele case the tender was only about the lowest price for wind energy offshore. • The respondent also deems that all the initiatives will be weighed against the financial costs. • Also, when it comes to reusing and recycling of materials, there lacks a smart approach to do so. By smart it means cost effective approach. Currently, it is cheaper to dump the materials in the graveyard than to reuse the materials which might hinder the circular transition. • Every tender you can see a new record in terms of cost and especially in the Netherlands you see subsidy free schemes, and everything needs to be cheaper.
Over exploitation of commons	*Easy Access to Resources* • Another major reason to avoid reusing the materials or use the recycled material is due to easy access to material resources. Steel is always easily available, and concrete is also easily available for the foundation and it does not encourage the developers to use reused materials.
Infrastructural Failure	*Lack of Technology* • When it comes to the use of secondary materials and use of certain type of material and for circular design solutions, the respondent deems that they are not completely aware of the available technologies. Particularly in terms of blade waste, there is no available technology at the moment to reuse the blades. *Blade waste and Composites* • The respondent deems that recycling technologies for these fiber glass composites are not yet available. This is something they are working with within the company and also with a lot of other actors in the wind industry. *Lack of Quality* • One of the major reasons for not using the reused material is due to uncertainty in quality and strength of the reused material.
Institutional Failure	*Innovations not directed towards circularity* • Most of the aspects like minimizing waste generation and minimal maintenance, the company has policies and programs to adopt such aspects. However, the respondent believes that these aspects are strictly considered for economic reasons and has nothing to do with becoming circular. • The respondent also deems that almost all the companies have their own policies and ambitions but is not aware of an existing central vision for circularity. • The evolution of the majority of the sector from the beginning was always focused on optimizing wind energy and cost effectiveness. *Lack of Regulations & Appropriate Policies* • It is interesting to point towards regulations on blade waste in particular. Because in some European countries, landfilling of blade waste is illegal by national law, which means that the business case for decommissioning and recycling is different than in countries where you can landfill blades at a lower cost. • Also,it is interesting to note that when it comes to circular economy aspects the wind industry is not as regulated when compared to other sectors.

Capabilities Failure	*Lack of Resources and Expertise* • In general, for the wind energy sector there is still room for improvement in the understanding of the circular economy aspects. There needs to be a good professional understanding of the issues in order to provide solutions for the issues. However currently, there is lack of resources and expertise within the project who can guide and work on the circular aspects.
Directionality Failure	*Lack of Need or Incentive* • The respondent reckons that often a lot of decisions taken during the design and development phase in terms of circular economy if any, is for the benefit of other stakeholders or for other departments or for a later point of time. It is not necessarily to the benefit of the decision maker in the design phase. For instance looking at glass fiber composites used for wind turbine blades currently, it is a very effective and cheap material to use and even though it cannot be effectively recycled at the end of life it is still used abundantly and that is because there are no proper incentives to ensure that this should not be happening. There aren't many economic incentives to recycle materials. • The respondent also advised the Borssele for some environmental and technical aspects in relation to the tender of Borssele, but they did not advise them regarding circularity. This is mainly because the tender was only about the lowest price for wind energy so there wasn't any incentive for the client to look broader. • The respondent also states that currently, he is not aware of any such policies that focus on attaining or incorporating circular aspects and the main reason being lack of need or incentive. *Lack of Shared Vision* • The respondent believes that there does not exist a shared vision within the company or within the wind industry in general. Almost all the companies have their own policies and ambitions and none of them have an existing central vision for circularity. *Need for Research* • The challenge like lack of knowledge and lack of information can be addressed if there is enough research and development activities. A lot could be achieved in terms of circularity by incentivizing research and development activities and recycling technologies. • Currently, there isn't a lot of research and development activities focused on the circular aspects for the wind energy sector particularly for the recycling of fiber glass composites and also research for alternate use of wind turbine blades.
Demand Articulation Failure	*Involvement of Suppliers* • The respondent believes that they have a strong tradition within the wind energy sector for cross collaboration across the value chain. But isn't very sure about how well the customers and designers collaborate on circular economy aspects. Because some of the decisions regarding circular economy are made during product development phase at the suppliers where the customers are involved. • Most of the important decisions are made in the design phase by the customers where the actors throughout rest of the value chain are not involved

2. Construction Phase

Circular Aspects

The respondent states that the company he is working with particularly focuses on its fuel consumption and the exhaust of CO_2 and other gases. They try to optimize fuel consumption by using the most optimal vessels to do that job and whenever possible they use the latest vessels with low emissions of CO2 and other gasses. Besides the fuel consumption, they also focus on design and development of specific equipment not only for one project but for multiple projects and for long term. For example, the instillation vessels or the lifting tools, they always try to design them or procure them for longer term and for multiple projects instead of only designing and procuring them for just one project and scrapping them at the end of the project. These aspects were also taken into consideration for the Borssele case. The respondent was also asked if various aspects from Table 1 were taken into consideration during the construction of Borssele 1 & 2. *Reducing waste* is something they always take into consideration. *Using recycled materials*, that is not very easy. Because currently talking about steel structures and other specific materials, the aim is for durable use of materials so that the materials don't have to be scraped after one project but rather design them for longer term. But *use of recycled materials* is not being considered at the moment. *Offsite construction* is considered partially because some of the parts are constructed off site but majorly everything is done onsite.

Challenges and Obstacles Identified

Cost Incentive

More often than not, it is difficult to make drastic changes in an established supply chain like the wind sector, and although you might have very good ideas for circular economy, you also have to be realistic and understand that that the offshore wind industry is on a very high pressure for cost reductions. Bottom line, if there are no cost reductions it will be very difficult to incorporate circular aspects. Currently, circular economy is not a part of the evaluation criteria, the major focus is on the cost reduction. Even today, majority of the clients are driven by cost reductions and this often is an hindrence to innovative ideas and serves as an obstacle for making the entire supply chain more carbon neutral and circular.

The respondent believes that all the designers and the manufacturers have the required information about circular economy and how to incorporate circularity. But the main driver is still cost reductions and until that is addressed, it is difficult to consider circular aspects. The respondent also states that cost and finacial incentives are the major barrier for circular economy and below is an excerpt from one of the interviews which implies that.

> *Costs and finance play a major role. As long as offshore wind energy supply chain is cost driven as it is today, circular transition is not possible. Circular aspects will be considered only if it comes at a same or a lower cost - Project Manager.*

Involvement of suppliers

One of the major obstacles is that the contractors are not in direct control of reusing the materials. Particularly the mission equipment that are used in offshore construction, the contractors are just responsible for the equipment design and the design is handed in to specific manufacturers and suppliers that manufacture or fabricate the design with the most suitable material and the contractors are not involved in this process.

Also, sometimes you can notice a strong connection between manufacturers and steel suppliers and those steel suppliers are not extremely interested in certain aspects of circular economy and therefore it might hinder circular transition.

The respondent also states that most of the crucial decisions are made by the governmental bodies and the wind farm developers. If the suppliers would get more involved in this process, then the aspect of circularity would definitely gain more attention.

Lack of Need or Incentive

The respondent believes that the main barrier to move towards circular economy is not related to lack of information rather it is willingness of people and lack of 'need' to do so. Even when it comes to subcontracting the equipment's for the project, the contractors did not have a specific demand for the use of reused or recycled material because there were no incentives to do so.

Easy access to Resources & Lack of Green Material

Another major challenge hindering circular transition is easy access to resources and lack of green material. If you look at European steel market, there is lack of green steel available. It is also often difficult to source the steel blades and other steel components required for constructing wind farm components. And if you limit yourself to the available green steel, which is limited in market at the moment, then it is not possible to meet the demand and timeline required for an offshore windfarm.

Lack of Regulations & Appropriate Policies

Currently, there exist no appropriate regulations and policies particularly concerning circular transition. The respondent believes that apart from zero subsidy regimes, other elements like circular economy, carbon footprint and innovation should also be a part of the evaluation criteria of developer bids. The respondent also deems that there are no existing policies to reuse and recycle the materials.

Competition

The aspect of circularity also majorly depends on the tender and tender criteria. If the circular economy is one of the evaluation criteria on the tender, then the aspect will get more focus. But if it's not a part of evaluation criteria, then the major focus is on cost reduction. For Borssele case it is heavily cost driven in combination with very reliable and robust execution plan. Also, if the circular economy aspects go hand in hand with cost reductions, they will be considered. If they are more expensive then it will be hard to consider, because chances of winning the tender is quite hard due to fierce competition.

Proud & Content

The respondent states that 95% of the people who work in the offshore wind business are old people or rather people who are proud about their job or proud about the business they work in. Meaning generating green energy and being a part of transition from non-renewable energy to renewable energy and this might be one of the reasons why circular transition is being overshadowed by the energy transition.

Lack of Interaction

Sometimes you also notice lack of interaction due to closely tied networks. There might be a strong connection between some manufacturers and some suppliers. And those suppliers are not extremely interested in certain aspects of circular economy and therefore it might hinder circular transition.

Lack of Resources & Expertise

The respondent also believes that there is lack of resources and expertise to incorporate circular aspects. The excerpt stated below verifies this statement.

If the manufacturers have never considered it or never built up expertise, of course the expertise and experts and the resource are lacking. It may be possible to get those resources and expertise from another business, but currently, those resources are scarce - Project manager

Types of Failures

All the challenges and obstacles identified in the construction phase are categorized based on Webber and Rohracher 'failures' framework.

Table 18: Types of Failures For the Construction Phase (Borssele 1 & 2)

Type of Failure	Failures Identified for the Construction Phase
Externalization of Costs	*Cost Incentive* • The offshore wind industry is on a very high pressure for cost reductions. Bottom line, if there are no cost reductions it will be very difficult to incorporate circular aspects. Currently, circular economy is not a part of the evaluation criteria, the major focus is on the cost reduction. • Even today, majority of the clients are driven by cost reductions and this often is an hindrence to innovative ideas and serves as an obstacle for making the entire supply chain more carbon neutral and circular. • The respondent believes that all the designers and the manufacturers have the required information about circular economy and how to incorporate circularity. But the main driver is still cost reductions and until that is addressed, it is difficult to consider circular aspects
Infrastructural Failure	*Lack of Green Material* • If you look at European steel market, there is lack of available green steel. It is also often difficult to source the steel blades and other steel components required for constructing wind farm components. And if you limit yourself to the available green steel, which is limited in market at the moment, then it is not possible to meet the demand and timeline required for an offshore windfarm.
Institutional Failure	*Proud & Content* • The respondent states that 95% of the people who work in the offshore wind business are old people or rather people who are proud about their job or proud about the business they work in. Meaning generating green energy and being a part of transition from non-renewable energy to renewable energy and this might be one of the reasons why circular transition is being overshadowed by the energy transition.
Interaction or Network Failure	*Lack of Interaction* • Sometimes you also notice lack of interaction due to closely tied networks. There might be a strong connection between some manufacturers and some steel suppliers. And those steel suppliers are not extremely interested in certain aspects of circular economy and therefore it might hinder the circular transition.
Capabilities Failure	*Lack of Resources and Expertise* • The respondent also believes that there is lack of resources and expertise to incorporate circular aspects.
	Lack of Need or Incentive • The respondent believes that the main barrier to move towards circular economy is not related to lack of information rather it is

Directionality Failure	willingness of people and lack of 'need' to do so. Even when it comes to subcontracting the equipment's for the project the contractors did not have a specific demand for the use of reused or recycled material because there was no incentive to do so. *<u>Competition</u>* • The aspect of circularity also majorly depends on the tender and tender criteria. If the circular economy is one of the evaluation criteria on the tender, then the aspect will get more focus. But if it's not a part of evaluation criteria, then the major focus is on the cost reduction. • For Borssele case it is heavily cost driven in combination with very reliable and robust execution plan. Also, if the circular economy aspects go hand in hand with cost reductions, they will be considered. If they are more expensive then it will be hard to consider, because chances of winning the tender is quite hard due to fierce competition.
Policy Coordination Failure	*<u>Lack of Regulations & Appropriate Policies</u>* • Currently, there exist no appropriate regulations and policies particularly concerning circular transition. The respondent believes that apart from zero subsidy regimes, other elements like circular economy, carbon footprint and innovation should be part of the evaluation criteria of developer bids. The respondent also deems that there are no existing policies to reuse and recycle the materials.
Demand Articulation Failure	*<u>Involvement of suppliers</u>* • One of the major obstacles is that the contractors are not in direct control of reusing the materials. Particularly the mission equipment that are used in offshore construction, the contractors are just responsible for the equipment design and the design is handed in to specific manufacturers that manufacture or fabricate the design with the most suitable material and the contractors are not involved in this process. • Also, sometimes you can notice a strong connection between manufacturers and steel suppliers and those steel suppliers are not extremely interested in certain aspects of circular economy and therefore it might hinder the circular transition. • The respondent also states that most of the crucial decisions are made by the governmental bodies and the developers. If the suppliers would get more involved in this process, then the aspect of circularity would definitely gain more attention.

3. Operation & Maintenance Phase

Circular Aspects

The developers are also responsible for the operation phase of the wind farm. Within the operational phase for the windfarm, considering the aspects from Table 1 there are company policies and programs to *minimize waste generation* and they also consider *minimal maintenance* but it also for strictly economic reasons. It is a similar case for *easy repair and operate as well*. More often than not, a lot of decisions made during the operation phase is the result of the decisions made during the design and construction phase and lot of these decisions, even though they tend to minimize waste generation and make maintenance and repair as easy as possible are probably not something that are achieved because circular economy was an incentive when those decisions were made. Circular economy incentives are overlapping with the economic and cost incentives.

Challenges and Obstacles Identified

Cost Incentive

Costs are one of the major aspects that were taken into consideration for this case. At the end of the day, all the decisions that were made have a cost incentive. For the operation phase in particular, all the aspects that are or will be taken into consideration have economic incentives. Like mentioned before, all the circular aspects like *minimize waste generation, minimal maintenance and easy repair and operate* are taken into consideration due to economic and financial reasons and circular economy incentives are overlapping with the economic and cost incentives.

Lack of Awareness

Firstly, only by the end of 2020 the project Borssele 1 & 2 will be fully commissioned, and only then the wind farm will be in operation phase. The respondent seemed unsure about the aspects of circularity being incorporated during the operation phase and almost all of his/her answers were particularly specified for the design and development phase as the respondent deems design and development phase is where the aspects of circularity can make a difference

Types of Failures

All the challenges and obstacles identified in the Operations & Maintenance phase are categorized based on Webber and Rohracher 'failures' framework.

Table 19: Types of Failures For the Operations & Maintenance Phase (Borssele 1 & 2)

Type of Failure	Failures Identified for the Operations & Maintenance Phase
Information Asymmetries	*Lack of Awareness* ➢ Firstly, only by the end of 2020 the project Borssele 1 & 2 will be fully commissioned, and only then the wind farm will be in operation phase. The respondent seemed unsure about the aspect of circularity being incorporated during the operation phase and almost all of his/her answers were particularly specified for the design and development phase as the respondent deems design and development phase is where the aspects of circularity can make a difference.
Externalization of Costs	*Cost Incentive* ➢ At the end of the day, all the decisions that were made have a cost incentive. For the operation phase in particular, all the aspects that are or will be taken into consideration have economic incentives. Like mentioned before, all the circular aspects like *minimize waste generation, minimal maintenance and easy repair and operate* are taken into consideration due to economic and financial reasons.

4. Decommissioning Phase

Circular Aspects & Challenges and Obstacles Identified

Wind farm Borssele 1 & 2 is set to be commissioned completely by the end of 2020 and the wind farm will only reach the end of life approximately 20-25 years after being commissioned. Thus, the respondent has no particular information when it comes to the decommissioning phase of wind farm. However, the respondent anticipated few of the circular aspects from Table 1 that may be taken into consideration during the decommissioning phase of wind farm. The respondent believes that *deconstruction and selective demolition* is something that will be definitely taken into consideration. The wind farms can be decommissioned the same wat they have been installed. However, the respondent wasn't sure if the cables will be left within the shore or taken out during decommissioning. Even though the aspects reuse of components/products, closed loop recycling, and open loop recycling are currently not being considered, the respondent believes that 20-25 years down the line all these aspects maybe taken into consideration. When asked about the challenges, the responded stated that particularly the waste management companies need to know when the wind farms are going to be decommissioned and they also need to know what materials are present within the different parts of the wind turbines for them to recycle and reuse the products. This information is something that is not always available for all the windfarms.

Types of Failures

All the challenges and obstacles identified in the Decommissioning phase are categorized based on Webber and Rohracher 'failures' framework.

Table 20:Types of Failures For the Deconstruction Phase (Borssele 1 & 2)

Type of Failure	Failures Identified for the Decommissioning Phase
Information Asymmetries	*Lack of Information* The responded sated that particularly the waste management companies need to know when the wind farms are going to be decommissioned and they also need to know what materials are present within the different parts of the wind turbines for them to recycle and reuse the products. This information is something that is not always available for all the windfarms.

4.2.3 Case Summary

The circular aspects and the challenges identified for the offshore case Borssele 1 & 2 are summarized in tables below.

Circular Aspects

In order to summarize all the circular aspects that were incorporated/not incorporated for the case Borssele 1 & 2, the circular aspects were scored using five-point scales ranging from **- -** for not being taken into consideration at all and **+ +** for completely being incorporated within the project. For all the five values (+ +, +, + / -, -, - -) qualitative description is given in Table 12 and Table 21 summarizes all the circular aspects for the case Borssele 1 & 2 by assigning the five point scale.

Table 21: Circular aspects being considered/not considered for Borssele 1 & 2

Phase of wind farm construction	Life-cycle stage	Circular Economy Aspect	Five Point Score
1. Design & Development Phase	Design	Design for deconstruction	**+**
		Design for adaptability and flexibility	**+**
		Design for standardization	**+**
		Design out waste	**-**
		Design in modularity	**+**
		Specify reclaimed materials	**- -**
		Specify recycled materials	**- -**
	Manufacture and Supply	Eco design principles	**+**
		Use less materials/optimize material use	**+**
		Use less hazardous material	**+ +**
		Increase the life span	**+ / -**

		Design for product disassembly	+
		Design for product standardization	+ +
		Use secondary materials	- -
		Take back schemes	-
		Reverse Logistics	-
2. Construction Phase	Construction	Minimize Waste	+
		Procure reused materials	-
		Procure recycled materials	-
		Off-site construction	+
3. Operation Phase	In use and Refurbishment	Minimize waste	+
		Minimal Maintenance	+
		Easy Repair and upgrade	+
		Adaptability & Flexibility	+
4. Decommissioning Phase	End of life	Deconstruction	+ +
		Selective Demolition	+
		Reuse of components/products	**NA**
		Closed loop recycling	**NA**
		Open loop recycling	**NA**

Types of Failures Identified For Each Phase of Wind Farm development.

All the types of challenges and obstacles identified in each phase of wind farm development for the case Borssele 1 & 2 based on the 'failures' framework is summarized in Table 22.

Table 22: Failures Identified For Each Phase of Wind Farm development (Borssele 1 & 2)

	Market Failures	Structural System Failures	Transitional System Failures
Design & Development Phase	➢ Information Asymmetries ➢ Knowledge Spill over ➢ Externalization of costs ➢ Over exploitation of commons	➢ Infrastructural Failure ➢ Institutional Failure ➢ Capabilities Failure	➢ Directionality Failure ➢ Demand Articulation Failure
Construction Phase	➢ Externalization of costs	➢ Infrastructural Failure ➢ Institutional Failure ➢ Interaction or Network Failure ➢ Capabilities Failure	➢ Directionality Failure ➢ Demand Articulation Failure ➢ Policy coordination failure
Operations & Maintenance Phase	➢ Information Asymmetries ➢ Externalization of costs		
Decommissioning Phase	➢ Information Asymmetries		

4.3 Case: Wind Park Wieringermeer

4.3.1 Introduction

The wind park Wieringermeer has 99 wind turbines making it the largest onshore wind farm in the Netherlands with a capacity of around 300MW. The construction of the wind park Wieringermeer is currently in Phase 3, this means that the construction and installation of the wind turbines are nearing the end and are expected to be in place by the end of 2020. The current progress can be seen in Figure 10. The project facts and figures are listed in Table 23.

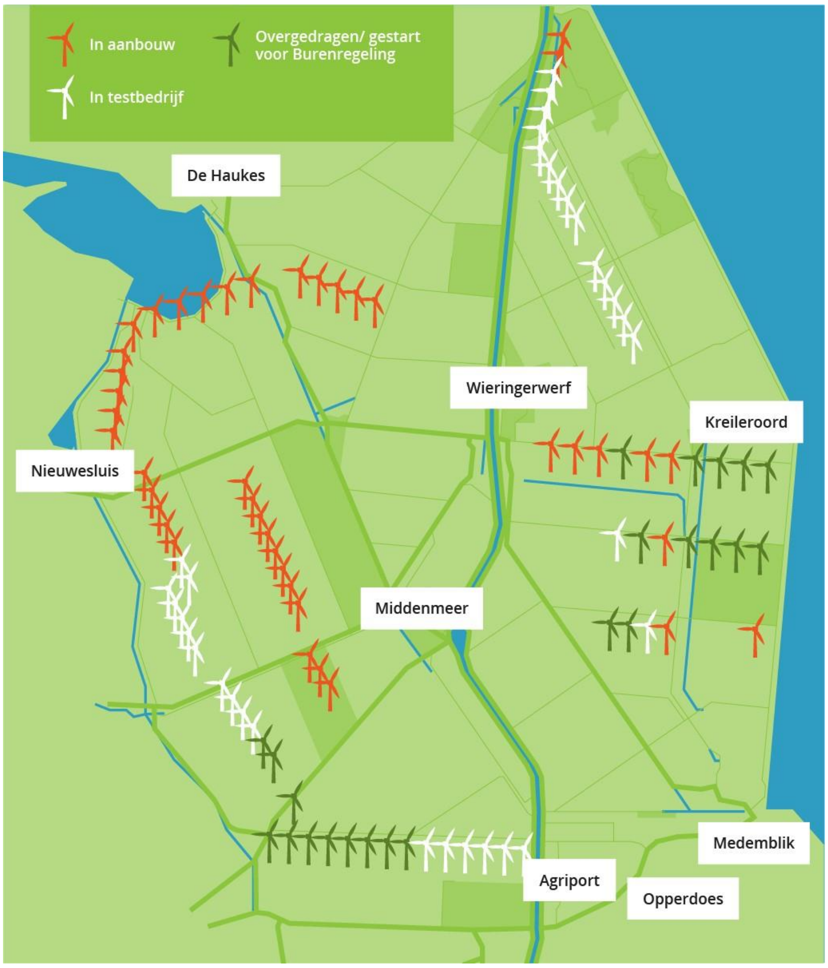

Figure 10: Wind Park Wieringermeer: Current Progress (Wind Park Wieringermeer, 2020)

Table 23: Facts and Numbers (Wind Park Wieringermeer, 2020)

SL NO:	Description	Facts and Numbers
1	Project Type	Onshore wind farm
2	Owner & Developer	Initiative of ECN Wind Energy Facilities BV and Vattenfall.
3	Location	Wieringermeer polder
4	Timeline	The park will be fully realized at the end of 2020
5	Number of Wind Turbines to be built	99
6	Total MW	300
7	Foundation	435 m_3 of concrete and 45 tons of steel

Location

Wind park Wieringermeer is being built in the Wieringermeer polder, at the head of North Holland. Figure 11 shows the location of Wind Pak Wieringermeer.

Figure 11: Wind Pak Wieringermeer, wind farm location (Wind park Wieringermeer, 2020)

Actors/Stakeholders Involved

The development of Wieringermeer wind farm started ten years ago through a collaboration between ECN, Vattenfall and partners, and Windcollectief Wieringermeer who work closely with the municipality of Hollands Kroon, the province of Noord-Holland and the State under the name Windkracht Wieringermeer (Wind park Wieringermeer, 2020). Vattenfall has signed contracts with three companies for the supply and construction of wind turbines, the construction of the infrastructure and the foundations of the wind farm. The Nordex group is responsible for the supply and installation of wind turbines. BAM Infra is responsible for the foundations of the wind farm. Van Gelder Group is responsible for the realization of the park roads, crane hardstands and for the supply and installation of the park cabling, including switching stations (*BAM Infra Nederland bouwt fundaties voor windpark Wieringermeer,* 2020).

Actors Interviewed For This case

A total of four actors were interviewed for this case. Each actor was involved with different phases of the wind farm development.

Table 24: Actors Interviewed for the case Wieringermeer

Interview Number	Roles	Organization
1	Environment & Sustainability Specialist	Owners/Developers
2	Senior Consultant	Engineering & Consultancy Company
3	Project Manager	Contractor
4	HSE Manager	Supplier & Manufacturer

Project Procedure
The council of states declared all the objections to the government integration plan 'Wind park Wieringermeer' in May 2016, and construction could start. Construction is now in full swing and delivery is scheduled by the end of 2020. Figure 14 in APPENDIX C shows the overview of legal procedures taken.

Project Goals
The project Wieringermeer pursues the following goals.

I. Contribute to the national target for realization of 6000MW on land by 2020 and provincial target of 685.5MW for North Holland; where electricity yield, economic feasibility and effects on the environment are in balance.
II. Implement the tasks of the Wind Plan Wieringermeer by restructuring of the existing stand-alone wind turbines, responsibly upscaling the existing wind turbine line arrangements and expansion of ECN's wind turbine test park.

The initiative is thus in line with the goals of the national and international environmental and energy policy aimed at the application of sustainable energy (a contribution of 14% in 2020, EU target for the Netherlands to 16% of the annual energy consumption in the Netherlands in 2023) and limiting the emission of greenhouse gases such as carbon dioxide (Wind Park Wieringermeer, 2020).

4.3.2 Case Study Results
Similar to the first two cases, for this case (Wind Park Wieringermeer) as well the data was collected via interviews for various challenges and obstacles experienced by the practitioners for the circular transition and also different circular aspects being/not being incorporated for the case. The challenges identified during the interview were given codes after transcribing and verifying the interview data. The codes given were based on terms and phrases used by the respondents. APPENDIX D consists of the excerpts from the transcribed interview with allotted codes. Similarly, the data was categorized based on different phases of wind farm development where the perspective of the owners/developers, consultants, suppliers/manufacturers and the contractors were taken into consideration, listed and then categorized based on the types of failures from the 'failures' framework.

1. Design & Development Phase

Design

Circular Aspects
The respondent emphasizes that design and development phase is the key to implement circularity and circular aspects. Similar to the previous cases, Circular economy is one of the aspects that was taken into consideration for the Wieringermeer case during the design and development phase. However, the aspects considered were not particularly labeled or categorized as circular aspects majorly because the term 'sustainability' is often used interchangeably with Circular Economy. Thus, in order to get a clear understanding of which activities incorporated were considered circular, the respondents were briefed about the concept of circular economy and circular construction and were later asked questions based on the phase of development they were involved with and which particular circular aspects from Table 1 were considered during the development of a wind farm.

Considering the aspects form Table 1 *Design for deconstruction* and *Design for adaptability and flexibility* are definitely taken onto consideration. All the wind turbines are designed to uninstall after their end of life. The respondent deems that *Design for standardization* is a bigger and more strategic task that needs to be worked on. With continuous change in technology, standardization needs to shift as well. But it is definitely something that is being taken into consideration. *Design for modularity* is a big one. Turbines by nature are quite modular. But looking at turbine blades for example they are made of lot of different materials and are not really modular where you can pull them apart and sell them. You have to mechanically grind them or use pyrolysis or other techniques to break them down. The respondent believes that *design out waste* is also something that is possible. A big example is using direct drive wind turbines instead of turbines with gearboxes. There's a lot less waste there, so you can *design out waste* by making choices that are currently in the market. *Specify reclaimed materials* and *Specify recycled materials* are something they are still working on.

Challenges and Obstacles Identified

Several challenges and failures for circular transition for the project Wieringermeer were experienced and anticipated by the respondent during the design phase which are explained in detail below.

Accountability

According to the respondent, the biggest challenge is ownership and accountability in the life cycle and project staging and the whole process in general. There needs to be corporation between the supplier and the developer, and the developer needs to be accountable for recycling of turbines. The respondent also believes that there needs to be a chain of custody and a centralized database that tracks the ownership of turbines and where they go next. Below is an excerpt from the interview that states the respondent's opinion about accountability.

> *''It is about taking the ownership. If you ask for a wind farm, you own the impacts for production. Therefore, you need to know what is happening in the entire supply chain and what is happening at end of life. But currently, that is not happening''.* - Environment & Sustainability specialist.

Image Perception

The respondent believes that circular transition is very important particularly for the wind energy sector because of image perception. For example, wind energy is quite green and clean organization that focuses on energy transition thus there is not much focus on making it circular. However, even with such a green image and green structure the wind industry still produces an ample amount of waste and has lot of inefficiencies.

Lack of Knowledge & Information

In the development phase, when the clients request a product from the manufacturer, they don't specifically ask what is in the turbines or what the blades are made of. They don't know the full composition. They just request for example a 1.5MW tower and nothing more in specific. They do not specify where it should come from, what sort of polymers should it have or what sort of fiber and glass composites are required in the turbine or where the steel has to come from. The developers do not have any of this information. The respondent acknowledges lack of information when it comes to the supply chain for materials. The respondent also believes that the word circularity and sustainability is on everyone's lips but not a lot of organizations know how to do it and lack knowledge.

Lack of Control

Vattenfall hired Nordex for this case, as the laying contractor, and Nordex has a number of subcontractors they hire for various elements like insulation, maintenance or for construction. Vattenfall has less control over those subcontractors. They may get through all of Nordex's supply chain but aren't involved or have control over the supply chain of the sub-contractors and you can see a lack of control further down the chain which might be an obstacle for circular transition. The developers also have less or no control over the turbines once they reach the end of life and are given away for reusing or for recycling companies since it is no longer their product.

Cost Incentive

The respondent deems that more often than not, costs are given number one priority. The focus is majorly on money and costs and quite often circularity falls of the priority list. For example, you can design out waste by making choices that are currently in the market. However, if it comes to costs or circularity and if there's a big discrepancy between the two, costs often win out.

The developers also have a contract that requires contractors to report every year what the hazardous and non-hazardous waste is through construction, operation and maintenance. That needs to be justified and reduced. But there is no contractual metric to make sure that it is reduced. But the waste needs to go to a licensed facility and that facility charges a lot of money to dispose that waste. So, by virtue of cost implications all the aspects that cost money end up being reduced and that leads to a sustainable outcome. It is not done because it is sustainable, it is done because it is cheaper.

Limited Turbine Suppliers

When you put out a tender for turbine suppliers and insulation, you usually receive two or at most three tenders coming back. So straight away you see a limitation. But for the civil works you can expect more tenders and you can be more stringent and have certain negotiations for the requirements. But in case of turbine suppliers, you cannot push too far. If you do, they walk away, and you cannot get the work done. So, conditions to get circularity into the contract is quite difficult, says the respondent.

Lack of Research & Development and Technology

SF6 gas is used in the switch gear all the time and it's a highly potent greenhouse gas. Although it is used in very small quantities and is always safely contained, it is still harmful to the environment and is continuously used. Currently, it is very hard to find an alternative and the technology doesn't exist and without sufficient investigation or research and development, it is not possible to find an alternative.

Lack of Attention

The respondent believes that circular aspects usually get little or no attention. In an organization there are a lot of people who have been around for a long time and some of them are less open to new ideas which often is the case with circular transition.

Lack of Regulations

Currently, a lot of initiates taken up regarding circularity, like the MKI approach for the project are internal approaches and not legislative. According to the respondent, a lot of legislation in the Netherlands is mostly based on reducing the environmental risk and direct impact on the environment. But in terms of secondary impacts, carbon footprints, showing full ownership of the supply chain and of life cycle analysis, it is not mandated in most of the cases. Thus, the respondent believes that the legislation is not as developed as it should be, and it is not pushing the wind industry to become more circular.

Social Norms & Culture

Countries like Norway and Sweden have really high levels of renewable energy use and also have very good conditions for things like hydroelectricity, wind etc. and they have taken a good advantage of it and the repondent speculates that soicial norms do play a role here. The respondent also believes that the Netherlands is quite progressive as well but it is quite surprising that it has such low proportion of renewable energy even though the people are quite open to sustainable ways of doing things. The respondent belives that there lacks a link between energy transition and circular transition and in some cases it requires investment to actually make this happen but it is also the mindset of getting away from linear thinking, producing and consuming.

Lack of Innovation

Within the wind industry there is a pattern of dealing with a lot of same players and same contractors or suppliers and they know how the developers work, their requirements and they already have a lot of materials needed by the developers. But due to this you do loose that innovation and question if you are doing it the right way, says the respondent.

Lack of Interaction

The respondent also stresse on the fact that the project teams don't talk to each other that often. Which is the case in all the organizations. What one team is doing from a circularity point of view might not be happening in another project. This majorly depends on various levels of networking and how much you cllaborate with the other organizations.

Lack of Requirement

The respondent believes that we do have a well-established system, but it is established in a fundamental stage and it still needs establishment in the areas of circularity. A lot of projects do have quite circular approaches, but they are not yet in the standard management system or contract set up. The reason the respondent felt a need to highlight this topic is because the people in the organization aren't aware or aren't motivated to bring circularity. However, if the system and the contract require them to do so, they are obliged to do it.

Lack of Shared Vision

The respondent also believes that not everyone has a shared vision when it comes to the aspect of circularity. For example, someone from the procurement team may not necessarily share the vision of circularity as the project manager. They might understand the need to reduce the environmental risk but for them it may be something on a smaller scale and circularity is not a priority. Every project has an environmental representative who has that sort of mindset or vision about circularity, but it is definitely not a shared vision amongst all the actors in the project.

Supplier Involvement

The respondent emphasizes that the suppliers play a major role in the supply chain to incorporate circular aspects. However, when it comes to the discussions and decisions made in terms of circularity, the supplier's involvement is fairly limited at the moment.

Manufacture & Supply

Circular Aspects

The respondent was mostly involved with the design and development phase particularly with manufacture and supply and also involved with the construction phase which involves installation of wind turbines. Thus, the respondent was asked which of the circular aspects from Table 1 were taken into consideration during the manufacture and supply and the construction phase. Below is an explanation of circular aspects being considered particularly for the manufacture and supply phase.

When it comes to the circular aspects particularly focused on manufacture and supply, the respondent is unsure about the aspect *Eco design principles* and deems it may or may not be taken into consideration. The aspects *Use less materials/optimize material use, Use less hazardous materials and Increase in life span* are something the respondent identifies as being considered for the project. Unlike the previous projects, new turbine design was adopted for the wind park Wieringermeer which are much easier to disassemble than the old ones, thus *Design for disassembly* is also taken into consideration. *Design for product standardization* is also something that is taken into consideration. The respondent deems that for every project there exists a third-party statutory inspector who check and recheck the products and stamp it before use. However, *Use of secondary materials* is something the respondent cannot identify or associate with the project. For example, one of their main activity is lifting and it is very dangerous to use or reuse the shackles or slings that lift the tower parts. It is life threatening and the product will be destroyed. Thus, they are obligated to use new lifting materials, and this is just one example. *Take back schemes* is something they do take into consideration. They have containers consisting of all kinds of materials that are being used. They try to reuse everything until it reaches end of its life cycle. Also, in compliance with the rules and regulations of holland, they take back everything possible, clean them, put them back into the containers and send it to Germany (headquarters). When there is another project, that container comes back to the new project and the materials and equipment's are certified and reused. The aspect of *reverse logistics* is also something the respondent speculates as being considered.

Challenges and Obstacles Identified

Competition

The respondent deems that one of the major obstacles hindering circular transition for the wind energy sector is competition between the companies. All the companies are trying to give a perfect product and are competing with each other. The companies do not prefer recycled materials as they consider recycled materials to be of inferior quality and expensive.

The respondent also believes that you can attain circular transition with the current infrastructure, however, the major obstacle is still high competition amongst the companies. Wind industry is booming and growing very fast and everyone is trying to get into this market which is increasing the competition within the market.

Cost Incentive

Along with competition within the market, the respondent also considers costs and finances as major obstacle hindering the circular transition for the wind energy sector. The respondent believes that the recycled material and circular aspects are more expensive comparatively.

Lack of Information

One of the major reasons why there is a lack in progress towards circularity within the wind energy sector is due to lack of efficient information within the project teams and the market as a whole, says the respondent.

Easy access to Resources

Easy access to resources is also one of the reasons hindering the circular transition for the wind energy sector. The respondent deems that there are a lot of different companies supplying lot of different materials and equipment making it easier to obtain all the required elements. This prevents the management from looking at different alternatives. They stick to one party instead.

Lack of Awareness & Social norms and Culture

The respondent also speculates shortcomings or hinderances in adopting circular aspects or carrying out circular innovations due to certain social norms and culture. The respondent believes that the Nordic countries are more advanced when it comes to renewable energy and recycling activities. And within the Netherlands, there might be lack of recycling culture and lack of awareness comparatively. They are doing their best to reuse and recycle, and they do have certain knowledge regarding the same, but they do not want to know more; says the respondent.

Lack of Expertise

The respondent believes that currently, there is lack of expertise in terms of circularity. Wind industry is still young and people working in this industry are coming from different industries like oil and gas for example, and the respondent suggest that they need more training, more knowledge and enlightenment bout this aspect. However, there is insufficient time due to restricted schedules.

Lack of Shared Vision

Even though a lot of them like the aspect of circularity you cannot see anything in action. The respondent believes that there is no shared vision when it comes the aspect of circularity and this might be due to careless attitude and also, the wind industry is booming very fast and they do not have enough man power to run all these projects and take circular aspectts into consideration.

Lack of Appropriate Policies & Regulations

The respondent also shares concerns regarding the lack of appropriate policies and regulations particularly for the aspects of circularity. They are always open to new ideas and implementing new ideas but rely on support from policies and regulations which are currently lacking. For example, the materials being used can be reused and recertified as most of the materials are still in good condition but more often than not are discarded due to lack of strict policies and regulations.

Lack of Need/Incentive

When asked about the biggest challenge you will have to overcome to adopt circularity, the respondent points at lack of incentive or the need to adopt circularity. The respondent believes that if the clients are willing to adopt circularity it becomes easier for circular transition and If they do not accept and keep insisting on certain products it will definitely be a challenge to adopt circularity.

Types of Failures

Similar to the first and the second case, all the challenges and obstacles identified in the design and development phase were analyzed based on open codes done by qualitative interpretation of texts using the qualitative data analysis software ATLAS.ti. These codes are now clustered into categories using axial codes based on occurrence of particular 'failures' according to Webber and Rohracher classification (theoretical framework adopted for this research).

Table 25: Types of Failure For the Design & Development Phase (Wind Park Wieringermeer)

Type of Failure	Failures Identified for the Design & Development Phase
Information Asymmetries	*Lack of Information* • In the development phase, when the developer's request a product from the manufacturer, they don't specifically ask what is in the turbines or what the blades are made of. They don't know the full composition. They just request for example a 1.5MW tower and nothing more in specific. They do not specify where it should come from, what sort of polymers should it have or what sort of fiber and glass composites are required in the turbine or where the steel has to come from. The developers do not have any of this information.
Knowledge Spill over	*Lack of Knowledge* • The respondent also believes that the word circularity and sustainability is on everyone's lips but not a lot of organizations know how to do it and lack knowledge.
	Cost Incentive • The focus is majorly on money and costs and quite often circularity falls of the list first. For example, you can design out waste by

Externalization of costs	making choices that are currently in the market. However, if it comes to costs or circularity and if there's a big discrepancy between the two, costs often win out. • By virtue of cost implications all of the aspects that cost money like disposal of hazardous waste end up being reduced and that leads to a sustainable outcome. It is not done because it is sustainable, it is done because it is cheaper. • The respondent also believes that the recycled material and circular aspects are more expensive comparatively.
Over exploitation of commons	*Easy Access to Resources* • The respondent deems that there are a lot of different companies supplying lot of different materials and equipment making it easier to obtain all the required elements. This prevents the management from looking at different alternatives. They stick to one party instead.
Infrastructural Failure	*Lack of R&D and Technology* • SF6 gas is used in the switch gear all the time and it's a highly potent greenhouse gas. Although it is used in very small quantities and is always safely contained it is still harmful to the environment and is continuously used. Currently, it is very hard to find an alternative and the technology doesn't exist and without sufficient investigation or research and development, it is not possible to find an alternative. *Limited Turbine Suppliers* • When you put out a tender for turbine suppliers and insulation, you usually receive two or at most three tenders coming back. So straight away you see a limitation and you cannot push too far. If you do, they walk away, and you cannot get the work done. So, conditions to get circularity into the contract is quite difficult, says the respondent.
Institutional Failure	Lack of Regulations • Currently, a lot of initiates take up regarding circularity, like the MKI approach for the project are internal approaches and not legislative. According to the respondent, a lot of legislation in the Netherlands is mostly based on reducing the environmental risk and direct impact on the environment. But in terms of secondary impacts, carbon footprints, showing full ownership of the supply chain and of life cycle analysis, it is not mandated in most of the cases. • The respondent says that they are always open to new ideas and implementing new ideas but rely on support from policies and regulations which are currently lacking. For example, the materials being used can be reused and recertified as most of the materials are still in good condition but more often than not are discarded due to lack of strict policies and regulations. *Lack of Control* • The clients are directly involved only with the contractors and may get through all of their supply chain but have no control over the supply chain of their sub-contractors which might be an obstacle for circular transition. • The clients also have less or no control over the turbines once they reach the end of life and are given away for reusing or for recycling companies since it is no longer their product.

	• This is majorly due to lack of regulations and strict laws. *<u>Lack of Awareness, Social norms and Culture</u>* • The respondent believes that the Nordic countries are more advanced when it comes to renewable energy and recycling activities. And within the Netherlands, there might be lack of recycling culture and lack of awareness comparatively. They are doing their best to reuse and recycle, and they do have certain knowledge regarding the same, but they do not want to know more, says the respondent. • The respondent also belives that there lacks a link between energy transition and circular transition and this is mostly due to the mindset of getting away from linear thinking, producing and consuming.
Interaction or Network Failure	*<u>Lack of Interaction</u>* • The respondent also stresse on the fact that the project teams don't talk to each other that often. Which is the case in all the organizations. What one team is doing from a circularity point of view might not be happening in another project. This majorly depends on various levels of networking and how much you cllaborate with the other organizations. <u>Lack of Innovation</u> • Within the wind industry there is a pattern of dealing with a lot of same players and same contractors or suppliers and they know how the clients work, their requirements and they already have a lot of materials needed by the clients. But due to this you do loose that innovation and question if you are doing it the right way, says the respondent *<u>Accountability</u>* • According to the respondent, the biggest challenge is ownership and accountability in the life cycle and project staging and the whole process in general. There needs to be corporation between the supplier and the developer, and the developer needs to be accountable for recycling of turbines.
Capabilities Failure	*<u>Lack of Expertise</u>* • Wind industry is still young and people working in this industry are coming from different industries like oil and gas for example, and the respondent suggest that they need more training, more knowledge and enlightenment bout this aspect. However, there is insufficient time due to restricted schedules.
Directionality Failure	*<u>Lack of Need or Incentive</u>* • When asked about the biggest challenge you will have to overcome to adopt circularity, the respondent points at lack of incentive or the need to adopt circularity. The respondent believes that if the clients are willing to adopt circularity it becomes easier for circular transition and If they do not accept and keep insisting on certain products it will definitely be a challenge to adopt circularity. • The respondent believes that we do have a well-established system, but it is established in a fundamental stage and it still needs establishment in the areas of circularity. A lot of projects do have quite circular approaches, but they are not yet in the standard management system or contract set up. • The reason the respondent felt a need to highlight this topic is because the people in the organization aren't aware or aren't

	motivated to bring circularity. However, if the system and the contract require them to do so, they are obliged to do it. *Lack of Shared Vision* • The respondent also believes that not everyone has a shared vision when it comes to the aspect of circularity. For example, someone from the procurement team may not necessarily share the vision of circularity as the project manager. They might understand the need to reduce the environmental risk but for them it may be something on a smaller scale and circularity is not a priority. *Competition* • All of the companies are trying to give a perfect product and are competing with each other. The companies do not prefer recycled materials as they consider recycled materials to be of inferior quality and expensive. Lack of Attention • The respondent believes that circular aspects usually get little or no attention. In an organization there are a lot of people who have been around for a long time and some of them are less open to new ideas which often is the case with circular transition. *Image Perception* • The respondent believes that circular transition is very important particularly for the wind energy sector because of image perception. For example, wind energy is quite the green and clean organization that focuses on energy transition thus there is not much focus on making it circular. However, even with such a green image and green structure the wind industry still produces an ample amount of waste and has lot of inefficiencies.
Policy Coordination Failure	*Accountability* • According to the respondent, the biggest challenge is ownership and accountability in the life cycle and project staging and the whole process in general. • Currently due to lack of appropriate policies or due to different policies by the clients, suppliers and the recycling companies, there lacks accountability and ownership of turbines after end of life.
Demand Articulation Failure	*Involvement of Suppliers* • The respondent emphasizes that the suppliers play a major role in the supply chain to incorporate circular aspects. However, when it comes to the discussions and decisions made in terms of circularity, the supplier's involvement is fairly limited at the moment.

2. Construction Phase

Circular Aspects

Wind energy was invented to try and be circular by using energy from natures specific elements like wind. However, making the wind turbines is a lot of waste. It looks great from the outside, but making the foundation and turbines alone demand a lot from nature and it is not circular; says the respondent.

When asked about the circular aspects for the construction phase from Table 1, the respondent could recognize most of the aspects. However, deems that the aspects were taken into consideration but not for incorporating circularity. Aspects like *minimize waste* is definitely taken into consideration because the projects get cheaper. The respondent recalls that they built 82 almost similar foundations for this case and it was good for them to reuse materials. After 7 or 8 foundations the whole building place needs basic amenities like water and toilet, and they made all these things movable. So, they try to think about minimize, reuse and recycle but more in terms of efficiency than circularity. In terms of *procuring reused materials*, the respondent says that no reused materials were procured for construction. However, the construction items like the formwork and scaffolding are all reused. They have been deconstructed and used in different locations and projects. When it comes to the *procuring of recycled materials*, it was not possible during construction due to client's contract. *In terms of offsite construction*, the respondents say that a part of the foundation is built offsite in Friesland but otherwise everything else is done onsite.

Challenges and Obstacles Identified

Lack of Norms and Regulations

The respondent deems that within the wind energy sector there are a lot of norms and regulations on how to make the turbines strong and safe, and especially in the Netherlands they are very particular about these rules. If you want to try something new in terms of circularity, you need to consider all these norms and regulations and the respondent believes that it is important to make sure it is safe but it is almost impossible to do and if you do so, you have to spend so much money and there is no business case in it. The respondent says that there needs to be norms and regulations to incorporate circularity for the wind sector.

Lack of Trust

For incorporating the aspects of circularity for the wind sector, the respondent believes that one of the greatest challenges is to build trust. The respondent deems that currently, within the wind energy sector you are advised not to think too much and stick to the basics. You are not allowed to try different things and be creative. The respondent believes that when you get trust from someone to try different things, it becomes a lot easier to try and incorporate circular aspects.

Cost Incentive

The respondent says that the biggest challenge is to have an employer in your work to tell us to try new things and accept all the risks. There are not many companies at the moment that do this because there is not enough money in this sector. All the innovations like circular economy will not be rolling until we accept that it needs money. The respondent says that the main problem is that there is no business case. The clients want to be safe and safety is their core business and they are very scared to try something new. Also, there is not a lot of money. Especially right now, all the companies are trying to survive, and as long as they just try to survive, they are not going to try something new and there is no room for investments for circularity.

Not mentioned in the Contract

The respondent emphasizes that she was surprised when she had a look at the contract because in the contract it was specifically mentioned not to try anything new and always use proved ways of building. This was one of the reasons why they couldn't do much in terms of circularity for this project.

Lack of Information

According to the respondent, a lot of information is missing. A nice example is Nordex is building the turbines and for the turbines the earthing given was 20 ohms. They hired an earthing company to advise them and they think it is irrational to have 20 ohms. In the Netherlands it never reaches 10 ohms and most of the times it is 5 ohms. Neither the clients nor the manufacturers knew why it was 20 ohms. When they contacted a lot of other turbine suppliers, they figured that there is an area in Spain that requires 20 ohms and is considered the maximum on earth. Thus, around the world they are building the turbines with 20 ohms as a safety measure which is not necessary. In the Netherlands, due to land and water surface it will never reach 20 ohms. When they explained all this to Nordex, they were ready to change, and they saved a lot of money and materials. When you talk with each other about various consequences you can save a lot of materials.

Lack of Inclusion of New Ideas

The respondent says that you can notice lack of inclusion of new ideas. And when it happens, you lose your enthusiasm, creativity and new ideas. The younger people in the team are always having great ideas about using materials and doing things differently but they all are being told to settled down.

Lack of Expertise

More often than not, the respondent also believes that there is lack of resources and expertise in the field of circular economy which might also be one of the obstacles for incorporating circular aspects for the wind energy sector.

Lack of Interaction

The respondent believes that especially in the wind energy market there is not much cooperation between various parties. This can be seen from a few excerpts taken from the interview with the respondent.

> *''Within the wind industry you have a turbine builder, foundation builder and substation and road builders. And they are always fighting with each other because they have never been put together and asked to save money and materials together''- Project Leader.*

> *''When you get a sub-contractor, you are charge and you are the boss. So, if you insist on doing something they will have to do so. But if you don't ask them what is better for the project and if you don't talk to them, you will never know, and you make your decisions without knowing their concern or opinion. You need to really work together without hierarchy.''- Project Leader.*

Supplier Involvement

The respondent also confirms that there is not much cooperation or active involvement with the suppliers.

Types of Failures

All the challenges and obstacles identified in the construction phase are categorized based on Webber and Rohracher 'failures' framework.

Table 26: Types of failure for the Construction Phase (Wind Park Wieringermeer)

Type of Failure	Failures Identified for the Construction Phase
Information Asymmetries	*Lack of Information* • According to the respondent, a lot of information is missing. • A nice example is Nordex is building the turbines and for the turbines the earthing given was 20 ohms. Neither the clients nor the manufacturers knew why it was 20 ohms. When they contacted a lot of other turbine suppliers, they figured that there is an area in Spain that requires 20 ohms and is considered the maximum on earth. Thus, in the entire world they are building the turbines with 20 ohms as a safety measure which is not necessary. In the Netherlands, due to land and water surface it will never reach 20 ohms. When they explained all this to Nordex, they were ready to change, and they saved a lot of money and materials. • When you talk with each other about various consequences you can save a lot of materials.

Externalization of Costs	*<u>Cost Incentive</u>* • The respondent says that the biggest challenge is to have an employer in your work to tell us to try new things and accept all the risks. There are not many companies at the moment that do this because there is not enough money in this sector. • All the innovations like circular economy will not be rolling until we accept that it needs money and we to try make it to work. The respondent says that the main problem is that there is no business case. The clients want to be safe and safety is their core business and they are very scared to try something new. • Also, there is not a lot of money. Especially right now, all the companies are trying to survive, and as long as they just try to survive, they are not going to try something new and there is no room for investments for circularity.
Institutional Failure	*<u>Lack of Norms and Regulations</u>* • The respondent deems that within the wind energy sector there are a lot of norms and regulations on how to make the turbines strong and safe, and especially in the Netherlands they are very particular about these rules. • If you want to try something new in terms of circularity, you need to consider all these norms and regulations and the respondent believes that it is important to make sure it is safe but it is almost impossible to do and if you do so you have to spend so much money and there is no business case in it. • The respondent says that there needs to be norms and regulations to incorporate circularity for the wind sector. *<u>Lack of Trust</u>* • The respondent deems that currently, within the wind energy sector you are advised not to think too much and stick to the basics. You are not allowed to try different things. The respondent believes that when you get trust from someone to try different things, it becomes a lot easier to try and incorporate circular aspects.
Interaction or Network Failure	*<u>Lack of Inclusion of New Ideas</u>* • The respondent says that you can notice lack of inclusion of new ideas. And when it happens, you lose your enthusiasm, creativity and new ideas. The younger people in the team are always having great ideas about using materials and doing things differently but they all are being told to settled down. *<u>Lack of Interaction</u>* • The respondent believes that especially in the wind energy market there is not much cooperation between various parties.
Capabilities Failure	*<u>Lack of Resources and Expertise</u>* • More often than not, the respondent also believes that there is lack of resources and expertise in the field of circular economy which might also be one of the obstacles for incorporating circular aspects for the wind energy sector.
Directionality Failure	*<u>Not mentioned in the Contract</u>* • The respondent emphasizes that she was surprised when she had a look at the contract because in the contract it was specifically mentioned not to try anything new and always use proved ways of

	building. This was one of the reasons why they couldn't do much in terms of circularity especially for this project.
Demand Articulation Failure	*Involvement of suppliers* • The respondent also confirms that there is not much cooperation or active involvement with the suppliers.

3. Operation & Maintenance Phase

Circular Aspects

The clients take full control as an owner/developer of Wieringermeer and are responsible for the operation phase. The turbine supplier has a full-service contract for the first 2 years, after which the client takes on full control in operations. The respondent from the client's side was asked regarding various circular aspects for operation phase from Table 1. The following response was obtained from the respondent.

Minimize waste: It is part of the contract that the contractors and clients must reduce and recycle waste where possible. As clients they have an annual internal reporting obligation to verify how much waste is produced for each project in operation. They are also looking into ways of improving their waste stream i.e. better solutions for blade waste.

Minimal Maintenance: This is quite a general category. The need for maintenance is of course minimized as much as possible. Regular routine maintenance checks of Wieringermeer's systems and equipment reduces the likelihood of major maintenance events being required.

Easy Repair and upgrade: The respondent is unsure about the design and how repair and replacement has been considered in the design or whether Wieringermeer has any innovations or special considerations in this area.

Adaptability & Flexibility: The Wieringermeer turbines need to adapt to changing conditions, in order to reduce impacts from shadow flicker, aviation light impacts on stakeholders, reducing collisions with bats and birds, and responsiveness to ice formation on blades. The systems to achieve this are quite advanced and responsive, allowing production to adapt to changing environmental factors.

Challenges and Obstacles Identified

Lack of control

The main challenges are that the majority of design decisions have already been made by the time you get to the operational phase. All the decisions regarding the material type, sourcing, modularity and general efficiency-based are already made.

Lack of Technology

On the other hand, material reuse and maintenance and improvements in recycling techniques can also factor in the future operating phases through trial and error, or introduction of new practices and technologies which may lead to innovations and better circularity than is being currently considered. In some respects, alternatives aren't mature enough yet or aren't even developed yet. Currently, they are looking at ways of exchanging the greenhouse gas SF6 used for switchgear, but alternatives are limited and prohibitive to technical limitations, says the respondent.

Types of Failures

All the challenges and obstacles identified in the Operations & Maintenance phase are categorized based on Webber and Rohracher 'failures' framework.

Table 27: Types of Failures For the Operation Phase (Wind Park Wieringermeer)

Type of Failure	Failures Identified for the Operations & Maintenance Phase
Infrastructural Failure	*Lack of Technology* • Material reuse and maintenance and improvements in recycling techniques can also factor in the future operating phases through trial and error, or introduction of new practices and technologies which may lead to innovations and better circularity than is being currently considered. • In some respects, alternatives aren't mature enough yet or aren't even developed yet. They are looking at ways of exchanging the greenhouse gas SF6 used for switchgear, but alternatives are limited and prohibitive to technical limitations, says the respondent.
Institutional Failure	*Lack of control* • The main challenges are that the majority of design decisions have already been made by the time you get to the operational phase. All the decisions regarding the material type, sourcing, modularity and general efficiency-based are already made.

4. Decommissioning Phase

Circular Aspects & Challenges and Obstacles Identified

Wind park Wieringermeer is set to be commissioned completely by the end of 2020 and the wind farm will only reach the end of life approximately 20-25 years after being commissioned. Thus, the respondent has no particular information when it comes to the decommissioning phase of wind farm. When asked about the circular aspects for the decommissioning phase as mentioned in Table 1, the respondent could only speculate about deconstruction and selective demolition with certainty as those are the only aspects the respondent was sure would be taken into consideration during decommissioning of the wind farms. The other aspects mentioned, the respondent wasn't really sure about their consideration and only hoped that they would be taken into consideration.

When asked about the challenges, the responded stated that it is still quite unsure if the clients would still be responsible for the deconstruction and decommissioning of the wind farm. There may be changes in the future where the clients could sell the windfarm to other parties or could dismantle the turbines for reuse elsewhere. At the moment, there is lack of information.

Types of Failures

All the challenges and obstacles identified in the Decommissioning phase are categorized based on Webber and Rohracher 'failures' framework.

Table 28: Types of failures for the deconstruction phase (Wind park Wieringermeer)

Type of Failure	Failures Identified for the Decommissioning Phase
Information Asymmetries	*Lack of Information* ➢ The responded stated that it is still quite unsure if the clients would still be responsible for the deconstruction and decommissioning of the wind farm. There may be changes in the future where the clients could sell the windfarm to other parties or could dismantle the turbines for reuse elsewhere. At the moment, there is lack of information.

4.3.3 Case Summary

The circular aspects and the challenges and obstacles identified for the onshore Wind park Wieringermeer case are summarized in tables below.

Circular Aspects

In order to summarize all the circular aspects that were incorporated/not incorporated for the case Wieringermeer, the circular aspects were scored using five-point scales ranging from **- -** for not being taken into consideration at all and **+ +** for completely being incorporated within the project. For all the five values (+ +, +, + / -, -, - -) qualitative descriptions are given in Table 12 and Table 29 summarizes all the circular aspects for the case Wieringermeer by assigning the five point scale.

Table 29: Circular aspects being considered/not considered for Wieringermeer

Phase of wind farm construction	Life-cycle stage	Circular Economy Aspect	Five Point Score
1. Design & Development Phase	Design	Design for deconstruction	**+ +**
		Design for adaptability and flexibility	**+**
		Design for standardization	**+**
		Design out waste	**-**
		Design in modularity	**+**
		Specify reclaimed materials	**- -**
		Specify recycled materials	**- -**
	Manufacture and Supply	Eco design principles	**+ / -**
		Use less materials/optimize material use	**+**
		Use less hazardous material	**+ +**
		Increase the life span	**+**
		Design for product disassembly	**+**
		Design for product standardization	**+ +**
		Use secondary materials	**- -**
		Take back schemes	**+ / -**
		Reverse Logistics	**-**
2. Construction Phase	Construction	Minimize Waste	**+**
		Procure reused materials	**-**
		Procure recycled materials	**-**
		Off-site construction	**+**
3. Operation Phase	In use and Refurbishment	Minimize waste	**+**
		Minimal Maintenance	**+**
		Easy Repair and upgrade	**+**
		Adaptability & Flexibility	**+**
4. Decommissioning Phase	End of life	Deconstruction	**+ +**
		Selective Demolition	**+**
		Reuse of components/products	**NA**
		Closed loop recycling	**NA**
		Open loop recycling	**NA**

Types of Failures Identified For Each Phase of Wind Farm development.

All the types of challenges and obstacles identified in each phase of wind farm development for the case Wieringermeer based on the 'failures' framework is summarized in Table 30.

Table 30: Failures Identified For Each Phase of Wind Farm development (Borssele 1 & 2)

	Market Failures	Structural System Failures	Transitional System Failures
Design & Development Phase	➢ Information Asymmetries ➢ Knowledge Spill over ➢ Externalization of costs ➢ Over exploitation of commons	➢ Infrastructural Failure ➢ Institutional Failure ➢ Interaction or Network Failure ➢ Capabilities Failure	➢ Directionality Failure ➢ Demand Articulation Failure ➢ Policy Coordination Failure
Construction Phase	➢ Information Asymmetries ➢ Externalization of costs	➢ Institutional Failure ➢ Interaction or Network Failure ➢ Capabilities Failure	➢ Directionality Failure ➢ Demand Articulation Failure
Operations & Maintenance Phase		➢ Infrastructural Failure ➢ Institutional Failure	
Decommissioning Phase	➢ Information Asymmetries		

4.4 Cross Case Analysis

Following the individual case reports, a cross case analysis was performed to mobilize the knowledge from individual case studies. As stated by Yin (2003), one of the possibilities of performing a cross case analysis is by presenting the data from individual cases by creating tables in the form of a unified framework. For this research, the challenges and obstacles obtained will be presented using 'failures' framework for different phases of wind farm development. The overall arrangement of gathered data and patterns obtained within the table will lead to conclusions. These new relations obtained across cases augment existing knowledge and experience and produce new knowledge.

Firstly, in section 4.4.1, a cross case comparison is done for each phase of wind farm development in terms of circular aspects being incorporated/not incorporated followed by challenges and obstacles identified for circular transition for the wind energy sector. Secondly, in section 4.4.2, cross case conclusions are drawn for each phase of wind farm development based on the comparison. Finally, in section 4.4.3, the cross-case conclusions are validated by experts working within the wind industry.

4.4.1 Cross Case Comparison

In this section a cross case comparison is performed for all the three cases for each phase of wind farm development (Design & development, Construction, Operations & Maintenance and Decommissioning phase) in terms of circular aspects being incorporated/not incorporated followed by challenges and obstacles identified for circular transition for the wind energy sector.

1. Design & Development Phase

Circular Aspects

Table 31 demonstrates how all the different circular aspects for the design and development phase are being considered for the three different cases based on the five point scale as described in *Table 12*. Within the design stage of life-cycle, for all the three cases, it is seen that the circular aspects like *design for adaptability and flexibility, design for standardization and design in modularity* are all partially incorporated and *design out waste* is not taken into consideration for the current projects but are going to be considered for the future projects. These aspects have been highlighted in blue in Table 31 as they have the same level of consideration in all the three cases. In terms of *design for deconstruction*, it is seen that it is partially incorporated in two cases and completely incorporated in the third case. The aspects of *specifying reclaimed and recycled materials* have either not been considered at all or will probably be taken into consideration for the upcoming projects.

Within the manufacture and supply stage of life cycle, for all the three cases, it is seen that the circular aspects like *use less hazardous material* and *design for product standardization* have been completely taken into consideration and incorporated. *Design for product disassembly* and *Use less materials/optimize material use* have been partially incorporated and the *use of secondary materials* have not been taken into consideration at all. These aspects have been highlighted in blue in Table 31 as they have the same level of consideration in all the three cases. The other aspects like the *eco design principles* and *increase in the life span*, are either partially incorporated or are in consideration for incorporation. Whereas, the aspects like *take back schemes* and *reverse logistics* are either being considered for incorporation or have not been considered for the current cases.

Table 31: Cross case comparison of Circular Aspects for Design & Development Phase

Phase of wind farm Construction	Life-cycle stage	Circular Economy Aspect	Wind Plan Blauw	Borssele 1 & 2	Wind Park Wieringermeer
Design & Development Phase	Design	Design for deconstruction	+	+	+ +
		Design for adaptability and flexibility	+	+	+
		Design for standardization	+	+	+
		Design out waste	-	-	-
		Design in modularity	+	+	+
		Specify reclaimed materials	-	- -	- -
		Specify recycled materials	-	- -	- -
	Manufacture and Supply	Eco design principles	+	+	+ / -
		Use less materials/optimize material use	+	+	+
		Use less hazardous material	+ +	+ +	+ +
		Increase the life span	+ / -	+ / -	+
		Design for product disassembly	+	+	+
		Design for product standardization	+ +	+ +	+ +
		Use secondary materials	- -	- -	- -
		Take back schemes	+ / -	-	+ / -
		Reverse Logistics	+ / -	-	-

[+ + Completely Incorporated] [+ Partially Incorporated] [+/- May/May not be incorporated under consideration] [- Not Incorporated Under consideration for Future Projects] [- - Not Under Consideration] [NA Not Applicable]

Challenges and Obstacles Identified

Table 32 demonstrates all the challenges and obstacles that have been identified for the design & development phase of wind farm development for all the three cases combined. These challenges and obstacles have been categorized based on the types of failures within the 'failures' framework.

Firstly, within Market Failures, you can notice challenges and obstacles being grouped in all four different types of failures. In terms of Information Asymmetries, the challenge or obstacle of *lack of information* is noticed for all the three case. In terms of Knowledge Spill over, the challenge or obstacle of *lack of knowledge* is noticed for all the three case. In terms of Externalization of costs, the challenge or obstacle of *cost incentive* is noticed for all the three case and in terms of Over Exploitation of Resources, the challenge or obstacle of *easy access to resources* is noticed for all the three case. These particular aspects have been highlighted in blue Table 32.

Secondly, when it comes to the category of Structural System Failures, although a lot of challenges and obstacles have been grouped into all the four types of failures, only two of the challenges and obstacles i.e. *lack of R&D and technology* under Infrastructural Failure and *lack of resources and expertise* under Capabilities Failure have been identified in all the three cases. These particular aspects have been highlighted in blue Table 32

Lastly, when it comes to the category of Transitional failures, although a lot of challenges and obstacles have been grouped into all the four types of failures, only three of the challenges and obstacles i.e. *lack of need/incentive* and *lack of shared vision* under Directionality Failure and *involvement of suppliers* under Demand Articulation Failure have been identified in all the three cases. These particular aspects have been highlighted in blue Table 32. However, what can also be noticed is that no challenge or obstacle was categorized under the reflexivity failure.

Table 32: Cross Case Comparison of Challenges & Obstacles Identified for Design & Development Phase

Failure Categories	Type of Failure	Challenges & Obstacles identified	Wind Plan Blauw	Borssele 1 & 2	Wind Park Wieringermeer
Market Failures	I. **Information Asymmetries**	➢ Lack of Awareness	✓		
		➢ Lack of Information	✓	✓	✓
	II. **Knowledge Spill over**	➢ Lack of Knowledge	✓	✓	✓
	III. **Externalization of Costs**	➢ Cost Incentive	✓	✓	✓
	IV. **Over Exploitation of Commons**	➢ Easy Access to Resources	✓	✓	✓
		➢ Dependent on Certain type of Materials	✓		
Structural System Failures	I. **Infrastructural Failure**	➢ Lack of R&D and Technology	✓	✓	✓
		➢ Lack of Knowledge	✓		
		➢ Uncertainty in Quality	✓	✓	
		➢ Blade waste and Composites		✓	
		➢ Limited Turbine Suppliers			✓
	II. **Institutional Failure**	➢ Innovations not directed towards circularity	✓	✓	
		➢ Liberal Approach	✓		
		➢ Lack of Regulations & Appropriate Policies		✓	✓
		➢ Lack of Control			✓
		➢ Lack of Awareness &			✓

		Social norms and Culture			
	III. **Capabilities Failure**	➢ Lack of Resources and Expertise	✓	✓	✓
	IV. **Network or Interaction Failure**	➢ Lack of Interaction			✓
		➢ Lack of Innovation			✓
		➢ Accountability			✓
Transitional Failures	I. **Directionality Failure**	➢ Lack of Need or Incentive	✓	✓	✓
		➢ Lack of Shared Vision	✓	✓	✓
		➢ Lack of Attention	✓		✓
		➢ Flexibility over Circularity	✓		
		➢ Need for Research		✓	
		➢ Competition			✓
		➢ Image Perception			✓
	II. **Demand Articulation Failure**	➢ Involvement of Suppliers	✓	✓	✓
	III. **Policy coordination failure**	➢ Lack of Appropriate Policies	✓		
		➢ Accountability			✓
	IV. **Reflexivity Failure**				

[✓ - Challenges & Obstacles faced by the practitioners] [- Challenges & Obstacles identified in all the 3 cases]

2. Construction Phase

Circular Aspects

Table 33 demonstrates how all the different circular aspects for the construction phase are being considered for the three different cases based on the five point scale as described in Table 12.

Within the construction stage of life-cycle, for all the three cases, it is seen that the circular aspects like *minimize waste* and *offsite construction* have been taken into consideration and partially incorporated whereas procuring of reused materials has not been considered, at least for these cases but might be taken into consideration for the upcoming projects. These aspects have been highlighted in blue in Table 33 as they have the same level of consideration in all the three cases. When it comes to procuring of recycled materials, it is either not being considered for the following cases or not being considered at all.

Table 33: Cross Case Comparison of Circular Aspects for Construction Phase

Phase of wind farm Construction	Life-cycle stage	Circular Economy Aspect	Wind Plan Blauw	Borssele 1 & 2	Wind Park Wieringermeer
Construction Phase	Construction	Minimize Waste	+	+	+
		Procure reused materials	-	-	-
		Procure recycled materials	- -	-	-
		Off-site construction	+	+	+

[+ + Completely Incorporated] [+ Partially Incorporated] [+/- May/May not be incorporated under consideration] [- Not Incorporated Under consideration for Future Projects] [- - Not Under Consideration] [NA Not Applicable]

Challenges and Obstacles Identified

Table 34 demonstrates all the challenges and obstacles that have been identified for the construction phase of wind farm development for all the three cases combined. These challenges and obstacles have been categorized based on the types of failures within the 'failures' framework.

Firstly, within Market Failures, you can notice challenges and obstacles being grouped in three of the four different types of failures. No particular challenge or obstacle was grouped under Over Exploitation of Resources. Of all the challenges and obstacles identified, only one of the challenges and obstacle i.e. *cost incentive* under Externalization of costs has been identified in all the three cases. This particular aspect has been highlighted in blue Table 34.

Secondly, when it comes to the category of Structural System Failures, although a lot of challenges and obstacles have been grouped into all the four types of failures, only two of the challenge and obstacle i.e. *lack of resources and expertise* under Capabilities Failure and *lack of communication and interaction* under Network or Interaction Failure have been identified in all the three cases. These particular aspects have been highlighted in blue Table 34

Lastly, when it comes to the category of Transitional failures, you can notice challenges and obstacles being grouped in three of the four different types of failures. No particular challenge or obstacle was grouped under Reflexivity Failure. Of all the challenges and obstacles identified, only one of the challenges and obstacle i.e. *lack of need/incentive* under Directionality Failure has been identified in all the three cases. This particular aspect has been highlighted in blue Table 34.

Table 34: Cross Case Comparison of Challenges & Obstacles Identified for Construction Phase

Failure Categories	Type of Failure	Challenges & Obstacles Identified	Wind Plan Blauw	Borssele 1 & 2	Wind Park Wieringermeer
Market Failures	I. **Information Asymmetries**	➢ Lack of Awareness	✓		
		➢ Lack of Information	✓		✓
	II. **Knowledge Spill over**	➢ Lack of Knowledge	✓		
	III. **Externalization of Costs**	➢ Cost Incentive	✓	✓	✓
	IV. **Over Exploitation of Commons**				

Structural System Failures	I. **Infrastructural Failure**	➢ Uncertainty in Quality	✓		
		➢ Lack of Green Material		✓	
	II. **Institutional Failure**	➢ Proud & Content		✓	
		➢ Liberal Approach	✓		
		➢ Lack of Regulations & Norms			✓
		➢ Lack of Trust			✓
	III. **Capabilities Failure**	➢ Lack of Resources and Expertise	✓	✓	✓
	IV. **Network or Interaction Failure**	➢ Lack of Inclusion of New Ideas			✓
		➢ Lack of communication & Interaction	✓	✓	✓
Transitional Failures	I. **Directionality Failure**	➢ Lack of Need or Incentive	✓	✓	✓
		➢ Lack of Shared Vision	✓		
		➢ Lack of Urgency	✓		
		➢ Competition		✓	
		➢ Not Mentioned in the Contract			✓
	II. **Demand Articulation Failure**	➢ Involvement of Suppliers		✓	✓
	III. **Policy coordination failure**	➢ Lack of Appropriate Policies	✓	✓	
	IV. **Reflexivity Failure**				

[✓ - Challenges & Obstacles faced by the practitioners] [- Challenges & Obstacles identified in all the 3 cases]

3. Operation & Maintenance Phase

Circular Aspects

Table 35 demonstrates how all the different circular aspects for the operation & maintenance phase are being considered for the three different cases based on the five point scale as described in *Table 12*.

Within the in use and refurbishment stage of life cycle, for all the three cases, all of the circular aspects *like minimize waste, minimal maintenance, easy repair and upgrade and adaptability & flexibility* have been taken into consideration and would be partially incorporated. These aspects have been highlighted in blue in Table 35 as they have the same level of consideration in all the three cases.

Table 35: Cross Case Comparison of Circular Aspects for Operation & Maintenance Phase

Phase of wind farm construction	Life-cycle stage	Circular Economy Aspect	Wind Plan Blauw	Borssele 1 & 2	Wind Park Wieringermeer
Operation Phase	In use and Refurbishment	Minimize waste	+	+	+
		Minimal Maintenance	+	+	+
		Easy Repair and upgrade	+	+	+
		Adaptability & Flexibility	+	+	+

[+ + Completely Incorporated] [+ Partially Incorporated] [+/- May/May not be incorporated under consideration] [- Not Incorporated Under consideration for Future Projects] [- - Not Under Consideration] [**NA** Not Applicable]

Challenges and Obstacles Identified

Table 36 demonstrates all the challenges and obstacles that have been identified for the operation and maintenance phase of wind farm development for all the three cases combined. These challenges and obstacles have been categorized based on the types of failures within the 'failures' framework.

Firstly, within Market Failures, you can notice challenges and obstacles being grouped in two of the four different types of failures. No particular challenges or obstacles were grouped under Knowledge Spill over and Over Exploitation of Resources. Also, of all the challenges and obstacles identified none of them were seen in all the three cases.

Secondly, when it comes to the category of Structural System Failures, you can notice challenges and obstacles being grouped in two of the four different types of failures. No particular challenges or obstacles were grouped under Capabilities Failure and Network and Interaction Failure. Also, of all the challenges and obstacles identified none of them were seen in all the three cases.

Lastly, when it comes to the category of Transitional failures, no particular challenges or obstacles found were grouped under this category.

Table 36: Cross Case Comparison of Challenges & Obstacles Identified for Operation & Maintenance Phase

Failure Categories	Type of Failure	Challenges & Obstacles identified	Wind Plan Blauw	Borssele 1 & 2	Wind Park Wieringermeer
Market Failures	I. **Information Asymmetries**	➢ Lack of Awareness	✓	✓	
		➢ Lack of Information	✓		
	II. **Knowledge Spill over**				
	III. **Externalization of costs**	➢ Cost Incentive		✓	
	IV. **Over exploitation of commons**				

Structural System Failures	I. **Infrastructural Failure**	➢ Lack of Technology			✓
	II. **Institutional Failure**	➢ Lack of Control			✓
	III. **Capabilities Failure**				
	IV. **Network or Interaction Failure**				
Transitional Failures	I. **Directionality Failure**				
	II. **Demand Articulation Failure**				
	III. **Policy coordination failure**				
	IV. Reflexivity Failure				

[✓ - Challenges & Obstacles speculated by the practitioners]

4. Decommissioning Phase

Circular Aspects

Table 37 demonstrates how all the different circular aspects for the decommissioning phase are being considered for the three different cases based on the five point scale as described in Table 12.

Within the end of life stage of life cycle, for all the three cases, the circular aspects like *deconstruction* will be taken into consideration and incorporated completely. Whereas *selective demolition* will be taken into consideration and incorporated partially. These aspects have been highlighted in blue in Table 37 as they have the same level of consideration in all the three cases. However, for the rest of the circular aspects it is uncertain at the moment because all the three cases are still at the construction phase and yet to reach the decommissioning phase.

Table 37: Cross Case Comparison of Circular Aspects for Decommissioning Phase

Phase of wind farm construction	Life-cycle stage	Circular Economy Aspect	Wind Plan Blauw	Borssele 1 & 2	Wind Park Wieringermeer
Decommissioning Phase	End of life	Deconstruction	**+ +**	**+ +**	**+ +**
		Selective Demolition	**+**	**+**	**+**
		Reuse of components/products	**+ / -**	**NA**	**NA**
		Closed loop recycling	**- -**	**NA**	**NA**
		Open loop recycling	**-**	**NA**	**NA**

[**+ +** Completely Incorporated] [**+** Partially Incorporated] [**+/-** May/May not be incorporated under consideration]
[**-** Not Incorporated Under consideration for Future Projects] [**- -** Not Under Consideration] [**NA** Not Applicable]

Challenges and Obstacles Identified

Table 38 demonstrates all the challenges and obstacles that have been identified for the decommissioning phase of wind farm development for all the three cases combined. These challenges and obstacles have been categorized based on the types of failures within the 'failures' framework.

Firstly, within Market Failures, you can notice challenges and obstacles being grouped in two of the four different types of failures. No particular challenges or obstacles were grouped under Externalization of costs and Over Exploitation of Resources. Of all the challenges and obstacles identified, only one of the challenges and obstacle i.e. *lack of information* under Information Asymmetries has been identified in all the three cases. This particular aspect has been highlighted in blue Table 38.

Secondly, when it comes to the category of Structural System Failures, no particular challenges or obstacles found were grouped under this category.

Lastly, when it comes to the category of Transitional failures, you can notice only one challenge i.e. *lack of urgency* under Directionality Failure and only in one of the cases.

Table 38: Cross Case Comparison of Challenges & Obstacles Identified for Decommissioning Phase

Failure Categories	Type of Failure	Challenges & Obstacles identified	Wind Plan Blauw	Borssele 1 & 2	Wind Park Wieringermeer
Market Failures	I. **Information Asymmetries**	➢ Lack of Awareness	✓		
		➢ Lack of Information	✓	✓	✓
	II. **Knowledge Spill over**	➢ Lack of Knowledge	✓		
	III. **Externalization of Costs**				
	IV. **Over Exploitation of Commons**				
Structural System Failures	I. **Infrastructural Failure**				
	II. **Institutional Failure**				
	III. **Capabilities Failure**				
	IV. **Network or Interaction Failure**				
Transitional Failures	I. **Directionality Failure**	➢ Lack of Urgency	✓		
	II. **Demand Articulation Failure**				
	III. **Policy coordination failure**				
	IV. Reflexivity Failure				

[✓ - Challenges & Obstacles speculated by the practitioners] [- Challenges & Obstacles identified in all the 3 cases]

4.4.2 Cross Case Conclusion

Following a cross case comparison, cross case conclusions are drawn in this for each phase of wind farm development (Design & development, Construction, Operations & Maintenance and Decommissioning phase) in terms of challenges and obstacles identified for circular transition for the wind energy sector.

Design & Development Phase

All the three cases chosen for the research have completed the design and development phase. The challenges and obstacles obtained within the design and development phase have been categorized under all the three categories i.e. Market Failure, Structural System Failures and Transitional Failures as mentioned in Table 32. The most common challenges and obstacles that were noticed in all the three cases were categorized under all the four different types of Market Failures. Within the structural system failures, even though only a few of the challenges and obstacles categorized under infrastructural failure and capabilities failure were noticed in all the three cases, overall, maximum number of challenges and obstacles were found under this category of failures which are split into all the four types of Structural System Failures. Within the Transitional Failures, similar to the structural system failures, only a few challenges and obstacles categorized under directionality failure and demand articulation failure were noticed in all the three cases. However, after the Structural System Failures, most number of challenges and obstacles were categorized under Transitional Failures which are split into three of the four types of Transitional Failures. No challenge or obstacle was categorized under the reflexivity failure. Taking all the twelve types of failures into consideration, for the design and development phase, most number of challenges and obstacles were identified under directionality failure followed by institutional failure.

Construction Phase

All the three cases chosen for the research are either in the beginning or mostly nearing the end of the construction phase. The challenges and obstacles obtained within the construction phase have also been categorized under all the three categories i.e. Market Failure, Structural System Failures and Transitional Failures as mentioned in Table 34. The least number of challenges and obstacles identified were categorized under Market Failures and within market failures, the challenges obtained were categorized under three of the four types of market failures. No challenge or obstacle was categorized under over exploitation of commons, probably because none of the practitioners consider over exploitation of resources or easy access to resources as one of the challenges or obstacles hindering circular transition for the wind energy sector. Within the structural system failures, even though only a few of the challenges and obstacles categorized under capabilities failure and network and interaction failure were noticed in all the three cases, overall, maximum number of challenges and obstacles were found under this category of failures which are split into all the four types of Structural System Failures. Within the Transitional Failures, only one of the challenges or obstacles categorized under directionality failure was noticed in all the three cases. However, after the Structural System Failures, the most number of challenges and obstacles were categorized under Transitional Failures which are split into three of the four types of Transitional Failures. No challenge or obstacle was categorized under the reflexivity failure. Taking all the twelve types of failures into consideration, for the construction phase, most number of challenges and obstacles were identified under directionality failure followed by institutional failure.

Operation & Maintenance Phase

None of the three chosen cases have been completely commissioned and haven't reached the operation and maintenance phase yet. Thus, the challenges and obstacles obtained in this phase have been speculated to be a probable challenge or an obstacle by the practitioners working in these cases. As seen in Table 36, only a few challenges and obstacles have been identified or speculated. Of all the challenges speculated, few of them were categorized under two (*Information Asymmetries and*

Externalization of costs) of the four types of Market Failures and the remaining have been categorized under two *(Infrastructural and Institutional failure*) of the four types of Structural System failure. Currently, no speculated challenge was categorized under Transitional Failure. The reason for limited challenges or obstacles in this phase is mainly due to lack of sufficient information and lack of awareness by the practitioners and more challenges and obstacles could be faced or identified during the ongoing or end of this phase for all the cases.

Decommissioning Phase

Since the chosen case are currently in the construction phase, the wind farms will reach the decommissioning phase only after 20-25 years from now. Thus, all the challenges and obstacles identified in this phase have been speculated to be a probable challenge or an obstacle by the practitioners working in these cases. As seen in Table 38, only a few challenges and obstacles have been identified or speculated. Of all the challenges speculated, most of them were categorized under Market Failures particularly under Information Asymmetries, Knowledge Spill over and Externalization of costs. The challenge or obstacle of *lack of information* under Information Asymmetries was noticed for all the three cases and the remaining one challenge or obstacle i.e. *lack of urgency* has been categorized as Directionality failure under Transitional failures. Currently, no speculated challenge was categorized under Structural system Failure. Similar to the operation and maintenance phase, the reason for limited challenges or obstacles in this phase is mainly due to lack of sufficient information and lack of awareness by the practitioners and more challenges and obstacles could be faced or identified during the ongoing or end of this phase for all the cases.

4.4.3 Expert Validation

The results obtained from cross case analysis were validated by experts working in the wind energy sector. The validation is based on two unstructured interviews with experts who have knowledge on circular economy and have been working in the wind energy sector for approximately more than ten to fifteen years. The first interviewee is the Manager of Business unit: Energy Transition at Witteveen+Bos, Netherlands and the second interviewee is a Senior offshore and Coastal expert at Witteveen+Bos, Belgium. The main aim of this expert validation was to discuss the findings from the cases and to analyze the transferability of the challenges and obstacles identified from the case studies and to test the generalizability of these findings. Experts from two different countries were interviewed to test the generalizability of the findings. Experts form different organizations were also considered for validation but could not be done due to time constraints and unavailability.

Firstly, both the interviewees could recognize and comprehend all the identified challenges and obstacles. Although there might have been a few unidentified challenges or obstacles that came across as unexpected, but the interviewees acknowledged all the identified challenges and obstacles. When it comes to transferability and generalizability of the results, both the interviewees have the opinion that the challenges and obstacles identified majorly depend on which country the project is located, the maturity of the wind industry, work ethics and the experience of the respondents. On the whole, the interviewees believe that the obtained results could serves as a basis to foresee the challenges and obstacles for circular transition within the wind energy sector.

4.5 Summary: Sub-Research Question 3

The main objective of this chapter was to provide an answer to the sub research question 3;

What are the challenges identified when a circular transition intervenes with the ongoing energy transition for the wind energy sector in the Netherlands?

Several challenges and obstacles were identified for each phase of wind farm development. First, for the design and development phase, under market failures various challenges and obstacles were categorized of which Lack of Information, Lack of Knowledge, Cost Incentive, Easy Access to Resource were observed in all the three cases. Under structural system failures, of all the challenges and obstacles identified, Lack of R&D and Technology and Lack of Resources & Expertise were observed in all the three cases, and finally under transitional failures, Lack of Need or Incentive, Lack of Shared Vision and Involvement of Suppliers were few of the identified challenges that were observed in all three cases. An overview of all the challenges and obstacles identified for the design and development phase can be seen in APPENDIX E under design and development phase.

Second, for the construction phase, under market failures various challenges and obstacles were categorized of which Cost Incentive was observed in all the three cases. Under structural system failures, of all the challenges and obstacles identified, Lack of Communication & Interaction and Lack of Resources & Expertise were observed in all the three cases, and finally under transitional failures, Lack of Need or Incentive was one of the few identified challenges that was observed in all three cases. An overview of all the challenges and obstacles identified for the construction phase can be seen in APPENDIX E under Construction Phase.

Third, for the operation & maintenance phase all the challenges and obstacles obtained in this phase have been speculated to be a probable challenge or an obstacle by the practitioners working in these cases. No particular challenge or an obstacle identified was noticed in all the three cases. The challenges and obstacles identified were categorized only under market and structural system failures and none in transitional system failure. An overview of all the challenges and obstacles identified for the operation & maintenance phase can be seen in APPENDIX E under operation & maintenance phase.

Finally, also for the decommissioning phase, all the challenges and obstacles obtained in this phase have been speculated to be a probable challenge or an obstacle by the practitioners working in these cases. Only Lack of Information categorized under market failure was noticed in all the three cases. No challenges or obstacle was categorized under structural system failure. Few challenges and obstacles were categorized under transitional failures, but none were observed in all the three cases. An overview of all the challenges and obstacles identified for decommissioning phase can be seen in APPENDIX E under decommissioning phase.

5. Discussion

This chapter focuses on the fourth sub-research question: *What are the implications of these challenges when two transitions (Circular economy and Energy transition) for the wind energy sector intervene?* The chapter starts with section 5.1, where the research findings are discussed in relation to circular aspects and the conceptual framework obtained from literature. Followed by section 5.2, which discusses the practical implications of the research. Finally, section 5.3 concludes the discussion chapter.

5.1 Conceptual Implications

Circular Aspects

As mentioned in the literature review, there has been a limited application of circular economy principles in the construction sector within the whole systems perspective, and this holds true for the wind energy sector as well. Table 1:Circular economy aspects for circular construction (Adams, et al., pg. 3, 2017) has an overview of circular economy aspects for circular construction and these aspects have been gathered from various literature and were taken into consideration for the wind farm construction as well.

Within the design and development phase it is noticed that the aspects like *design out waste, specify reclaimed and recycled materials and use secondary materials have the least consideration* which shows that the practitioners within the wind energy sector hesitate to use secondary or reused or recycled material for the wind farm development. All or most of the other aspects that are taken into consideration are being considered either because it is an obligation or because there is a cost incentive to it and not because they want to be more circular per se. For instance, design for deconstruction or design for standardization are taken into consideration because it is a legal requirement to obtain the permit to build the wind farm. And aspects like *Use less materials/optimize material use* and *Use less hazardous material* are taken into consideration to cut down on costs. Even within the construction phase it is noticed that the aspects like procure recycled materials or procure reused materials have the least consideration which substantiates my previous statement, the practitioners within the wind energy sector hesitate to use reused or recycled material for the wind farm construction. All the other aspects particularly the aspects under the operation and maintenance phase are solely being considered either because it is an obligation to obtain permit or to reduce cost overruns. Like *minimize waste, minimal maintenance, easy repair and upgrade and adaptability & flexibility,* all of them are just taken into consideration to reduce cost overruns although it is in favor of circular transition. Within the decommissioning phase, the aspects of deconstruction and selective demolition are being considered because it is an obligation to do so and no statement can be made on the other aspects as of yet, because the cases selected have not reached the decommissioning phase yet and the practitioners are not really sure about the consideration of those aspects.

On the whole, all the circular economy aspects for circular construction were also applicable for wind farm construction and no additional circular aspect was identified during the process of data collection. Although there might be room to expand the conceptual scope and add more circular aspects to the Table 1:Circular economy aspects for circular construction (Adams, et al., pg. 3, 2017), the existing table served the purpose of identifying all the circular aspects being incorporated/not incorporated during the development of wind farms.

Literature review also mentions that several studies regarding the environmental impact of wind turbines and turbine recycling, especially for blades have been carried out. Targets for recyclability have also been set by few manufacturers for their wind turbines (Andersen, et al., 2014). Using the concept of circular economy, Hao, et al., (2020) recommend recycle of the anthropogenic materials in the form of extracted carbon fibers to close the circular economy loop.

However, what can be inferred from the obtained results is that although the practitioners set targets for recyclability, practitioners within the wind energy sector hesitate to use recycled material for the wind farm construction. Ghisellini et al., (2016) also state that focus lies mainly on recycling rather than high-quality re-using of materials. From the obtained results it can be seen that practitioners within the wind energy sector hesitate to use secondary or reused or recycled material for the wind farm development. More often than not, they do not specify or procure reused or recycled materials and few of the many reasons for this is due to uncertainty in quality and higher costs. At the end of life, the materials are considered for recycling but for other purposes and not for the wind farm construction per se. This might be one of the reasons why focus just lies mainly on recycling rather than high-quality re-using of materials.

Several authors have conducted research and triggered discussion in terms of circular economy for the energy transition. Gielen & Saygin, (2019) have an opinion that Circular economy is related to the concept of energy transition by building on the foundations of energy efficiency and renewable energy and suggest that new policies, new regulatory mechanisms, new funding methods and even digital marketplaces for the management of the circular economy would be required to guide this growth in a different direction. Chen, W. M., & Kim, H. (2019) performed an extensive analysis of the circular economy and energy transition frameworks and found that there is a crucial void in the energy transition system, it cannot provide a basis for the investigation of non-energy use. Their study suggested that energy transition discourse needs to be expanded to include the transition from non-energy usage and the achievement of a closed non-energy usage loop, which is part of the circular economy. Hao, et al., (2020), used the concept of circular economy to reenter the anthropogenic materials used for wind turbines, in the form of carbon fibers at the highest standard possible and recommends the reuse of extracted carbon fibers to close the circular economy loop. Giurco, et al., (2014), conducted a research to view the future of mineral and energy production and what the mineral-energy nexus looks like. They use three illustrative examples at the nexus of (i) rare earths-renewables, (ii) coal-steel and (iii) uranium-nuclear and introduce a research agenda for an extended definition of responsible minerals that acknowledges the importance of the mineral-energy nexus and ties it to sustainable future developments. Metabolic, (2018) also conducted research on metal demand for renewable electricity generation in the Netherlands and proposed implementation of global and strong climate policies along with circular economy strategies to reduce critical metal dependence and to ensure sufficient supply of metals. On similar lines, this research also focused on circular economy for the energy transition, particularly the wind energy sector and made a first attempt to identify the challenges and obstacles when circular transition intervenes with the wind energy transition. The results obtained show that there are several challenges and obstacles when circular transition intervenes with the wind energy transition and the plethora of challenges and obstacles indicate the onset of circular transition for the wind energy sector and is currently at the early stages.

Failures Framework

Weber & Rohracher's failures framework was particularly designed to legitimize policies for a transformative change and so far, the framework was used in a lot of scenarios particularly for innovation systems and innovation policies. However, a first attempt was made to use this Weber & Rohracher's failures framework to capture challenges and obstacles for circular transition and incorporation of circular aspects at implementation and project level particularly focused at each phase of wind farm development. Weber & Rohracher's failures framework was quite suitable and practical for the analysis of the obtained data as it allowed to qualify several identified challenges and obstacles to adopt circular transition in each phase of wind farm development for cases chosen within the Netherlands. The significance of the failures framework is that firstly, it integrates market, transition and innovation studies insights into one framework that highlights twelve different types of failures and secondly, all the challenges and obstacles to adopt circular transition for the wind energy sector identified in this research could be grouped and categorized under the twelve different types of failures. However, no particular challenge or obstacle identified was grouped under the Reflexivity failure. Reflexivity, in general refers to the assessment of one's own viewpoints, decisions and practices during the research process and how these may have influenced the research or field of work (Finlay 1998). Currently, not much has been done in terms of circular economy for the wind energy sector and thus there might have been no assessment to reflect upon and hence no particular challenge or obstacle was identified currently. However, the reflexivity failure is relevant to all the three types of transitional failures (Directionality, Policy coordination and Demand articulation) and has its own repercussions. Thus, reflexivity failure could be anticipated in the near future. Although Weber & Rohracher's failures framework was suitable and appropriate for this research, it had few challenges and downsides which are described in detail below.

First, the amount of failures Weber and Rohracher identify leaves the researcher with a plethora of choices which becomes a challenge on how to code and classify the challenges and obstacles that appear from data analysis. Furthermore, certain failures mentioned within the framework seem to be interrelated. For instance, within the market failures, knowledge spill over (lack of knowledge) seems related to information asymmetries (lack of information) for example, poor knowledge transfer might lead to lack of sufficient information and asymmetric information. In terms of structural system failures and transitional failures, infrastructure failure (lack of R&D and Technology, Lack of Knowledge) seems related to capabilities failure (Lack of Resources and Expertise), without the required resources and expertise, there would be lack in technology and knowledge infrastructure. The directionality failure (Lack of need/incentive and Lack of shared vision) seems related to institutional failure (Lack of regulation & appropriate policies, Lack of control and liberal approach) as poorly aligned regulations and policies and liberal approach can be regarded as the result of lack of need/incentive and lack of directionality when these policies were drafted. The directionality failure (Lack of shared vision) also seems related to the policy coordination failure due to lack of commonly shared vision. All the three failures might also have roots in Network or Interaction Failure (Lack of interaction and Lack of innovation). The later also seems related to demand articulation failure (Involvement of suppliers). There is a lack of interaction between suppliers and the clients or the suppliers and the contractors which serves as an obstacle for the circular transition. Overall, I believe most of the failures are interrelated.

Second, one of the conceptual dilemmas faced during the data collection and analysis process and also mentioned by the experts during validation is the fundamental use of the term 'failures' and what they actually are. Do they relate to the fact of not doing something you must or expected to do more in a physical sense or rather failures in terms of policy/institutional framework causing undesirable consequences when implemented? Also, most of the respondents consider the term 'failures' as a negative aspect and would rather not use the word. Thus, I wonder if an alternative term could be used. Also, in case of an empirical research, I wonder what could be the 'dependent variable' while using the sustainable transition failures framework.

Finally, although there might be room to expand the conceptual scope of the failures framework, it serves the purpose to capture all the challenges and obstacles faced by the practitioners to adopt and embrace circular transition for each phase of wind farm development and was successfully used at implementation and project level making it suitable to capture challenges and obstacles hindering circular transition for the wind energy sector and potentially for the construction and development of other energy transition sectors as well.

5.2 Practical Implications

Three different case studies were conducted for this research and for each case one actor from the owners/developers, engineering and consultancy firms, contractors and the manufacturers/supplier's perspective was taken into consideration which gives an overview of challenges and obstacles throughout the supply chain. Having taken multiple actor perspective for the research makes the research relevant for all the organizations that would be involved for the development of a wind farm and would want to incorporate the aspects of circularity.

The challenges and obstacles obtained for the Design & Development phase can assist and benefit the owners/ developers, engineering and consultancy firms and suppliers/manufactures of wind turbines. The challenges and obstacles obtained for the construction phase can assist and benefit the contactors responsible for foundations of turbines and suppliers/manufactures responsible for turbine installation. Although very few challenges and obstacles could be identified for the operation phase and decommissioning phase, they can still assist the owners/ developers and the contractors who are responsible for operation phase and decommissioning phase respectively.

Like mentioned in literature review, the aspect of circular economy is still at the nascent stage for the wind energy sector or for the whole of the energy transition sectors for that matter. This research is one of the first steps taken to identify the challenges and obstacles for adopting circular transition for the energy transition sectors, particularly the wind energy sector. Several challenges and obstacles were identified for each phase of wind farm development and even though all the identified challenges and obstacles may not be seen for all the cases, they sure can serve as a foundation and can be used as a guideline to avoid slipups while trying to embrace circular transition.

One of the main reasons for selecting three different cases (onshore, offshore and near the shore) is to get a complete overview of the wind energy sector in terms of challenges and obstacles to adopt circular aspects. Section 4.4 highlights the cross-case comparison between all the three cases and more often than not, it is seen that the challenges and obstacles identified to adopt circular transition are very similar for all the three cases. Obviously, there are a few differences when it comes to onshore and offshore construction. From the opinion of the respondents and from the results obtained, the major difference between onshore and offshore windfarms is the material usage, equipment usage and logistics. Comparatively, offshore windfarms are often larger and require more materials, resources, fuel and equipment. While, onshore windfarms have roads and concrete foundations, offshore you are mostly dealing with steel. The size of the blades is also different for onshore and offshore windfarms and sometimes you need to have completely different construction and decommissioning techniques as well. There are also few concerns in terms of logistics for offshore windfarms as the materials and resources need to be shipped to the location from harbor and back to the harbor while decommissioning. Taking all these differences into consideration, it may require more planning and effort to adopt circularity for the offshore wind farms and considering more use of resources and materials, the need to adopt circularity might be higher for the offshore windfarms comparatively. However, in general, all the challenges and obstacles identified in this research are applicable to both onshore and offshore windfarms or all the wind farms in general within the Netherlands. Although the focus of the research was particularly on the wind energy sector, the obtained challenges and obstacles can also be speculated for other sectors (solar, biomass etc.) that particularly focus on energy transition. However, it may or may not be the case for every other sector undergoing circular transition.

All the challenges and obstacles identified have been categorized using Weber & Rohracher's failures framework which is a comprehensive framework that draws insights from transition studies and more significantly in a policy framework that is based on the innovations system approach and the multi-level perspective. Thus, the obtained results could also be very interesting for the policy makers to design and legitimize policies in order to promote the development and adoption of circular transition for the wind energy sector. Overall, the results obtained from the research could be very interesting and serve as a foundation for multiple actors within the wind energy sector.

5.3 Summary: Sub-Research Question 4

The main objective of this chapter was to provide an answer to the sub research question 4;

What are the implications of these challenges or obstacles when two transitions (Circular economy and Energy transition) for the wind energy sector intervene?

Conceptual Implications

As mentioned in the literature review, there has been a limited application of circular economy principles in the construction sector within the whole systems perspective, and this holds true for the wind energy sector as well. Table 1:Circular economy aspects for circular construction (Adams, et al., pg. 3, 2017) has an overview of circular economy aspects for circular construction and these aspects have been gathered from various literature and were taken into consideration for the wind farm construction as well. On the whole, all the circular economy aspects for circular construction were also applicable for wind farm construction and no additional circular aspect was identified during the process of data collection. Although there might be room to expand the conceptual scope and add more circular aspects, the existing table served the purpose of identifying all the circular aspects being incorporated/not incorporated during the development of wind farms.

Several authors have conducted research and triggered discussion in terms of circular economy for the energy transition and on similar lines, this research also focused on circular economy for the energy transition, particularly the wind energy sector and made a first attempt to identify the challenges and obstacles when circular transition intervenes with the wind energy transition. The results obtained show that there are several challenges and obstacles when circular transition intervenes with the wind energy transition and the plethora of challenges and obstacles indicate the onset of circular transition for the wind energy sector and is currently at the early stages.

A first attempt was made to use this Weber & Rohracher's failures framework to capture challenges and obstacles for circular transition and incorporation of circular aspects at implementation and project level particularly focused at each phase of wind farm development. The framework had both advantages and downfalls. Although there might be room to expand the conceptual scope of the failures framework, it served the purpose to capture all the challenges and obstacles faced by the practitioners to adopt and embrace circular transition for each phase of wind farm development and was successfully used at implementation and project level making it suitable to capture challenges and obstacles hindering circular transition for the wind energy sector and potentially for the construction and development of other energy transition sectors as well.

Practical Implications

This research is one of the first steps taken to identify the challenges and obstacles for adopting circular transition for the energy transition sectors, particularly the wind energy sector. Three different case studies were conducted for this research and for each case one actor from the owners/developers, engineering and consultancy firms, contractors and the manufacturers/supplier's perspectives were taken into consideration. Several challenges and obstacles were identified for each phase of wind farm development and even though all the identified challenges and obstacles may not be seen for all the cases, having taken multiple actor perspective for the research makes the research relevant for all the organizations that would be involved for the development of a wind farm and would want to incorporate the aspects of circularity. All the challenges and obstacles identified can serve as a foundation and can be used as a guideline to avoid slipups while trying to embrace circular transition.

The research focuses on onshore, offshore and near the shore cases. Offshore wind farms comparatively use more resource and materials and may require more planning and effort to adopt circularity and the need to adopt circularity might be higher for the offshore windfarms comparatively. However, in general, all the challenges and obstacles identified in this research are applicable to both onshore and offshore windfarms or all the wind farms in general within the Netherlands.

Overall, the results obtained from the research could be very interesting and serve as a foundation for multiple actors within the wind energy sector and could also be very interesting for the policy makers to design and legitimize policies in order to promote the development and adoption of circular transition for the wind energy sector.

6. Conclusion

In this chapter the conclusions of the research are described by primarily answering all the sub-research questions in section 6.1 followed by answer to the main research question in section 6.2. Section 6.3 is focused on research limitations which is followed by recommendations for further research in section 6.4. This chapter ends with section 6.5 which focuses on recommendations for practice.

6.1 Answers to the Sub-Research Questions

I. *What transition approach describes best and is able to capture the challenges of a circular transition alongside the ongoing energy transition for the wind energy sector?*

Firstly, an elaborate literature review was conducted to understand the growth of the wind energy sector and the current state of energy transition, followed by the possibility of a circular transition for the wind energy as well. The circular aspects (circular construction) relevant for the development of a wind farm are also discussed. For this transition to befall, an elaborate literature review was conducted on transition studies, with a major focus on sustainable transitions like SNM, MLP, TM, TIS. Building on the analysis of complementarities between these frameworks, particularly on MLP and Innovation Systems framework, and by combining the four main types of system failures introduced by Woolthuis et al. (2005), market failures and four additional types of transition failures, Weber & Rohracher (2012) obtained a *comprehensive 'failures framework'* that address both structural and transitional failure. Considering, there does not exist a transition framework for a circular transition, the comprehensive 'failures framework' was considered the most feasible method to capture the challenges and obstacles for the circular transition alongside the ongoing energy transition for the wind energy sector.

II. *How to capture the challenges for adopting circular transition along with the ongoing energy transition of the wind energy sector in the Netherlands?*

Considering the explorative nature of the research with a focus on examining the contemporary events and to address the question on 'How' to capture the challenges for adopting circular transition along with the ongoing energy transition of the wind energy sector in the Netherlands, the 'Case Study' research strategy is chosen as the most suitable methodology to conduct this research. Three cases, an onshore- Wind farm Wieringermeer, an offshore- Borssele 1 & 2, and a near the shore- Wind Plan Blauw, cases are selected from various parts of the Netherlands. Data is collected from each case on various challenges and obstacles for the circular transition for the wind energy sector. Data collection for these cases is primarily done by interviews. In order to conduct the interviews, an interview protocol is adopted to give a complete insight and guidance during the interview which can be found in APPENDIX A.

The interview protocol basically consists of the introduction, interview questions and post interview analysis. A sample group of around 12 respondents (4 per case) are selected based on the respondent criteria, that consist of actors/stakeholders across all the life-cycle stages of a wind farm development in order to get a complete overview of challenges and obstacles for a circular transition for the wind energy sector in the Netherlands. Post interview, the transcribed documents are sent back to the respondents for verification. The collected data will be analyzed by a cross case analysis method. Firstly, the qualitative interview data is evaluated by applying open and axial coding techniques, following that an individual case report is written. Based on the documented data and individual case reports, cross case conclusions are drawn.

III. *What are the challenges identified when a circular transition intervenes with the ongoing energy transition for the wind energy sector in the Netherlands?*

Several challenges and obstacles were identified for each phase of wind farm development. First, for the design and development phase, under market failures various challenges and obstacles were categorized of which Lack of Information, Lack of Knowledge, Cost Incentive, Easy Access to Resource were observed in all the three cases. Under structural system failures, of all the challenges and obstacles identified, Lack of R&D and Technology and Lack of Resources & Expertise were observed in all the three cases, and finally under transitional failures, Lack of Need or Incentive, Lack of Shared Vision and Involvement of Suppliers were few of the identified challenges that were observed in all three cases. An overview of all the challenges and obstacles identified for the design and development phase can be seen in APPENDIX E under design and development phase.

Second, for the construction phase, under market failures various challenges and obstacles were categorized of which Cost Incentive was observed in all the three cases. Under structural system failures, of all the challenges and obstacles identified, Lack of Communication & Interaction and Lack of Resources & Expertise were observed in all the three cases, and finally under transitional failures, Lack of Need or Incentive was one of the few identified challenges that was observed in all three cases. An overview of all the challenges and obstacles identified for the construction phase can be seen in APPENDIX E under Construction Phase.

Third, for the operation & maintenance phase all the challenges and obstacles obtained in this phase have been speculated to be a probable challenge or an obstacle by the practitioners working in these cases. No particular challenge or an obstacle identified was noticed in all the three cases. The challenges and obstacles identified were categorized only under market and structural system failures and none in transitional system failure. An overview of all the challenges and obstacles identified for the operation & maintenance phase can be seen in APPENDIX E under operation & maintenance phase.

Finally, also for the decommissioning phase, all the challenges and obstacles obtained in this phase have been speculated to be a probable challenge or an obstacle by the practitioners working in these cases. Only Lack of Information categorized under market failure was noticed in all the three cases. No challenges or obstacle was categorized under structural system failure. Few challenges and obstacles were categorized under transitional failures, but none were observed in all the three cases. An overview of all the challenges and obstacles identified for decommissioning phase can be seen in APPENDIX E under decommissioning phase.

IV. *What are the implications of these challenges or obstacles when two transitions (Circular economy and Energy transition) for the wind energy sector intervene?*

Conceptual Implications

As mentioned in the literature review, there has been a limited application of circular economy principles in the construction sector within the whole systems perspective, and this holds true for the wind energy sector as well. Table 1:Circular economy aspects for circular construction (Adams, et al., pg. 3, 2017) has an overview of circular economy aspects for circular construction and these aspects have been gathered from various literature and were taken into consideration for the wind farm construction as well. On the whole, all the circular economy aspects for circular construction were also applicable for wind farm construction and no additional circular aspect was identified during the process of data collection. Although there might be room to expand the conceptual scope and add more circular aspects, the existing table served the purpose of identifying all the circular aspects being incorporated/not incorporated during the development of wind farms.

Several authors have conducted research and triggered discussion in terms of circular economy for the energy transition and on similar lines, this research also focused on circular economy for the energy transition, particularly the wind energy sector and made a first attempt to identify the challenges and obstacles when circular transition intervenes with the wind energy transition. The results obtained show that there are several challenges and obstacles when circular transition intervenes with the wind energy transition and the plethora of challenges and obstacles indicate the onset of circular transition for the wind energy sector and is currently at the early stages.

A first attempt was made to use this Weber & Rohracher's failures framework to capture challenges and obstacles for circular transition and incorporation of circular aspects at implementation and project level particularly focused at each phase of wind farm development. The framework had both advantages and downfalls. Although there might be room to expand the conceptual scope of the failures framework, it served the purpose to capture all the challenges and obstacles faced by the practitioners to adopt and embrace circular transition for each phase of wind farm development and was successfully used at implementation and project level making it suitable to capture challenges and obstacles hindering circular transition for the wind energy sector and potentially for the construction and development of other energy transition sectors as well.

Practical Implications

This research is one of the first steps taken to identify the challenges and obstacles for adopting circular transition for the energy transition sectors, particularly the wind energy sector. Three different case studies were conducted for this research and for each case one actor from the owners/developers, engineering and consultancy firms, contractors and the manufacturers/supplier's perspectives were taken into consideration. Several challenges and obstacles were identified for each phase of wind farm development and even though all the identified challenges and obstacles may not be seen for all the cases, having taken multiple actor perspective for the research makes the research relevant for all the organizations that would be involved for the development of a wind farm and would want to incorporate the aspects of circularity. All the challenges and obstacles identified can serve as a foundation and can be used as a guideline to avoid slipups while trying to embrace circular transition.

The research focuses on onshore, offshore and near the shore cases. Offshore wind farms comparatively use more resource and materials and may require more planning and effort to adopt circularity and the need to adopt circularity might be higher for the offshore windfarms comparatively. However, in general, all the challenges and obstacles identified in this research are applicable to both onshore and offshore windfarms or all the wind farms in general within the Netherlands.

Overall, the results obtained from the research could be very interesting and serve as a foundation for multiple actors within the wind energy sector and could also be very interesting for the policy makers to design and legitimize policies in order to promote the development and adoption of circular transition for the wind energy sector.

6.2 Answer to the Main Research Question

"What challenges or obstacles hinder the transition towards circular economy alongside the ongoing energy transition for the wind energy sector in the Netherlands?"

A comprehensive list of challenges and obstacles were identified for each phase of wind farm development which can be seen in APPENDIX E. These broad lists of challenges identified in each phase of wind farm development show that although wind energy sector is outdoing in terms of energy transition and transformation towards a zero-carbon future, it is still at its infancy when it comes to circular transition. Energy transition was in discussion for decades and finally you can notice the transition. However, it took a lot of effort in corporate innovation, trial research, getting the regulations right etc. for this transition to befall. Perhaps it might be the same case for circular transition as well. It is a concept that has to be matured and then be incorporated.

Focusing a bit more in detail on the comprehensive list of identified challenges and obstacles, they are categorized under the twelve failures mentioned in the failures framework distinctly for each phase of wind farm development which are categorized are listed below in Table 39. The failures that are highlighted in orange were observed in all the three cases. Eleven out of twelve types of failures were identified in the design and development phase and ten out of twelve types of failures were identified in the construction phase. And of all the challenges and obstacles identified majority of them were categorized under *directionality failure* followed by *institutional failure.* These failures have been highlighted in orange and underlined in blue. However, no challenges and obstacles have been categorized under these two failures in operation & maintenance phase and decommissioning phase only because the cases taken into consideration have not reached these phases of development yet. But these failures can be speculated to occur in both operation phase and decommissioning phase.

What can also be of interest is even though there are major differences for the development of onshore and offshore wind farms particularly in terms of materials and equipment used, construction and decommissioning techniques, logistics etc. the identified challenges and obstacles hindering the circular transition are more or less the same for both the types of wind farms making the results applicable to almost all the projects within the wind energy sector in the Netherlands. Although, all the identified challenges and obstacles may not be applicable to every case but, the framework of failures obtained from this research definitely serves as a foundation or the starting point to understand why there is reluctance to adopt circular transition for the wind energy sector and what challenges are hindering this transition.

On the whole, this research gives an overview of challenges and obstacles hindering circular transition for each phase of wind farm development and for the wind energy sector in general. The research also highlights different circular aspects and their level of consideration during the development of wind farms. Although the research does not focus on providing solutions to the identified challenges and obstacles hindering circular transition and focuses on just the wind energy sector, it definitely takes one step towards the nexus of energy transition and circular transition.

Table 39: Challenges hindering the transition towards circular economy alongside the ongoing energy transition for the wind energy sector in the Netherlands

	Market Failures	Structural System Failures	Transitional System Failures
Design & Development Phase	➢ **Information Asymmetries** ➢ **Knowledge Spill over** ➢ **Externalization of costs** ➢ **Over exploitation of commons**	➢ **Infrastructural Failure** ➢ **Institutional Failure** ➢ Interaction or Network Failure ➢ **Capabilities Failure**	➢ **Directionality Failure** ➢ **Demand Articulation Failure** ➢ Policy Coordination Failure
Construction Phase	➢ Information Asymmetries ➢ Knowledge Spill over ➢ Externalization of costs	➢ Infrastructural Failure ➢ **Institutional Failure** ➢ **Interaction or Network Failure** ➢ **Capabilities Failure**	➢ **Directionality Failure** ➢ Demand Articulation Failure ➢ Policy Coordination Failure
Operations & Maintenance Phase	➢ Information Asymmetries ➢ Externalization of costs	➢ Infrastructural Failure ➢ Institutional Failure	
Decommissioning Phase	➢ **Information Asymmetries**	➢ Infrastructural Failure	➢ Directionality Failure

6.3 Research Limitations

Although having put a lot of effort to identify all the challenges and obstacles to adopt circular transition for the wind energy sector, there are certain limitations to this research which are explained in detail below.

First, the research could only analyze three cases and interview only limited people for each phase of windfarm development per case, due to unavailability and time constraints which limits the generalizability of the research. Maybe more challenges and obstacles could have been identified if more practitioners were interviewed or if more case studies were conducted. Also, all the cases chosen for the research are within the Netherlands which again limits the generalizability of the results. Even though the results obtained may or may not be foreseen in other countries, they are particularly focused for the wind energy sector in the Netherlands since the results obtained depend on which country the case is located, work culture, experience of the practitioners and the maturity of the wind energy sector.

Second, one of the limitations to the obtained results is that they might have been subject to the interpretation of the researcher. Although the obtained data was coded based on a repetitive pattern from the excerpts of the transcribed interview, all the challenges and obstacles identified were labelled by the researcher and were categorized in the framework based on his understanding and interpretation.

Third, all the cases chosen are still in the construction phase and have not reached the operation phase and decommissioning phase yet. Thus, there is a limitation to the results obtained for the operation phase and decommissioning phase. More challenges and obstacles could have been identified if the cases chosen had gone through all the four phases of wind farm development

Fourth, the research primarily focused on construction and installation of wind turbines and not so much on the construction and installation of the park cables, including substation and switching stations. Maybe a different set of challenges and obstacles would hinder the transition towards circular economy for the latter.

Finally, the comprehensive 'failures' framework adopted for the research is not often used to capture challenge and obstacles for implementation and project phase and has not been used particularly for circular transition. The framework is often used for innovation systems, innovation policies and sustainable transitions. Due to the relative uncommon application of this framework not much literature could be found to verify and validate its interpretation and application for the research.

6.4 Recommendations for Future Research

- Research could be conducted on wind farms that have been decommissioned in order to get a complete overview of challenges in both operation and maintenance phase and decommissioning phase.
- Since the research conducted focuses on cases within the Netherlands, further research could be conducted on cases in different geographic locations (countries) to test the generalizability of the results.
- The research gives an overview of challenges and obstacles per each phase of development based on limited perspectives. Perhaps more research could be done with a focus on one particular phase of wind farm development and multiple practitioner perspective for that particular phase.
- The future research could also take into consideration the construction and installation of the park cables, including substation and switching stations while identifying the challenges and obstacles hindering circular transition for the wind energy sector.
- A comprehensive list of challenges and obstacles have been identified hindering circular transition for the wind energy sector, research could also be conducted for challenges and obstacles hindering circular transition for other energy transition sectors.
- Since most of the challenges identified were categorized under directionality failure or institutional failure, perhaps a fine-grained research could be conducted on these challenges.
- Further research could also be done to find solutions in order to overcome these identified challenges and obstacles hindering circular transition for the wind energy sector.

6.5 Recommendations for Practice

Based on the challenges and obstacles identified in each phase of wind farm development, certain recommendations are suggested for practice during the construction and development and the complete life cycle of a wind farm.

Design and Development phase is the key to incorporate the aspects of circularity for the entire project lifecycle. It is the phase where you can get information for things like materials passports, life-cycle analysis and have an understanding regarding the full breakdown of the products being used which can give a clear picture during the end of life of the product and therefore can be reused or recycled accordingly. And all of these aspects need to be factored into the contract.

It could be very interesting if the developer or the local government could state what the circular goals of the project are during the early design phases of the project. And the government could work on coming up with strict regulations and change permit conditions making circular aspects a need and incentive for the wind energy sector. There is a need for new policies, new regulatory frameworks and even new financing tools for the management of a circular economy. Not just the role of the governments would help this transition but also the decision makers at the developers side lack awareness and they don't push for circular aspects or ask for it and the contractor and suppliers don't deliver if not asked and I think that's how you can break the cycle, start from the developer side. In the early phases of the project you could contractually oblige the developer to make sure that the circular aspect is considered in contracting.

In order to make circularity an incentive, the first step would be making it a tender obligation. The ministry of a province can adopt the quality demands into the tender regarding circularity for wind farms and this could be one of the major aspects to score points within the tender.

A unique selling point would be if the suppliers and manufacturers can make circular economy the main focal point. Currently, supplier involvement is lacking in the early phases of design and development. So, bringing the turbine suppliers early into the process and having the technical competencies early into the process could be helpful. Also, you could probably introduce a couple of design sessions with maybe developers, consultants and suppliers and look at the potential options in terms of circularity. For instance, the suppliers can test the wind turbines and probably would like to use less materials.

Also, incentivizing research and development activities, recycling technologies and scaling up the existing recycling technologies can urge the recycling and waste management companies to enhance the existing technologies and find solutions to the current problems such as blade waste and fiber glass composites.

One of the major reasons why practitioners hesitate to use secondary and recycled materials is due to the uncertainty in quality. This can be avoided if the recycling companies can provide certificate of proof for the recycled materials and also by conducting pilot studies to show the use of secondary and recycled material for wind farm development.

On the whole, circular transition cannot be achieved for the wind energy sector only if one or few actors focus on circular economy. It is a joint development in the network of value chain.

7. Bibliography

- Adams, K. T., Osmani, M., Thorpe, T., & Thornback, J. (2017, February). Circular economy in construction: current awareness, challenges and enablers. In Proceedings of the Institution of Civil Engineers-Waste and Resource Management (Vol. 170, No. 1, pp. 15-24). Thomas Telford Ltd.
- Amaratunga, D., Baldry, D., Sarshar, M., & Newton, R. (2002). Quantitative and qualitative research in the built environment: application of "mixed" research approach. Work Study, 51(1), 17–31. doi: 10.1108/00438020210415488
- Analysis: Why scientists think 100% of global warming is due to humans. (2020, January 28). Retrieved from https://www.carbonbrief.org/analysis-why-scientists-think-100-of-global-warming-is-due-to-humans
- Andersen, P. D., Bonou, A., Beauson, J., & Brøndsted, P. (2014). Recycling of wind turbines. In H. Hvidtfeldt Larsen, & L. Sønderberg Petersen (Eds.), DTU International Energy Report 2014: Wind energy — drivers and barriers for higher shares of wind in the global power generation mix (pp. 91-97). Technical University of Denmark.
- Anonymous. (2016, November 23). EU law on climate change and protection of the ozone layer. Retrieved from https://ec.europa.eu/clima/about-us/climate-law_en
- Anonymous. (2019, November 15). Paris Agreement. Retrieved from https://ec.europa.eu/clima/policies/international/negotiations/paris_en
- BAM Infra Nederland bouwt fundaties voor windpark Wieringermeer van. (n.d.). Retrieved September 02, 2020, from https://www.bam.com/nl/pers/persberichten/2017/11/bam-infra-nederland-bouwt-fundaties-voor-windpark-wieringermeer-van-nuon
- Barriball, K. L., & While, A. (1994). Collecting data using a semi-structured interview: A discussion paper. *Journal of Advanced Nursing, 19*(2), 328-335. doi:10.1111/j.1365-2648.1994.tb01088.x
- Basics of Wind Energy. (n.d.). Retrieved from https://www.awea.org/wind-101/basics-of-wind-energy
- Bilali, H. E. (2019). The Multi-Level Perspective in Research on Sustainability Transitions in Agriculture and Food Systems: A Systematic Review. Agriculture, 9(4), 74. doi: 10.3390/agriculture9040074
- Blanco, C. F., Cucurachi, S., Peijnenburg, W. J. G. M., Beames, A., & Vijver, M. G. (2020). Are Technological Developments Improving the Environmental Sustainability of Photovoltaic Electricity? Energy Technology, 1901064. doi: 10.1002/ente.201901064
- Borssele 1 & 2. (n.d.). Retrieved August 04, 2020, from https://orsted.nl/onze-windparken/borssele-1-and-2?utm_source=googleads
- Borssele 1 and 2 wind farms off the Netherlands coast. (n.d.). Retrieved August 04, 2020, from https://www.nexans.com/newsroom/news/details/2018/11/Nexans-is-awarded-a-multimillion-euro-contract-for-Orsteds--Borssele-1-and-2-wind-farms-off-the-Netherlands-coast.html
- Caniëls, M. C., & Romijn, H. A. (2008). Strategic niche management: towards a policy tool for sustainable development. Technology Analysis & Strategic Management, 20(2), 245–266. doi: 10.1080/09537320701711264
- Causes of climate change. (2017, June 28). Retrieved from https://ec.europa.eu/clima/change/causes_en
- Chen, W. M., & Kim, H. (2019). Circular economy and energy transition: A nexus focusing on the non-energy use of fuels. Energy & Environment, 30(4), 586-600.
- Citing ATLAS.ti in your research. (2020, February 16). Retrieved October 08, 2020, from https://atlasti.com/2020/01/31/citing-atlas-ti-in-your-research/
- Climate Change Evidence: How Do We Know? (2019, December 30). Retrieved from https://climate.nasa.gov/evidence/
- Corbin, J. S., & Strauss, A. A. 2008. *Basics of qualitative research: Techniques and procedures for developing grounded theory*, *3*.

- Creswell, J. W. (1998). Qualitative inquiry and research design: Choosing among five traditions. Thousand Oaks, CA: Sage Publications.
- Dictionary, C. (2016). Cambridge Dictionaries Online [Electronic resource].
- Eisenhardt, K. M. (2010). Building theories from case study research. *Academy of management review*, *14*(4), 532-550.
- Ellen MacArthur Foundation. (2013). Towards the Circular Economy: Economic and business rationale for accelerated transition. Journal of Industrial Ecology. https://doi.org/10.1162/108819806775545321
- Ellen MacArthur Foundation. (2015). Growth Within: A Circular Economy Vision for a Competitive Europe. Owes: Ellen MacArthur Foundation
- European Circular Economy Stakeholder Platform. (2016, September). Retrieved from https://circulareconomy.europa.eu/platform/en/strategies/circular-economy-netherlands-2050
- Feola, G. (2014). Societal transformation in response to global environmental change: A review of emerging concepts. Ambio, 44(5), 376–390. doi: 10.1007/s13280-014-0582-z
- Finlay, L. (1998). Reflexivity: an essential component for all research? *British Journal of Occupational Therapy*, *61*(10), 453-456.
- Fowler Jr, F. J. (2013). Survey research methods. Sage publications.
- Future Of Wind. (2019). [e-book] International Renewable Energy Agency. Available at: <https://www.irena.org//media/Files/IRENA/Agency/Publication/2019/Oct/IRENA_Future_of_wind_2019.pdf>.
- Geels, F.W., Schot, J., 2007. Typology of sociotechnical transition pathways. Res. Policy 36, 399–417.
- Geels, F.W., Schot, J., 2010. The dynamics of sociotechnical transitions – a sociotechnical perspective. In: Grin, J., Rotmans, J., Schot, J. (Eds.), Transitions to Sustainable Development. Routledge, pp. 9–101.
- Geels, F. W. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. Environmental Innovation and Societal Transitions, 1(1), 24–40. doi: 10.1016/j.eist.2011.02.002
- Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. Journal of Cleaner Production, 114, 11–32. doi: 10.1016/j.jclepro.2015.09.00
- Gielen, D., & Saygin, D. (2019). Circular Economy for the Energy Transition. Payne Institute Commentary Series: Viewpoint
- Gill, P., Stewart, K., Treasure, E., & Chadwick, B. (2008). Methods of data collection in qualitative research: interviews and focus groups. British Dental Journal, 204(6), 291–295. doi: 10.1038/bdj.2008.192
- Giurco, D., McLellan, B., Franks, D. M., Nansai, K., & Prior, T. (2014). Responsible mineral and energy futures: views at the nexus. Journal of cleaner production, 84, 322-338.
- Government of Netherlands. (2016). A Circular Economy in the Netherlands by 2050 [PDF file]. Retrieved from file:///D:/Users/nadn/Downloads/17037+Circulaire+Economie_EN%20(1).PDF
- Greenwald, Bruce, Stiglitz, & Joseph. (1993, January 1). Financial Market Imperfections and Business Cycles. Retrieved from https://econpapers.repec.org/article/oupqjecon/v_3a108_3ay_3a1993_3ai_3a1_3ap_3a77-114.htm
- Hao, S., Kuah, A. T., Rudd, C. D., Wong, K. H., Lai, N. Y. G., Mao, J., & Liu, X. (2020). A circular economy approach to green energy: Wind turbine, waste, and material recovery. Science of The Total Environment, 702, 135054. doi: 10.1016/j.scitotenv.2019.135054
- Hölscher, K., Wittmayer, J. M., & Loorbach, D. (2018). Transition versus transformation: What's the difference? Environmental Innovation and Societal Transitions, 27, 1–3. doi: 10.1016/j.eist.2017.10.007

- Jamshed, S. (2014). Qualitative research method-interviewing and observation. Journal of Basic and Clinical Pharmacy, 5(4), 87. doi: 10.4103/0976-0105.141942
- Kalchenko, O., Evseeva, S., Evseeva, O., & Plis, K. (2019). Circular economy for the energy transition in Saint Petersburg, Russia. In E3S Web of Conferences (Vol. 110, p. 02030). EDP Sciences.
- Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the Circular Economy: An Analysis of 114 Definitions. SSRN Electronic Journal. doi: 10.2139/ssrn.3037579
- Korhonen, J., Honkasalo, A., & Seppälä, J. (2018). Circular Economy: The Concept and its Limitations. Ecological Economics, 143, 37–46. doi: 10.1016/j.ecolecon.2017.06.041
- Korhonen, J., Nuur, C., Feldmann, A., & Birkie, S. E. (2018). Circular economy as an essentially contested concept. Journal of Cleaner Production, 175, 544–552. doi: 10.1016/j.jclepro.2017.12.111
- Kunič, R. (2017). Carbon footprint of thermal insulation materials in building envelopes. Energy Efficiency, 10(6), 1511–1528. doi: 10.1007/s12053-017-9536-1
- Lavrakas, P. J. (2008). Encyclopedia of survey research methods. Sage Publications.
- Liu, P., & Barlow, C. Y. (2017). Wind turbine Blade waste in 2050. Waste Management, 62, 229–240. doi: 10.1016/j.wasman.2017.02.007
- Longo, S. B., & Clausen, R. (2011). The Tragedy of the Commodity. Organization & Environment, 24(3), 312–328. doi: 10.1177/1086026611419860
- Loorbach, Derk, & Kemp. (2007, September 1). Transition management: origin, evolution, critique. Retrieved from https://repub.eur.nl/pub/37240/
- Loorbach, D. (2010). Transition Management for Sustainable Development: A Prescriptive, Complexity-Based Governance Framework. Governance, 23(1), 161–183. doi: 10.1111/j.1468-0491.2009. 01471.x
- Loorbach, D., Frantzeskaki, N., & Huffenreuter, R. L. (2015). Transition Management: Taking Stock from Governance Experimentation. Journal of Corporate Citizenship, 2015(58), 48–66. doi: 10.9774/gleaf.4700. 2015.ju.00008
- Markard, J., Raven, R., & Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. Research Policy, 41(6), 955–967. doi: 10.1016/j.respol.2012.02.013
- Markard, J., Hekkert, M., & Jacobsson, S. (2015). The technological innovation systems framework: Response to six criticisms. Environmental Innovation and Societal Transitions, 16, 76–86. doi: 10.1016/j.eist.2015.07.006
- Metabolic, (2018). Navigating a complex supply chain. Retrieved from https://www.metabolic.nl/projects/critical-metal-demand-for-the-energy-transition
- Mey, G., & Mruck, K. (2011). *Grounded theory reader* (Vol. 2). Wiesbaden: VS Verlag für Sozialwissenschaften.
- Ministerie van Algemene Zaken. (2017, July 26). Wind energy on land. Retrieved from https://www.government.nl/topics/renewable-energy/wind-energy-on-land
- Ministerie van Algemene Zaken. (2020, April 29). Offshore wind energy. Retrieved from https://www.government.nl/topics/renewable-energy/offshore-wind-energy
- Ministerie van Economische Zaken en Klimaat. (2019, May 23). Kennisgeving Windplan Blauw, Ministerie van Economische Zaken en Klimaat. Retrieved July 27, 2020, from https://zoek.officielebekendmakingen.nl/stcrt-2019-27992.html
- Ministry of Economic Affairs, Netherlands. (2016). Energy Agenda: Towards a low carbon energy supply. Government of Netherlands.
- Morse, J. M. (1994). Designing funded qualitative research. In Denizin, N. K. & Lincoln, Y. S., Handbook of qualitative research (2nd Ed). Thousand Oaks, CA: Sage.
- Ness, D. A., & Xing, K. (2017). Toward a Resource-Efficient Built Environment: A Literature Review and Conceptual Model. Journal of Industrial Ecology, 21(3), 572-592.

- Netherlands - Energy Netherlands - Energy. (n.d.). Retrieved from https://www.export.gov/article?id=Netherlands-Energy
- Netherlands Enterprise Agency. (2018, July 24). Clean Energy Transition. Retrieved from https://www.hollandtradeandinvest.com/dutch-solutions/clean-energy
- Newsletter Editorial: Building a Sustainable Wind Industry For The Energy Transition. (2019, October 14). Retrieved from https://gwec.net/newsletter-editorial-building-a-wind-industry-for-the-energy-transition/
- Ogg, F., 2018. The Netherlands. [ebook] WWEA Policy Paper Series (PP-02-18-C). Available at: <https://www.wwindea.org/wp-content/uploads/2018/06/the_netherlands_full.pdf>
- Reike, D., Vermeulen, W. J., & Witjes, S. (2018). The circular economy: New or Refurbished as CE 3.0? — Exploring Controversies in the Conceptualization of the Circular Economy through a Focus on History and Resource Value Retention Options. Resources, Conservation and Recycling, 135, 246–264. doi: 10.1016/j.resconrec.2017.08.027
- Rijkswaterstaat. (2015). Circular economy in the Dutch construction sector. [PDF file]. Netherlands. Rijkswaterstaat – Water, Verkeer en Leefomgeving National Institute for Public Health and the Environment (RIVM). Retrieved from https://www.rivm.nl/bibliotheek/rapporten/2016-0024.pdf
- Rogelj, J., Den Elzen, M., Höhne, N., Fransen, T., Fekete, H., Winkler, H., ... & Meinshausen, M. (2016). Paris Agreement climate proposals need a boost to keep warming well below 2 C. Nature, 534(7609), 631-639.
- Schot, J., & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. Technology Analysis & Strategic Management, 20(5), 537–554. doi: 10.1080/09537320802292651
- Silva, A., & Stocker, L. (2018). What is a transition? Exploring visual and textual definitions among sustainability transition networks. Global environmental change, 50, 60-74.
- Statistics Netherlands. (2018, March 5). More wind and solar electricity. Retrieved from https://www.cbs.nl/en-gb/news/2018/09/more-wind-and-solar-electricity
- Stirling, A., 2014. Emancipating Transformations: From Controlling 'the Transition' to Culturing Plural Radical Progress, STEPS Working Paper 64. STEPS Centre, Brighton.
- Switch to a circular economy is vital, also for the energy transition. (n.d.). Retrieved from https://www.ecn.nl/news/item/switch-to-a-circular-economy-is-vital-also-for-the-energy-transition/index.html
- Trachuk, A., & Linder, N. (2019, May 28). Knowledge Spillover Effects: Impact of Export Learning Effects on Companies' Innovative Activities. Retrieved from https://www.intechopen.com/books/current-issues-in-knowledge-management/knowledge-spillover-effects-impact-of-export-learning-effects-on-companies-innovative-activities
- Transitions. (n.d.). Retrieved from https://drift.eur.nl/about/transitions/
- Visser, M. (2019). Renewable energy in the Netherland. Entrance, Center of expertise energy.
- Watari, T., McLellan, B. C., Giurco, D., Dominish, E., Yamasue, E., & Nansai, K. (2019). Total material requirement for the global energy transition to 2050: A focus on transport and electricity. Resources, Conservation and Recycling, 148, 91-103.
- Waterstaat. (2020, January 27). Accelerating the transition to a circular economy. Retrieved from https://www.government.nl/topics/circular-economy/accelerating-the-transition-to-a-circular-economy
- Weber, K. M., & Rohracher, H. (2012). Legitimizing research, technology and innovation policies for transformative change: Combining insights from innovation systems and multi-level perspective in a comprehensive 'failures' framework. Research Policy, 41(6), 1037-1047.
- Weig, B. (2017): BONUS BALTSPACE internal project report: Spatial Economic Benefit Analysis.

- Weig, B., & Schultz-Zehden, A. (2019). Spatial Economic Benefit Analysis: Facing integration challenges in maritime spatial planning. Ocean & Coastal Management, 173, 65–76. doi: 10.1016/j.ocecoaman.2019.02.012
- Wind. (n.d.). Retrieved from https://www.irena.org/wind
- Wind park Wieringermeer. (n.d.). Retrieved September 02, 2020, from https://www.planviewer.nl/imro/files/NL.IMRO.0000.EZip14wpwieringer-0003/t_NL.IMRO.0000.EZip14wpwieringer-0003.html
- Windpark Wieringermeer. (n.d.). Retrieved September 02, 2020, from https://www.hollandskroon.nl/ontwikkelen/projecten/windpark-wieringermeer
- Wind Plan Blauw. (2020, July 15). Retrieved July 27, 2020, from https://windplanblauw.nl/windplanblauw/
- Windpark Windplan Blauw: RVO.nl: Rijksdienst. (n.d.). Retrieved July 28, 2020, from https://www.rvo.nl/onderwerpen/bureau-energieprojecten/lopende-projecten/windparken/windpark-windplan-blauw
- Woolthuis, R. K., Lankhuizen, M., & Gilsing, V. (2005). A system failure framework for innovation policy design. Technovation, 25(6), 609–619. doi: 10.1016/j.technovation.2003.11.002
- Yang, H., & Steensma, H. K. (2014). When do firms rely on their knowledge spillover recipients for guidance in exploring unfamiliar knowledge? *Research Policy*, *43*(9), 1496–1507. doi: 10.1016/j.respol.2014.04.016
- Yin, R. K. (2003). Case study research and applications: Design and methods. Applied Social Research Methods Series, 5, 1–53. https://doi.org/10.1016/j.jada.2010.09.005
- Zaken, M. van E., Landbouw, & Innovatie. (2020, January 31). Climate policy. Retrieved from https://www.government.nl/topics/climate-change/climate-policy

APPENDIX

APPENDIX A

Interview Protocol

To identify the challenges of circular transition for an ongoing energy transition of the wind energy sector in the Netherlands.

Date:	
Name of the Respondent/Interviewee:	
Company/Organization:	
Name of the Interviewer:	
Organization:	
Interview Number	

INTRODUCTION

- Self Introduction
  In this section, firstly, I introduce myself, my study background and the organization I am doing my thesis with. Secondly, the respondent will be informed about the details of the interview, duration of the interview (approximately an hour) and the confidentiality agreement.

- Aim of the research
  The interviewee is explained the aim and objective of the research. And what is expected out of the interview. *The main aim of the research is to identify the challenges for a circular transition for the ongoing energy transition of the wind energy sector*.

- Purpose of the Interview
  The main purpose of the interview is to gain insights into the various challenges faced by the practitioners that are involved in the development of a wind farm projects. All the practitioners involved throughout the lifecycle of wind farm are considered as potential respondents for the interview.

- Structure of the Interview
  The interview mainly consists of three different parts. The first part of the interview will focus on the circular economy and different aspects of circular economy. The questions will be focused on different circular aspects in different stages of development. In the second part of the research the questions will be focused on the theoretical framework. Finally, your opinion regarding future of circular economy for the wind energy sector will be asked.

- Consent Form
  Before proceeding with the interview, the respondents are asked a few questions regarding their consent and confidentiality of the information provided during the interview.

I. How would you like to be addressed? With or without your name, role and organization?
II. Can the interview be recorded? Yes or No?
III. The interview will be summarized based on the recording. Is that okay or not?

SL NO:	**Please tick the appropriate boxes.**	**Yes**	**No**
1	I have read and understood the study information dated [DD/MM/YYYY], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.		
2	I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.		
3	I understand that taking part in the study involves an audio recorded interview and written notes. And the audio recorded interviews will be transcribed as text and will be sent back for verification.		
4	I understand the information provided will be used for the research and the final report.		
5	I understand that personal information collected about me that can identify me, such as [e.g. my name or where I work], will not be shared beyond the study team.		

Finally, before I start with the interview questions, I would like to inform that the questions are formulated just to help me with the research. Should you consider any of the questions irrelevant or unpleasant and would rather not answer, you are free to do so. And if you would like to share more information other than what is asked, you are more than welcome to do so. The interview will be held in confidence and the data will not be shared with others. Do you have any questions so far?

INTERVIEW QUESTIONS

- Introductory Questions

  Firstly, the interviewee will be asked few questions to introduce himself. The following questions will be asked;

  I. A short self-introduction.
  II. Brief introduction of the company you work for.
  III. Your role/position in the company.

- Interview Part 1: General Questions

  1. What do you understand by the term circular economy?
  2. Do you think circular transition is necessary for the wind energy sector?
  3. If yes, How do you and your company work with circular economy for the wind energy sector for this particular case? More specifically, which activities are performed regarding circularity?

➢ Interview Part 2: Challenges for circular transition

Construction Phase	Life-cycle stage	Circular Economy Aspect
1. Design & Development Phase	Design	Design for deconstruction
		Design for adaptability and flexibility
		Design for standardization
		Design out waste
		Design in modularity
		Specify reclaimed materials
		Specify recycled materials
	Manufacture and Supply	Eco design principles
		Use less materials/optimize material use
		Use less hazardous material
		Increase the life span
		Design for product disassembly
		Design for product standardization
		Use secondary materials
		Take back schemes
		Reverse Logistics
2. Construction Phase	Construction	Minimize Waste
		Procure reused materials
		Procure recycled materials
		Off-site construction
3. Operation Phase	In use and Refurbishment	Minimize waste
		Minimal Maintenance
		Easy Repair and upgrade
		Adaptability & Flexibility
4. Decommissioning Phase	End of life	Deconstruction
		Selective Demolition
		Reuse of components/products
		Closed loop recycling
		Open loop recycling

4. Which of the following circular economy aspects (from the table above) are taken into consideration for the development of a wind farm?
5. What are the major challenges/failures for incorporating these aspects for the development of a wind farm?
6. Are there any other circular aspects you would like to see incorporated but couldn't due to a particular challenge/failure? If yes, what were the main challenges here?

➢ Interview Part 3: Questions Based on Theoretical Framework.

7. What does not having the same information as the other parties or lack of efficient information in the market mean for circular transition for this case.
8. Do costs and finance play a role in adopting/not adopting circular aspects for wind farm construction? How so?
9. Do you think the easy access to resources is hindering the circular transition for this particular case?

10. Concerning the particular case, Can you attain circular transition with the current infrastructure? If yes, what are the challenges that hinder this transition. If no, what infrastructure changes are required to help attain circular transition.
11. Are there any shortcomings or hinderances in adopting circular aspects or carrying out circular innovations?

- Due to certain laws regulations and standards
- Due to social norms, values and culture?

12. Have you experienced lack of inclusion of new ideas (in terms of circular aspects) due to intense cooperation and closely tied networks? If yes, how does it affect incorporating circular aspects for this case?
13. Did lack of resources and competencies at actor and firm level hinder circular transition for this case? If so, can you give an example from this particular case?
14. Do you think there exists a shared vision amongst the actors and firm to attain this circular transition? If yes, what is still preventing this circular transition. If no, what is the major reason for the same?
15. When it comes to the suppliers and consumers, how well are they involved while making decisions regarding the circular aspects. And how does their involvement/non-involvement affect the circular transition?
16. Regarding policies, do you think their sufficient and appropriate policies present to attain circular transition?

- If yes, how well do you think the policies are coordinated within the different sectors for wind farm construction?
- If no, what policies/actions need to be taken to encourage the adoption of circular aspects for the wind energy sector.

17. Final question, sooner or later, do you see circular aspects being incorporated within the wind energy sector? And what according to you is the biggest hinderance/challenge for this to happen?

INTERVIEW CLOSURE & POST INTERVIEW

Finally, after asking all the questions mentioned above, the interview comes to an end. The respondent is thanked for his/her time and is informed that the a copy of the transcribed interview with all the challenges/failures for a circular transition of wind energy sector will be sent to him/her.

Post interview, the recorded interview will be analyzed and coded, and the transcribed interview with an overview of challenges/failures for a circular transition of wind energy sector will be mailed to the respondent to verify the results.

APPENDIX B

Transcribed Interviews

This appendix contains confidential information.

For more information, please contact

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APPENDIX C

Figures

- Figure 12: Wind plan Blauw schedule (Wind plan Blauw, 2020)
- Figure 13: Borssele 1 & 2 schedule (Orsted-Borssele 1& 2, 2020)
- Figure 14: Project Procedure (Wind Park Wieringermeer, 2020)

Figure 12: Wind plan Blauw schedule (Wind plan Blauw, 2020)

Figure 13: Borssele 1 & 2 schedule (Orsted-Borssele 1& 2, 2020)

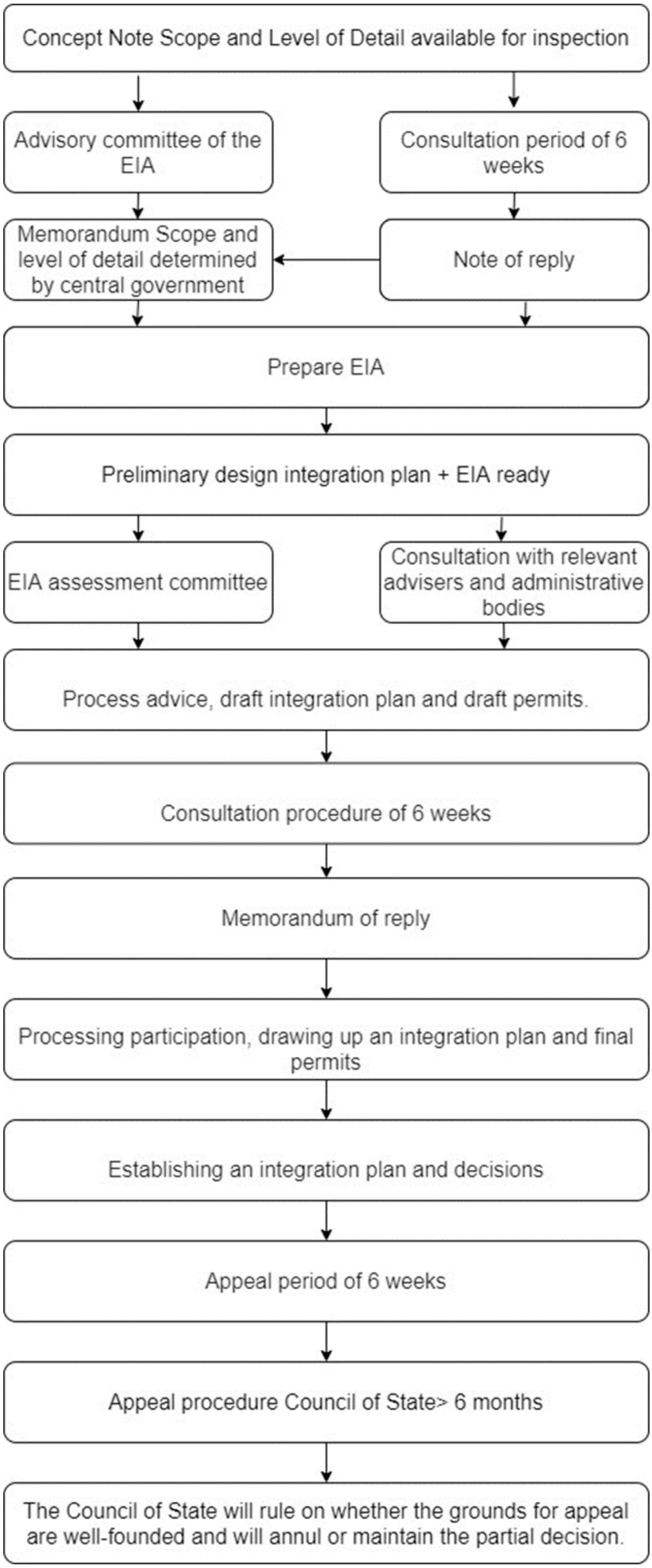

Figure 14: Project Procedure (Wind Park Wieringermeer, 2020)

APPENDIX D

Open Codes: Case Study - Wind Plan Blauw

	Codes	Times Mentioned
1	Competition	1
2	Consumer Involvement	2
3	Cost Incentive	12
4	High-Cost	5
5	Innovations not directed towards circularity	3
6	Lack of appropriate policies	5
7	Lack of Awareness	7
8	Lack of Communication	1
9	Lack of focus on circularity	1
10	Lack of Information	6
11	Lack of Knowledge	9
12	Lack of Need/Incentive	8
13	Uncertainty in Quality	3
14	Lack of Resources (P)- Yes	2
15	Lack of shared vision	3
16	Lack of Urgency	3
17	Liberal approach by companies and government	3
18	Material Concern	3
19	No Alternatives	1
20	Optimizing wind production	2
21	Prefer flexibilty over circularity	2
22	Proud & Content	2
23	Social norms, Values & Culture (Yes)	1
24	Supplier Involvement	7
25	Technology Availability	1

Open Codes with Excerpts: Case Study - Wind Plan Blauw

	Codes Assigned	Excerpts From the Transcribed Interviews
1	Competition	➢ It can only be perceived as costly or complex and that doesn't help you in a competitive environment. I think suppliers and contractors are quite reluctant to bring it up specially in competition.
2	Consumer Involvement	➢ I am not really sure. But at least in the development phase the consumers and the suppliers are not involved. ➢ Consumers will not be necessarily involved in the actual doing of it
3	Cost Incentive	➢ it is difficult to prioritize this topic unless there is cost incentive ➢ I think the problem is lot of decision makers believe that circular economy is costing a lot of money. And I think you can only persuade them if you have the right argument and the right argument should be about money that it will save money and create value somewhere in the value chain then I think you will grab the interest of the decision makers. You need to have an incentive

		➢ Will have to pay for taking the soil offsite and you pay again or the new material, but again this is money driven decision and not a decision made due to circularity or sustainability. ➢ And we do it only because we can, and we have the technology and we make money, and these are the things driving it and not because we want to create a better future from an environmental or sustainable perspective. ➢ My guess would be it is largely money driven industry and on the production of renewable energy but that's also financially related and I think that it is also up to the production companies to have those standards ➢ The other one would be looking at the climate subsidies and very liberal polices we have within the Netherlands that majorly focus on reducing the costs of these production installations. I think it is a large hindrance as well. ➢ virgin fibers are still cheaper than the recycled fibers which then for sure is not an incentive for blade manufacturers to use the recycled fibers ➢ So, it would be interesting to better understand how much this is actually wanted by customers and would they be willing to pay for it. ➢ Costs, the circular material we want to use, does it cost more or less. Also costs in respect to enough time and resources to invest into the knowledge base and technology ➢ But what we see now in the market is that the business models dictate the lifetime of the turbines and technical and economic lifetime isn't the driver anymore. Since this is the case what see happening now is manufacturers optimize their technical lifetime to match the economic lifetime better in order to have a competitive offer. This was a big game changer as the clients preferred a less durable turbine that is cheaper and fits the business case rather than having a turbine with longer lifetime ➢ What we currently see in the market right now is the customers usually prefer lowest cost per kwh. This tells us we focus less on circularity and sustainability ➢ You see an immense cost pressure in this sector in genera
4	High-Cost	➢ It can only be perceived as costly or complex and that doesn't help you in a competitive environment ➢ I think the problem is lot of decision makers believe that circular economy is costing a lot of money. ➢ Also costs, because sometimes it depends on what you do. So, if you want to have more sustainable solutions it is more expensive ➢ But there is a concern I would say that it is more costlier and that is what is hampering the transition. ➢ There is a general understanding that if you want to be more sustainable it is more costly and that is why it is sometimes harder to trigger the business to really take this forward.
5	Innovations not directed towards circularity	➢ As much as I know, the current innovations in case of wind turbines are mainly directed towards making the wind turbines lager and making sure it doesn't break under high wind velocity so that it can be certified.

		➢ So, I think in a way it is forcing the hand of the turbine developer to make a strong, large turbine and are very efficient with the use of materials but on the other hand it is not mainly promoting the innovation of recycling or upcycling afterwards. ➢ However, for wind energy I don't think we are at that point. All the things I read about innovation is mostly about building the wind turbine faster or making it modular or building it crane less or not having to use concrete foundation but using a steel foundation like you use it sea because you can certify it better. These are few aspects you could call circular, but I don't think that's the main reason they are doing it.
6	Lack of appropriate policies	➢ But then again you can think why I should if there is no obligation coming from permits and regulations or policies. ➢ No, I think it's not the case ➢ And so no, I don't think there are appropriate policies regarding circular economy. ➢ The other one would be looking at the climate subsidies and very liberal polices we have within the Netherlands that majorly focus on reducing the costs of these production installations. I think it is a large hindrance as well. ➢ Because the current policies just focus on high level energy but not so much on circular waste
7	Lack of Awareness	➢ There is a lack of awareness ➢ I think the one of it is people are unfamiliar with it ➢ Yes, maybe. Because I don't think people really see that there's a limitation or scarcity of materials ➢ I think first of all is knowledge and awareness. I think that takes a lot of time and sometimes a generation for people to become aware of it being an issue. ➢ It all happens in the early stages of the project and there isn't too much awareness to make the wind energy sector circular ➢ most of the governments are unaware ➢ First of all, I think it is about the awareness. Not every government is aware about the materials used for the wind turbine
8	Lack of Communication	➢ We do not communicate with each other
9	Lack of focus on circularity	➢ I think it is a matter of focus. If we were to focus on circular design, we could achieve that and we could hire the expertise. But what is difficult to do is time to market is increasing in pace
10	Lack of Information	➢ I think the information is really poor. ➢ Yes. Like we already discussed there is lack of knowledge, lack of understanding, information and lack of urgency ➢ Discussing this in the interview makes me aware I have a lack of information as well. I am not sure if any of the wind turbine producers/manufacturers that I know of has well these kinds of standards. ➢ lack of information. I read news articles weekly and of all the news articles I have read about wind turbines, there is very little concerning recycling and circular design for the wind turbine.

		➢ I think it is mainly due to lack of expertise and lack of information from the government.
11	Lack of Knowledge	➢ But yes, the knowledge gap and knowledge transfer is really poor. There's a few that understand but not everyone. ➢ Yes. Like we already discussed there is lack of knowledge, lack of understanding and lack of urgency. ➢ I think first of all is knowledge and awareness. I think that takes a lot of time and sometimes a generation for people to become aware of it being an issue. And shortest of supply will also speed up the transition but the question is whether or not it is relevant for short term. ➢ And also, knowledge I would say is an obstacle. How to optimize circularity, what is the base line we are actually meaning to step up from and also analysis or methodology, so how can we measure that we are actually getting better. ➢ so, there is already high optimization in place but it is difficult to understand where can we further optimize ➢ I think knowledge is key here. I think there is a lot we might be able to do if we have right understanding on how to do. ➢ And again, I think it is more of lack of clear understanding in this topic which is hampering the faster progress. ➢ Like I said before it isn't yet really clear what do we mean by circular economy in the wind business and what are the points to address
12	Lack of Need/Incentive	➢ We are proactive in this and we think it is something we should do, and we believe that it is the right thing, but it is not something we need to do ➢ However, what I see is, for a project like Blauw, is not obliged to follow EU tender regulations which is not aanbestedingsplicht as we call in Dutch, we are not obliged to tender. ➢ If it is not an obligation, lets try to ignore it until someone tells us otherwise. ➢ Majority of the people are in a position to do something about it but are turning a blind eye to it as there are no incentives. ➢ I don't think we need additional infrastructure. I think it is a matter of prioritizing it and doing it. And the moment we are not doing it. ➢ Most of the developers are not challenged enough to think about the circular aspects due to lack of need to do so. ➢ And also, in the development phase not many parties are asking or demanding for it
13	Uncertainty in Quality	➢ I think one big part is quality. So, you need to have certain quality of material which is not always given while using the recycled materials ➢ The second one I believe is that people struggle to believe that reused material are good as the new ones ➢ We need to have a good quality material for the construction of windfarms which lasts longer say 25 years, but do we have the same quality in the recycled materials we use.

14	Lack of Resources (P)- Yes	➢ We can try and standardize the project and make sure every project has a same step-up transformer. But you need resources, skill and portfolio to do so. ➢ Yes. I think if we would have more resources to focus only on that topic then it could increase the speed but on the other hand, I also see that it's a step together also with other developers and suppliers to take this forward together.
15	Lack of shared vision	➢ No. I don't think there exists a shared vision. The reason for that is we lack the common understanding and common agenda. ➢ No, I think there isn't. ➢ When it comes to shared vision, I think we are just at the beginning
16	Lack of Urgency	➢ urgency that hinders this. ➢ Yes. Like we already discussed there is lack of knowledge, lack of understanding and lack of urgency ➢ Like I said the main reason is we are not feeling the sense of urgency there.
17	Liberal approach by companies and government	➢ liberal approach like reducing costs in subsides and not stating any quality aspects in rewarding subsidies leads to very efficiently built production units, in this case wind turbines, but not responsibly produced wind turbines ➢ Majority of the people are in a position to do something about it but are turning a blind eye to it. ➢ The other one would be looking at the climate subsidies and very liberal polices we have within the Netherlands that majorly focus on reducing the costs of these production installations. I think it is a large hindrance as well.
18	Material Concern	➢ That is mostly to extend the lifetime of the products. In terms of circularity within the company, we are looking at where we source our materials from and see if we can source it in an ethical way. But there are always some components that are really difficult to recycle, and this is mainly concerning rotor blades which is the currently the big talking point in the industry in general. ➢ I think the main issue is the dependence on certain types of materials. If want a very cost-effective generative design. You are very dependent of these kinds of material and you don't really have other options. ➢ The biggest challenge would be the material choice.
19	No Alternatives	➢ But both of them have a significant impact but there no alternative at the moment.
20	Optimizing wind production	➢ within the whole wind turbine industry, the major focus is still about optimizing production ➢ However, for wind energy I don't think we are at that point. All the things I read about innovation is mostly about building the wind turbine faster or making it modular or building it crane less or not having to use concrete foundation but using a steel foundation like you use it sea because you can certify it better.
21	Prefer flexibilty over circularity	➢ In such cases the developers would prefer maximum flexibility but in terms of being circular you could minimize the amount you use.

22	Proud & Content	➢ We are very proud to be reclaiming the land from the sea. But environmental perspective it doesn't make sense. ➢ I see that the Netherlands are much more of a front runner than a lot of other countries. ➢ that is quite unique compared to other European countries
23	Social norms, Values & Culture	➢ Ya definitely. You don't have to travel far to spot the differences. Just go to Belgium or UK or Germany, you can spot the differences. The socio-cultural element is Important. We Dutch are a bit lazy regarding this topic
24	Supplier Involvement	➢ The manufacturers are not directly involved in this process. ➢ It is also very interesting to conclude that the turbine supplier isn't involved that much in this (design) phase of the project. ➢ contracting the wind turbine supplier is usually done the after the planning phase, thus there is no reason for the developer or the government to go into that level of detail yet in an early phase. ➢ we should probably introduce a couple of design sessions with maybe suppliers as well and look at the options you still have. ➢ So, bring the turbine suppliers early into the process and have the technical competencies early into the process because I think there is lack in that aspect at least for this particular project. ➢ without the supplier's involvement we cannot get circular.
25	Technology Availability	➢ Next is technology availability, so if we are thinking for example about green steel, steel produced with low carbon emissions that's also not yet available in quantity and quality which is needed for the wind farm construction

Open Codes: Case Study - Borssele 1 & 2

	Codes	Times Mentioned
1	Blade waste & Composities	6
2	Competition	4
3	Cost Incentive	19
4	Easy Access to Resources	2
5	Improved Awareness	1
6	Innovations/Activities not directed towards circularity	4
7	Lack of appropriate policies	5
8	Lack of Capabilities	2
9	Lack of green materials	2
10	Lack of Information	4
11	Lack of Interaction	3
12	Lack of Knowledge	5
13	Lack of Need/Incentive	8
14	Uncertainty in Quality	1
15	Lack of Regulations	4
16	Lack of Resources and expertise	3
17	Lack of Shared Vision	1
18	Lack of Technology	2
19	Liberal approach by companies and government	1
20	Need for research	3
21	Proud & content	1
22	Social norms, Values & Culture	1
23	Supplier Involvement	5
24	Tender Criteria	1

Open Codes with Excerpts: Case Study - Borssele 1 & 2

	Codes Assigned	Excerpts From the Transcribed Interviews
1	Blade waste & Composities	➢ At a corporate level, the main issue when it comes to the circular economy is the blade waste of the wind turbines and the composite fiber glass ➢ A lot of materials can be recycled as they are, and the challenging part is the turbine blades and the fiber glass composites. ➢ Currently, carbon fibers are being used which are more expensive but perhaps also easier to recycle. ➢ I am quite sure regarding the fiber glass composites; a lot of other materials used for the wind turbines the circular economy solutions are already here, at least in the form of recycling technologies. ➢ However, the big challenge is when the wind turbine is at the end of the economic life cycle and blade waste
2	Competition	➢ If we see that it makes things more expensive then it will be hard to consider, because chances of us wining the tender is hard due to competition. ➢ But you still fail to see that because firstly it has to go hand in hand with the cost reductions, because otherwise due to fierce competition it is very hard to include a lot of circular

		economy aspects if that is making the development of wind farm more expensive ➢ Yes absolutely, we see certain elements being considered already today. Biggest challenge is – as said before – the (cost) competitiveness with the current considerations. ➢ Also, offshore wind until recently has been kind of a niche industry and there has been a massive focus to bring down the cost of the technology to even be competitive with fossil fuels and now we are at a time where the offshore wind is at a competitive stage with fossil fuels.
3	Cost Incentive	➢ We still see today that majority of our clients are cost focused and driven by cost incentive and that is often not allowing innovative Ideas and allow for making the entire supply chain more carbon neutral and circular ➢ And I think with the designers and the manufacturers the information about the circular economy and how to improve on that is available, but I think the main drive is still the cost and as long as that problem is not solved. ➢ Because I think everyone understands the need and the benefits of circular economy but I personally not being extremely aware of that, I believe it is mainly cost driven and it is the main barrier. ➢ I fear that cost play a major role and in every country the subsidies being reduced or sometimes not existing is the main barrier. ➢ Also, I think like I said, cost plays a major role. And as long as offshore wind energy supply chain is cost driven as it is today, the transition is only possible if it comes at a same or a lower cost and then like we discussed it also the availability. ➢ But you still fail to see that because firstly it has to go hand in hand with the cost reductions, because otherwise due to fierce competition it is very hard to include a lot of circular economy aspects if that is making the development of wind farm more expensive ➢ The biggest challenge is the financial incentive.
4	Easy Access to Resources	➢ I think that it is one of the problems. Materials are easily available. ➢ Yes of course. Steel is always easily available, and concrete is also easily available for the foundation and it does not encourage the developers.
5	Awareness	➢ I think the awareness by the developers and the government is growing in the past few years. For example, if you see in the company policy of Orsted, it is one their biggest challenges for the coming years to minimize the CO_2 reduction therefore circularity is very important for them. So, if you look back at the last five years there is a positive trend
6	Innovations/Activities not directed towards circularity	➢ windfarm we have company policies and programs to minimize waste generation and we do also consider minimal maintenance but it also for strictly economic reasons not because of circularity

		➢ In terms of design for flexibility and adaptability, the foundation (monopoles) is designed based on the location and based on the strength of the waves etc. ➢ There is wind organization NWEA which is a Dutch wind energy association, but circularity isn't at their agenda a lot. ➢ Yes, because the majority of the sector evolved from the beginning and the growth was focused on cost effectiveness and not circularity
7	Lack of regulations & appropriate policies	➢ And also I think it is interesting to note that when it comes to circular economy aspects the wind industry is not super regulated when compared to other sectors for instance the single use plastic is banned within the EU which is a quite strict regulation for that industry. ➢ So, I think if economic regimes and taxations and regulation are supported in a better way for the circular principles, it will only make it easier for the wind industry to follow the circular economy principles ➢ I think the biggest shortcoming is that there isn't a financial incentive and lack in regulations. ➢ No. at least I am not aware of any such polices.
8	Lack of Capabilities	➢ So, there are some capabilities that needs to be built for everything to play its part in a circular economy and that's something that can be done.
9	Lack of green materials	➢ If I look at European steel market, I think there is lack of green steel available. ➢ And secondly, it also take time, like the green steel needs to available, the resources and expertise needs to be available.
10	Lack of Information	➢ This information is not something that is always available at all windfarms and it is something that is important to support the ease of recycling by different companies. ➢ Yes. Because there isn't a lot of information and standardized approach on how you can reuse the turbines the be. ➢ It is really hard to say what the others know about this topic to be honest.
11	Lack of Knowledge	➢ I think for general decision maker circular economy would be somewhat of a complex phenomenon ➢ That's a good question. In general, for the wind sector there is still room for improvement in the understanding of the circular economy aspects. As circular economy is a complex concept, hopefully it will mature over time ➢ I think speaking from my personal experience, I think it is a complex subject and for circular economy to be really successful there is lot of pieces that needs to sort of align together. ➢ I think it is difficult to reuse the old materials because there lacks a smart approach and knowledge to do so.
12	Lack of Need/Incentive	➢ I think that it is the main barrier to move towards circular economy and I think it is not related to lack of information rather it is lack of need and them not willing to move towards circular economy. ➢ For instance, looking at glass fiber composites used for wind turbine blades currently, it is a very effective and cheap

		material to make and even though it cannot be effectively recycled at the end of life, there are no proper incentives to ensure that this should be happening. ➢ Also, on the other hand they aren't really many economic incentives to recycle materials. ➢ the tender was only about the lowest price for wind energy offshore so there wasn't any incentive for the client to look broader. ➢ But for the wind turbines, you don't have such incentives at the moment. ➢ The biggest one I can think at the moment is that the policies that are present at the moment and if you want to be completely circular at the moment it only pays off if you are forced to. If there is a regulation or an incentive or a need to do
13	Uncertainty in Quality	➢ And maybe another reason for not reusing the materials is the uncertainty in quality and strength of the materials.
14	Lack of Regulations	➢ I think it is interesting to point towards regulations on blade waste in particular. Because in some European countries, landfilling of blade waste is illegal by national law, which means that the business case for decommissioning and recycling is different than in countries where you can landfill blades at a lower cost. ➢ One being having the right technology and other being having the right regulation and consumer preference. ➢ I think the biggest shortcoming is that there isn't a financial incentive and lack in regulations.
15	Lack of Resources and expertise	➢ I think for a certain extent, yes. If the manufacturers have never considered it or never built up expertise, of course the expertise and experts and the resource are lacking. ➢ And secondly, it also takes time, like the green steel needs to available, the resources and expertise needs to be available. ➢ There needs to be a good professional understanding of the issues in order to provide solutions for the issues.
16	Lack of Shared Vision	➢ No, I don't think a shared vision exists.
17	Lack of Technology	➢ One being having the right technology ➢ I think for certain materials or for design solutions we are not completely aware of the available technologies.
18	Liberal approach by companies and government	➢ Certain client and developers might be interested in paying premium for having more circular economy aspects for their offshore development of wind farms, but they maybe then confronted with availability issues and certification issues which make a lot harder than we would hope for.
19	Need for research	➢ I think there is need for increased research and development for recycling of fiber glass composites and also research for alternate materials to use. ➢ I think a lot could be achieved by public support and incentivizing research and development activities and recycling technologies. ➢ Thus, further research for that part is very necessary.
20	Proud & content	➢ I think 95% of the people I meet who work in the offshore wind business is old people or rather let's say people who

		are proud about their job or proud about the business they work in. Meaning generating green energy and being a part of transition from non-renewable energy to renewable energy
21	Social norms, Values & Culture	➢ I think as with many other priorities in a corporate sustainability strategy the external stakeholder landscape being the expectations of the civil society and hard and soft regulation that plays an important role in shaping what companies do and what they don't.
22	Supplier Involvement	➢ But in general, it is not a common practice to use recycled materials. It is not that we are willing to do so, but I think we are dependent on our sub-contractors there. ➢ Very limited, the decision-making sits with the governmental bodies and the OWF developers. In the event the suppliers and/or consumers would get more involvement, the circular economy would definitely be more promoted. ➢ Because some of the decisions regarding circular economy are made during product development phase at our suppliers. They also need to know that there is market for more circular products. But the important decisions are made in the design phase.
23	Tender Criteria	➢ Also, it majorly depends on the tender and tender criteria. If the circular economy is one of the evaluation criteria on the tender, we will definitely look into that aspect and put more focus on it.

Open Codes: Case Study - Wind Park Wieringermeer

	Codes	Times Mentioned
1	Lack of attention	2
2	Lack of awareness	1
3	Lack of control	2
4	Lack of appropriate policies	1
5	Lack of inclusion of new ideas	1
6	Lack of Information	4
7	Lack of innovation	1
8	Lack of Interaction	1
9	Lack of knowledge	2
10	Lack of norms & Regulations	1
11	Lack of ownership	4
12	Lack of R&D	1
13	Lack of regulations	1
14	Lack of Requirement	1
15	Lack of resources (P)	2
16	Lack of shared vision	2
17	Lack of technology	1
18	Lack of Trust	1
19	Limited turbine suppliers	1
20	Not mentioned in the contract	1
21	Social Norms	1

22	Solution	7
23	Supplier Involvement	2
24	Time & Cost	2

APPENDIX E

Design and Development Phase

Failure Categories	Type of Failure	Challenges & Obstacles identified
Market Failures	I. **Information Asymmetries**	➢ Lack of Awareness
		➢ Lack of Information
	II. **Knowledge Spill over**	➢ Lack of Knowledge
	III. **Externalization of costs**	➢ Cost Incentive
	IV. **Over exploitation of commons**	➢ Easy Access to Resources
		➢ Dependent on Certain type of Materials
Structural System Failures	I. **Infrastructural Failure**	➢ Lack of R&D and Technology
		➢ Lack of Knowledge
		➢ Uncertainty in Quality
		➢ Blade waste and Composites
		➢ Limited Turbine Suppliers
	II. **Institutional Failure**	➢ Innovations not directed towards circularity
		➢ Liberal Approach
		➢ Lack of Regulations & Appropriate Policies
		➢ Lack of Control
		➢ Lack of Awareness & Social norms and Culture
	III. **Capabilities Failure**	➢ Lack of Resources and Expertise
	IV. **Network or Interaction Failure**	➢ Lack of Interaction
		➢ Lack of Innovation
		➢ Accountability
Transitional Failures	I. **Directionality Failure**	➢ Lack of Need or Incentive
		➢ Lack of Shared Vision
		➢ Lack of Attention
		➢ Flexibility over Circularity
		➢ Need for Research
		➢ Competition
		➢ Image Perception
	II. **Demand Articulation Failure**	➢ Involvement of Suppliers
	III. **Policy coordination failure**	➢ Lack of Appropriate Policies
		➢ Accountability
	IV. **Reflexivity Failure**	

Construction Phase

Failure Categories	Type of Failure	Challenges & Obstacles identified
Market Failures	I. **Information Asymmetries**	➢ Lack of Awareness ➢ Lack of Information
	II. **Knowledge Spill over**	➢ Lack of Knowledge
	III. **Externalization of costs**	➢ Cost Incentive
	IV. **Over exploitation of commons**	
Structural System Failures	I. **Infrastructural Failure**	➢ Uncertainty in Quality ➢ Lack of Green Material
	II. **Institutional Failure**	➢ Proud & Content ➢ Liberal Approach ➢ Lack of Regulations & Norms ➢ Lack of Trust
	III. **Capabilities Failure**	➢ Lack of Resources and Expertise
	IV. **Network or Interaction Failure**	➢ Lack of Inclusion of New Ideas ➢ Lack of communication & Interaction
Transitional Failures	I. **Directionality Failure**	➢ Lack of Need or Incentive ➢ Lack of Shared Vision ➢ Lack of Urgency ➢ Competition ➢ Not Mentioned in the Contract
	II. **Demand Articulation Failure**	➢ Involvement of Suppliers
	III. **Policy coordination failure**	➢ Lack of Appropriate Policies
	IV. **Reflexivity Failure**	

Operation and Maintenance Phase

Failure Categories	Type of Failure	Challenges & Obstacles identified
Market Failures	I. **Information Asymmetries**	➢ Lack of Awareness ➢ Lack of Information
	II. **Knowledge Spill over**	
	III. **Externalization of costs**	➢ Cost Incentive
	IV. **Over exploitation of commons**	
Structural System Failures	I. **Infrastructural Failure**	➢ Lack of Technology
	II. **Institutional Failure**	➢ Lack of Control
	III. **Capabilities Failure**	
	IV. **Network or Interaction Failure**	

Transitional Failures	I. **Directionality Failure**	
	II. **Demand Articulation Failure**	
	III. **Policy coordination failure**	
	IV. Reflexivity Failure	

Decommissioning Phase

Failure Categories	Type of Failure	Challenges & Obstacles identified
Market Failures	I. **Information Asymmetries**	➢ Lack of Awareness ➢ Lack of Information
	II. **Knowledge Spill over**	➢ Lack of Knowledge
	III. **Externalization of costs**	➢ Cost Incentive
	IV. **Over exploitation of commons**	
Structural System Failures	I. **Infrastructural Failure**	
	II. **Institutional Failure**	
	III. **Capabilities Failure**	
	IV. **Network or Interaction Failure**	
Transitional Failures	I. **Directionality Failure**	➢ Lack of Urgency
	II. **Demand Articulation Failure**	
	III. **Policy coordination failure**	
	IV. Reflexivity Failure	